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The Effect of Severity of Closed Head Injury on Memory Functioning.

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The effect of severity of closed head injury on memory functioning

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The Louisiana State University and Agricultural and Mechanical Col., 1990

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THE EFFECT OF SEVERITY OF CLOSED HEAD INJURY ON MEMORY FUNCTIONING

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Department of Psychology

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Abstract

This study was undertaken to examine the relationship between neuroanatomy of memory, the structural mechanics of closed head injury, and the resulting effects on memory functioning. The experimental groups were composed of 30 closed head injured individuals equally divided by severity of injury based on posttraumatic amnesia (PTA). The first group included 15 mild head injured patients whose PTA was defined as less than 60 minutes. Group two was composed of 15 severely head injured patients whose PTA was greater than 24 hours. The comparison group consisted of 15 non-head injured volunteers matched to the experimental group by age, gender, race and education. The groups were essentially homogeneous with regard to age, education, premorbid intellectual functioning and time interval from injury to assessment. Within a single session, each subject was administered the Wechsler Adult Intelligence Scale - Revised (WAIS-R), the Wechsler Memory Scale - Revised (WMS-R) and the California Verbal Learning Test (CVLT). Univariate analysis of variance (ANOVA) tests followed by Tukey's Studentized Range Tests were used to analyze the data on 19 dependent variables. Significant differences in intellectual functioning were found between the severely head injured subjects and controls on Full Scale, Verbal and Performance IQ's. With regard to
performance on the WMS-R, both the mild and severe individuals scored significantly lower than controls on verbal memory, visuospatial memory and delayed recall. Significant group differences were also indicated on 10 out of 11 CVLT variables which measured immediate and delayed free and cued recall and learning strategies employed by the subjects. The results of the study indicated that closed head injury produces severe deficits in learning and recall of both verbal and nonverbal stimuli, with degree of impairment related to severity of injury (PTA). Mild head injured persons exhibited deficits in consolidation of stimuli, whereas patients with severe head injury showed significant impairment in encoding, consolidation and retrieval reflecting cortical and subcortical damage.
Chapter I

Traumatic brain injury or TBI is defined as "direct damage or the threat of damage to the brain." (Marshall, Sadler, & Marshall, 1981, p. 3). Although estimates vary according to inclusion criteria, the incidence of TBI is increasing at an alarming rate (Grimm & Bleiberg, 1986). Estimates have ranged from 1 million (Kraus, 1980) to 7 million (Caveness, 1977) head injuries occurring annually. Due to advanced medical technology, patients are currently more likely to survive head injuries (Jennett & Teasdale, 1981) and rehabilitation efforts have been estimated at a cost of near $4 billion per year (Anderson & McLaurin, 1980). Studies of the epidemiology of head injury have found that persons are more likely to suffer TBI include children and young adults (Jennett et al., 1977) with males twice as likely to be involved as females (Kalsbeek, McLaurin, Harris & Miller, 1989). Motor vehicle accidents are cited as the most frequent causes of TBI (Rimel & Jane, 1983), followed by sporting accidents, industrial accidents, falls and assaults (Grimm & Bleiberg, 1986).

Pathology of Head Injuries

Head injuries are usually classified as "open" or "closed" depending on the type of injury sustained. An open head injury involves penetration of the skull generally
produced by gun-shot wounds or resulting from fragments from exploding shells (Levin, Benton & Grossman, 1982). Because damage to the brain tissue is usually restricted to the path of the incoming missile, open head injuries are more likely to produce focal lesions with predicted effects on intellectual functioning (Lezak, 1983). However, diffuse damage may as well result from a penetrating missile due to explosive shock waves, intracerebral bleeding, edema, infection, cerebrospinal fluid leakage, recurrent seizures and bone fragments from the skull penetrating brain tissue (Haymaker, 1969; Caviness, 1966). As a result, neuropsychological deficits generally associated with diffuse brain damage including impairment in memory, attention, concentration, problem solving and information processing have been found following open head injuries (Teuber, 1975).

A closed head injury can result when a person is struck in the head with a blunt object (Grimm & Bleiberg, 1986). In this type of head injury referred to as a "static injury", the skull initially bends inward resulting in a contusion (bruise) and this point of impact is referred to as "coup" (Lezak, 1983). A rebound effect follows this in which the skull compensates for the injury and bends outward (Haymaker, 1969). If the force is severe, contrecoup lesions may occur which involve contusions in the area of the brain opposite to the point of initial
impact (Grubb & Coxe, 1978). According to Graham, Adams and Gennarelli (1987), head injuries produced by contact can result in fracture of the skull, laceration of the scalp and cerebral contusions and lacerations. In addition, they state that these "contusions and lacerations occur characteristically in the frontal and temporal poles and on the inferior surfaces of the frontal and temporal lobes where brain tissue comes in contact with bony protuberances at the base of the skull." (p. 73).

A second type of closed head injury involves the striking of a stationary object by a moving head as in motor vehicle accidents or falls. This type of injury results in acceleration and deceleration of the skull which causes rotation of the brain resulting in shearing of axons and rupture of blood vessels. The stretching and shearing of axons is referred to as diffuse axonal injury (DAI) (Graham et al., 1987). Initial studies of the mechanics of closed head injury were pioneered by Holbourn who discovered that rotational acceleration produces shearing of axons and cell bodies (Levin et al., 1982). With the use of a paraffin wax model of the brain, Holbourn (1943) found that the greatest axonal shearing occurred in regions of the anterior tip of the temporal lobe. In later studies based on Holbourn's results, Ommaya and Gennarelli (1974) concluded that shearing effects occur in a centripetal sequence which "begins on the surface of the brain in cases
of mild closed head injury and extends inward to affect the diencephalic core in the most severe injuries." (Levin et al., 1982, p. 14). In addition to DAI, other direct effects of closed head trauma include damage to blood vessels, microscopic lesions throughout the brain and damage to the corpus callosum, brain stem and reticular activating system producing loss of consciousness (Ommaya & Gennarelli, 1974; Oppenheimer, 1968; Graham et al., 1987). Indirect effects of closed head injury including hemorrhage, increased intracranial pressure and edema are of significant concern during initial medical management due to their impact on recovery and residual deficits following closed head injury (Levin et al., 1982; Grimm & Bleiberg, 1986).

Determining the severity of a head injury can provide indication of a patient's prognosis. Several factors are used in determining severity of TBI including length and depth of coma and duration of posttraumatic amnesia (Miller, 1966). Posttraumatic amnesia or PTA is defined as that period following coma in which the patient demonstrates confusion and memory loss (Levin et al., 1982). Russell (1971) includes length of coma in his definition of PTA and defines end of PTA as recovery of continuous memory. Berg, Franzen and Wedding (1987) state that "the total duration of posttraumatic amnesia is a more useful predictor of degree of injury and likelihood of
recovery than either retrograde amnesia or the length of time a patient is comatose." (1987, p. 22). Retrograde amnesia refers to memory loss for information occurring prior to brain trauma (Lezak, 1983). Russell and Smith (1961) developed categories of mild, moderate and severe head injury based on length of coma and PTA. Mild TBI is defined as coma plus PTA of less than 1 hour, whereas moderate head injury involves coma plus PTA of 1-24 hours. A severe head injury is defined as coma plus PTA of 1 to 7 days and a very severe head injury is characterized by coma plus PTA of more than 7 days. It is generally found that prognosis following TBI worsens as length of coma and PTA increases (Miller, 1986).

Effects of TBI

Although the effects following TBI are multiple and varied and not within the scope of the current study, the most common physical and psychosocial/emotional deficits of head injury will be highlighted. Cognitive impairment following TBI will be discussed in greater detail with particular emphasis on memory functioning after closed head injury.

Physical deficits

Physical difficulties following TBI involve motor and sensory/perceptual deficits. Motor deficits include hemiparesis, hemiplegia, quadriparesis or quadriplegia. Estimates of hemiparesis following severe head injury have
ranged from 40% (Roberts, 1979) to 49% (Jennett & Teasdale, 1981). Additional residual motor impairments include spasticity, apraxia and ataxia (Lehmkuhl, 1985). Sensory/perceptual deficits include decrease in equilibrium and hearing acuity and impaired visual perception such as poor depth perception, visual field deficits, diploplia, impaired visual scanning of environment and reduction in visual acuity (Lehmkuhl, 1985). Jennett and Teasdale (1981) found that following severe head injury, 5% of patients in their study were hemianopic and 32% demonstrated cranial nerve palsies. Visual reaction time is also found to be impaired following TBI. Miller (1970) found that simple reaction time was within normal limits, whereas complex reaction time was significantly reduced in head injured patients. In addition, severity of head injury was found to affect performance in a forced choice reaction task (Van Zomeren & Deelman, 1970). Reaction time was found to be within normal limits in mild and moderate TBI groups 2 years post-injury, whereas reaction time in severe head injury subjects was significantly lower than controls.

**Psychosocial/emotional deficits**

Behavioral and emotional changes occur frequently following closed head injury. Miller (1986) states that family members and rehabilitation personnel cite personality changes as the most disruptive variable in the recovery process. In a study of head injured patients,
Lishman (1960) found that 86% exhibited some form of behavioral disturbance and Dikman and Reitan (1977) report that most victims of TBI demonstrate both cognitive and emotional impairments concurrently. Miller (1986) reviews phases of emotional disturbance following head injury developed by Stern (1978). The initial phase is characterized by PTA, confusion, disorientation, and agitation. The second phase involves anxiety, memory impairment and introversion. Lastly, the third phase includes impairment in higher executive functions such as planning and judgment.

The most common personality disturbance noted after TBI include irritability, impulsivity, decreased motivation, emotional lability, and socially inappropriate behaviors (Prigatano, 1986). Additional behavioral problems associated with moderate to severe head trauma include egocentricity, impaired judgment, impatience, depression, hypersexuality, hyposexuality, aggression, apathy and disinhibition (Fisher, 1985). In addition, persons with head injury tend to exhibit impaired emotional control (Howard & Bleiberg, 1983).

Although no formal classification scheme for emotional disturbances following TBI has been developed, Prigatano (1986) discusses four areas of behavioral impairment for which treatment during rehabilitation is essential to recovery. The first behavioral class includes anxiety and
the "catastrophic reaction." Goldstein (1952) states that catastrophic reaction refers to the frustration, agitation and aggression demonstrated by head injured patients when faced with tasks that they are unable to solve. A common result of repeated failure is for the head injured patient to withdraw from his environment. The second area of personality disturbance involves denial of illness referred to as anosognosia. This phenomenon is generally associated with damage to the right cerebral hemisphere and patients often demonstrate hostility and aggression when confronted with actual neuropsychological deficits during assessment or by family members. Catastrophic reaction and withdrawal are common results following confrontation of anosognostic deficits. Paranoia and psychomotor agitation comprise the third class of behavioral disturbance. It is generally within the acute phase of recovery that the patient exhibits agitation, confusion, paranoid ideation and impaired mental status with disorientation to person, place and time. Although antipsychotic drugs are often prescribed during the acute phase of recovery, paranoia and agitation may actually be exacerbated by these medications and reduction or change in medication may be warranted. The last and final area of emotional disturbance involves depression, amotivation and social withdrawal. These factors can impede progress in rehabilitation due to the patient's unwillingness to cooperate and participate in
therapies. Depression and withdrawal often appear as the patient develops an increasing awareness into his/her cognitive and physical deficits and with repeated failure in his/her environment.

Lezak (1978) also provided categories of "characterological alterations" which are most problematic for family members of head injured patients. The first category includes a reduction in social perceptiveness which results in egocentricity and lack of empathy. The following area consists of reduced control and self-regulation which produces impulsivity and impatience. The third category is comprised of dependence on others, lack of initiative and impairment in planning behaviors. Emotional behaviors including apathy, irritability and hypo/hypersexuality form the fourth category of personality disturbance followed by the last category which involves an inability to profit from external feedback and experience.

**Cognitive deficits**

**Orientation/attention/concentration.** A result of axonal injury and multiple microscopic lesions following TBI is diffuse brain damage (Seitelberger & Jellinger, 1971). Diffuse brain damage is typically manifested in such behavioral disturbances as impaired alertness, orientation, attention and concentration (Deelman, 1977). Many TBI patients demonstrate impaired mental status in that they are unable to correctly identify personal orientation
(name, age, date of birth), environmental orientation (name of facility, city, state) and temporal orientation (date, time of day). Disorientation and impairment in arousal and attention often occur during acute recovery following TBI (Howard & Bleiberg, 1983). Distractibility and inability to sustain attention in order to complete tasks are often the initial targets during treatment in rehabilitation due to their significant role in higher cognitive functions (Gouvier, Webster & Blanton, 1986).

Howard and Bleiberg (1983) describe four specific attentional deficits following TBI. Impaired selective attention involves difficulty in "screening out" irrelevant stimuli in order to focus on important aspects of environment to complete a task. Persons with TBI often continually change the focus of attention which results in disorganized verbal and motoric behaviors. The second type of attentional deficit is perseveration which is defined as the inability to shift attention from one topic or activity to another. After initiating a task, the patient demonstrates extreme difficulty in discontinuing the activity to begin a new task. Impairment is also noted in the ability to start a new task once the patient discontinued the previous activity. The third attentional deficit is impaired vigilance which refers to the inability to sustain attention in order to complete an activity. The last attentional deficit includes hemi-attention or
unilateral neglect which involves inattention to or denial of the side of the body opposite to the side of TBI. This deficit can result in problems of safety management and adaptive living to the patient and should be addressed by multiple disciplines and family members during rehabilitation of the patient.

**Intellectual functioning.** Intellectual functioning following TBI has traditionally been assessed with the use of the Wechsler Scales (W-B, WAIS or WAIS-R) (Benton, 1979). The following information is derived from Miller (1986) and Benton (1979) who have reviewed the literature regarding verbal and performance intellectual measures following closed head trauma. Many studies have concluded that impairment in intellectual functioning tends to diminish over time as recovery progresses in persons with TBI. Ruesch and Moore (1943) and Ruesch and Bowman (1945) found that scores on the Wechsler-Bellevue Scale involving cognitive speed and visuomotor speed significantly increased three months following mild head injury. Mandleberg and Brooks (1975) used the WAIS with 40 severely head injured patients, all of whom exhibited PTA's of four days or longer. Significant improvement in both verbal and performance scores were noted over time as evidenced by assessments given up to 3 years post trauma. No significant differences were found in verbal, performance and full scale scores between the head injured patients and a
non-injured control group at 3 years following TBI.

Contradictory results are reported by Levin and his colleagues. Levin and Grossman (1978) found that median Verbal and Performance scores were 15 points below that which would be predicted based on education in 20 severe closed head injured patients. They also did not find significant differences in median Verbal and Performance scores between severe (coma 2-28 days) and less severe (coma less than 1 day) closed head injured patients. In a study of 27 severe closed head injured subjects, Levin, Grossman, Rose and Teasdale (1979) found that intellectual functioning following TBI was consistent with global outcome on the Glasgow Outcome Scale. They reported that patients who were characterized as severely and moderately disabled exhibited significant cognitive impairment.

It has been noted in some studies of intellectual functioning following head trauma that Performance scores are significantly more impaired than Verbal scores during acute recovery (Becker, 1977; Dye, Saxon & Milby, 1981). Although these results may lead to the interpretation that verbal functions are spared following TBI, more thorough assessments following head injury have found significant impairment in specific language functions (Fisher, 1985). Explanations regarding the difference in Verbal and Performance scores have included overlearning and resiliency of verbal material and the requirement of
more complex responses, task novelty, attention and motor speed in Performance tasks as compared to Verbal tasks (Vocabulary, Information, etc.) (Mandleberg & Brooks, 1975).

Many researchers have argued that the WAIS is a measure of overall intellectual functioning and lack of impairment noted in these scores does not indicate a lack of cognitive impairment in other areas such as memory and higher executive functions (Miller, 1986). Levin et al. (1982) state that the WAIS is not sensitive to subtle cognitive impairments following closed head injury and Fisher (1985) adds that conclusions should not be based on WAIS data alone given the plethora of findings of persistent cognitive deficits derived from more specific assessments of these functions.

Language functions. Lezak (1983) defines aphasia as "defects of symbol formulation" (p. 32). She describes several types of aphasia which are determined according the particular deficits exhibited. Expressive or Broca's aphasia is characterized by difficulty with production of speech, with relatively intact comprehension. Receptive or Wernicke's aphasia involves fluent but garbled jargonistic speech with impairment in comprehension. Intact comprehension with garbled words and repetition deficits is referred to as conduction aphasia. Lastly, global aphasia is characterized by a combination of both expressive and
comprehension deficits. Compared to open head injuries, complete aphasic disorders occur rarely following closed head trauma (Hillbom, 1960). In a study of 750 closed head injured patients, Heilman, Safran and Geschwind (1971) found only 13 patients who demonstrated language disorders sufficiently severe to be labeled "aphasia". The aphasic disorders exhibited were expressive deficits with difficulty with word finding and naming objects or of a Wernicke's type in which oral comprehension was impaired and neologistic speech common. Levin, Grossman and Kelly (1976) used the Multilingual Aphasia Examination with 50 closed head injured patients. They found only minimal aphasia but specific linguistic deficits including difficulty with picture naming, writing from dictated verbal information, word associations, and short term verbal retention. The patients also demonstrated circumlocution and paraphasic errors which is certainly consistent with dysnomia or poor picture naming. However, deficits in sentence repetition and reading comprehension were not found. Benton (1979) concludes that the results of this study indicate that verbal associative processes such as word production and naming are most affected following TBI.

Levin et al. (1982) (as cited in Miller, 1986) state that although aphasia is uncommon following closed head
injury, specific dysphasic deficits may be found without obvious aphasia. However, they have found that when a frank aphasia disorder is present, the patient is more likely to have suffered diffuse brain injury or lesions in the dominant hemisphere. These authors also note that dysarthria may or may not occur in the presence of aphasia and that linguistic impairments such as writing disorders, ideomotor praxis and tactile naming are often found at a higher rate in severely head injured patients. In a follow up study investigating aphasia after TBI, Levin, Grossman, Sarwar and Meyers (1981) found that more than half of their patients in the study demonstrated residual deficits including impairment in word finding and naming at 6 months post injury.

Sarno (1980, 1984) assessed language functions in 69 head injured patients at 48 weeks and 1 year post injury. Although linguistic impairment could not be identified simply by monitoring the patients' conversations, the author found significant deficits with standardized clinical assessments including dysarthria, dysphasia and impairment in language processing. Additional studies have concluded that "subclinical" language deficits are common following TBI such as impairment in naming, verbal fluency, syntax, spelling, sentence construction, auditory comprehension and integration of receptive and expressive language functions (Adamovich, Henderson &
Grimm and Bleiberg (1986) argue that although language impairments are found after head injury, differentiating formal language disorders from impairment in communication that are a result of additional significant cognitive deficits is an extremely difficult task. They cite studies in which patients have demonstrated linguistic deficits in conjunction with diffuse cognitive impairment and therefore conclude that "we would agree with Halpern, Darley and Brown (1973) that the most common disorder is confused language." (p. 500).

**Higher executive functions.** Higher executive functions include such skills as information processing, organization, planning and adaptability (Fisher, 1985). Many head injured patients demonstrate impairments in abstract reasoning which incorporates cognitive functions as integration of knowledge and perception and the ability to formulate future actions based on current information (Goldstein, 1942, 1943). Impairment in organization and strategic planning has often been associated with damage to the frontal lobes (Luria, 1980; Adamovich, Henderson & Auerbach, 1985). Additional effects of damage to the dorsolateral frontal cortex include concrete thinking, disinhibition and reductions in spontaneity, initiation, drive and self-monitoring (Lezak, 1988b). Grimm and Bleiberg (1986) state that rigidity, perseveration, mental
inflexibility, and failure to initiate plans and shift strategies which have proven to be ineffective in solving a task are all characteristic of patients with TBI. They also cite self-centeredness and the failure to monitor one's own behaviors as common following head injury which result in ineffective management of the environment. Together with impaired abstract thinking, persons with TBI often demonstrate impaired judgment regarding appropriate social behavior and decisions which significantly impact their lives such as returning to work or caring for personal finances (Howard & Bleiberg, 1983).

Studies of reaction time following head trauma have led to conclusions that information processing and decision making abilities are significantly impaired in TBI patients, particularly with the increase in complexity of tasks (Gronwall & Wrightson, 1981). Although persons with TBI perform comparably to controls on simple tasks of reaction time, their performance is significantly lower on choice reaction tasks involving simultaneous processing of increasing amounts of information (Norrman & Svahn, 1961; Van Zomeren & Deelman, 1976).

**Memory functioning.** Compared to other cognitive deficits, impairment in memory functioning is often cited by patients as the most disruptive problem following TBI (Benton, 1979). Memory impairment is common following head trauma due to the damage sustained to structures known to
play a role in memory functioning including the medial temporal lobes (Levin & Eisenberg, 1979), basal forebrain (Damasio, Graff-Redford, Eslinger, Damasio & Kassell, 1985), and midline diencephalon (Victor, Adams & Collins, 1971). Crosson, Novack, Trenerry and Craig (1989) outlined specific memory functions associated with these brain structures. Encoding of information has been associated with the diencephalon (Cermak, Butters & Gerrein, 1973), whereas consolidation of information within long term memory is reportedly a function of the medial temporal lobes (Squire, 1987). Encoding of information is defined as representation of external physical stimuli within the nervous system as an internal code for the external stimuli (Houston, 1981). Information can be encoded by physical and sensory characteristics or by meaningful associations which facilitates organization of material in long term memory (Lezak, 1983). Consolidation refers to the transfer and storage of information from short to long term memory (Carson, 1984). Retrieval is defined as the accessibility of that stored information (Houston, 1981). Structures associated with retrieval of information may be the cingulate gyrus (Lhermitte & Signoret, 1976) and basal ganglia (Butters, Wolfe, Granholm & Martone, 1986). Crosson et al. (1989) argue that memory deficits following head injury are not all or none, but they generally consist of partial encoding, encoding and/or retrieval deficits which
result in different patterns of performance on standardized tests of memory functioning.

Long term memory functioning including encoding, consolidation and retrieval of information has been extensively researched in patients with Korsakoff's Syndrome (KS), Huntington's disease (HD) and Alzheimer's disease (AD) by Nelson Butters and his colleagues (Butters, Granholm, Salmon & Grant, 1987; Butters, 1984; Butters et al., 1986; Butters, Wolfe, Martone, Granholm & Cermak, 1985). Moss, Albert, Butters and Payne (1986) studied recognition memory in patients with these syndromes. Patients with HD demonstrated adequate recognition memory but performances on recall were significantly impaired. These findings suggest a deficit in the retrieval of information rather than the consolidation or storage of this material. HD is associated with biochemical changes in the basal ganglia, a structure associated with retrieval processes (O'Keefe & Nadel, 1978). The AD subjects exhibited significant rate of forgetting over a short delay which suggests deficits in storage of information. Neuropathologic changes in AD are generally found in the basal forebrain, amygdala and hippocampus. The authors conclude that the basal forebrain may play a role in immediate registration and storage, whereas the amygdala and hippocampus are involved in longer storage of information. In comparison, the KS subjects
demonstrated a normal rate of forgetting with little impairment in recall but significant deficits in recognition indicating deficits in consolidation of information.

In contrast to dementia, studies of encoding, consolidation and retrieval following closed head injury are relatively sparse. Schacter and Crovitz (1977) and Levin et al. (1982) provide reviews of the literature regarding long term memory after termination of PTA. In a study of 30 closed head injury patients of varying severity, Brooks (1975) found that recall of verbal material following a delay was significantly lower for the head injured subjects than for controls. The author attributed these results to an impairment in consolidation or storage of information rather than retrieval deficits. However, this study did not investigate memory processing as related to severity of head injury. Investigation of this relationship is required to draw sharper conclusions regarding long term memory following TBI (Levin et al., 1982).

The concept of severity was addressed by Levin and Eisenberg (1979) who used a selective reminding task with 96 young adult and adolescent head injured patients classified by type of injury. Mild was defined as no loss of consciousness or coma not beyond several minutes, whereas more severe injury was defined as coma persisting
beyond several minutes. Additional groups included patients with lateralized mass effect or bilateral mass lesion. Retrieval and recall of verbal information across trials was found to be significantly lower for patients with serious injury than those characterized by mild injury. Consolidation and retrieval were found to be more greatly impaired in patients with left temporal lesions as compared to left nontemporal and right hemisphere patients which reaffirms the significant role of the left temporal lobe in verbal memory functioning.

Levin and Goldstein (1986) compared verbal learning and memory in 12 severely head injured patients with 10 matched controls. They found that head injured subjects recalled significantly fewer words across trials than controls, but that recall for both groups was greater with a clustered list than with unrelated and related-unclustered lists. Enhancement of memory by organization, which is seen in head injured patients, is not found in patients with progressive dementia (Weingartner, Kaye, Smallberg, Ebert, Gillin & Sitram, 1981). Recall by head injured patients tended to be more random than controls with less use of clustering and subjective organization suggesting a passive learning style. Lastly, the head injured patients demonstrated greater number of intrusions compared to controls, which the authors attributed to the inability to separate memory
stores and to screen out irrelevant stimuli as a result of injury to the frontotemporal region.

Brooks (1974) found that severely head injured patients demonstrated poorer recognition on a continuous memory task as compared to normals due to deficits in initial learning (encoding). In a following study, Hannay, Levin and Grossman (1979) used a similar recognition task but employed subjects of varying severity. They classified patients into Grade I, II or III depending on duration of coma. A reduction in memory efficiency was demonstrated in the moderate and severe groups as the mild head injured patients achieved more correct responses. Gronwall and Wrightson (1981) also used Grades I, II and III to indicate severity of head injury. However, these grades were based on duration of PTA (defined as interval between accident and return of continuous memories) not duration of coma. Deficits in consolidation were found in the head injured subjects and these deficits were highly correlated with duration of PTA. That is, a significant correlation between number of words in storage and duration of PTA was found. Retrieval deficits were also found with head injury compared to normals but duration of PTA could not predict this impairment.

Rationale

The relationship between neuropathologic processes and neuroanatomical memory structures has been investigated
extensively in amnesia and dementia. However, research is significantly lacking in addressing the relationship between neuroanatomy of memory, the structural mechanics of closed head injury and the resulting effects on memory functions. Although previous research has attempted to differentiate encoding, consolidation and retrieval processes following closed head trauma, few studies have postulated deficits in these functions given the known structural mechanics of head injury, associated damage to neuroanatomical structures and severity of injury. Also, definitions of severity have been applied inconsistently from study to study which impedes comparisons and generalizations from the results. In addition, most studies have either utilized subjects of one level of severity or combined subjects of differing severities when analyzing the results.

Assessment tools used to measure multiple facets of memory functioning are numerous. According to Delis, Cullum, Butters, Cairns, and Prifitera (1988) criticisms of traditional memory scales include psychometrically unsound scoring procedures and inability to measure spared memory functions in addition to deficits (Lezak, 1983). However, these authors argue that the Wechsler Memory Scale - Revised (WMS-R; Wechsler, 1987) and the California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, Ober & Fridlund, 1987) have addressed these criticisms and offer
separate but complementary methods of assessing memory. In their study involving a correlational analysis of these two scales, the authors reported that the WMS-R indicates the amount of information retained, whereas the CVLT measures how a person's memory functions in terms of strategies, processes and errors. Although they found convergence between the two scales, several indices were not strongly related suggesting that these two assessment tools can be used with clinical populations as complementary measures of memory functions.

Reliability coefficients are provided for both the WMS-R subtests and composite scores. Test-retest coefficients were used as reliability estimates for five of the subtests with internal consistency estimates for the remaining seven subtests. The average reliability coefficients across age groups for subtests and composites ranged from .41 to .90 with a median value of .74. Factor analyses of immediate recall subtests have revealed a two factor structure of the WMS-R including learning and retention and attention and concentration. When delayed recall measures were included in the factor analysis, three factors of verbal memory, nonverbal memory, and attention were identified (Bornstein & Chelune, 1988). Additional studies have indicated criterion-related validity for the WMS-R in that consistently significant differences across clinical groups such as psychiatric groups, alcoholism,
head injury and dementia were found (Wechsler, 1987).

Reliability of the CVLT is estimated utilizing measures of internal consistency and test-retest methods. Internal reliability was found to be estimated at .92 for the total score over five trials. Test-retest reliabilities were significant for 13 out of 18 subtests ranging from .47 to .79. Validity of the CVLT was investigated using factor analyses, correlations with the WMS and differentiation of clinical groups based on CVLT variables. Factor analyses of the CVLT has revealed six factors including general verbal learning, response discrimination, learning strategy, proactive effect, serial position effect and acquisition rate (Delis et al., 1987). The total score across trials for the CVLT correlated .66 with the WMS Memory Quotient. Lastly, different levels and patterns of the CVLT scores were found for selected neurological groups including alcoholism, Parkinson's disease, multiple sclerosis, Huntington's disease and Alzheimer's disease.

Both the WMS-R and the CVLT have been applied to clinical populations. Butters et al. (1988) found that indices on the WMS-R differentiated between amnestic and demented patients. The amnesic and Alzheimer's patients demonstrated more rapid rate of forgetting of verbal and visual information compared to normals and Huntington's patients. In addition, the amnesic patients with temporal lobe damage exhibited a more rapid rate of forgetting as
compared to amnesic patients with diencephalic damage. Crossen and Wiens (1988) examined memory functioning in head injured patients using the WMS-R. Patients with moderate to severe head injury were used and the findings indicated that head injured subjects scored significantly lower on all indices with the exception of Attention/Concentration. The CVLT has also been used with head injured patients. Crosson, Novack, Trenerry and Craig (1988) found that severely head injured subjects demonstrated both deficits in retrieval and consolidation by using recall and recognition measures from the CVLT. They found that these subjects demonstrated lower scores across the learning trials, more intrusions in output and less use of efficient learning strategies (semantic clustering) compared to controls. Retrieval deficits were postulated to result from "the failure to store information by semantic categories (which) leads to a decreased ability to later retrieve information in long-term storage during free recall, but providing semantic categories improves retrieval during cued recall." (p. 765). Consolidation deficits were inferred by performance on the recognition trial of the CVLT which minimizes retrieval demands to more accurately assess the number of items in long term memory. Crosson et al. (1989) used the recognition trial of the CVLT to differentiate encoding, consolidation and retrieval
deficits in severely head injured patients. Patients who demonstrated lower scores over the learning trials, below normal correct recognitions and above normal false recognitions were interpreted as exhibiting encoding deficits. Below normal correct recognitions and normal false recognitions indicated impairment in consolidation processes, whereas normal correct and normal false recognitions but reduction in free recall on delayed trials demonstrated retrieval deficits.

The purpose of the current study was to assess memory functioning with the WMS-R and the CVLT to examine the effects of severity of head injury on encoding, consolidation and retrieval mechanisms. Consistent with widely accepted understanding of the mechanics of closed head injury, DAI occurs principally on the surface (cortical) with mild injury and extends inward to the diencephalon (subcortical) with increasing severity (Levin et al., 1982). Using PTA as an indicator of severity of brain damage sustained in a closed head injury, predictions regarding memory functioning following TBI can be made based on the neuroanatomy of memory and neuropathology of closed head injury. Significant differences between head injured patients across severity and controls were anticipated with normals exhibiting superior performance on all memory measures.

With regard to performances on the WMS-R, a linear
reduction in all indexes (Verbal Memory, Visual Memory, General Memory, Delayed Recall) with the exception of Attention/Concentration was predicted in the head injured groups compared to the controls. Herman (1988) provides a description of the indexes of the WMS-R. The Verbal Memory Index includes memory for two brief stories and verbal paired associates. The Visual Memory Index is comprised of measures of memory for figural designs and visual paired associates. The Verbal and Visual Memory Indexes are combined to form the General Memory Index. The Delayed Recall Index includes administration of two verbal and two nonverbal subtests approximately 30 minutes following the initial presentation. Lastly, the Attention/Concentration Index includes digit span, mental control and a visual analog of the digit span. Within the head injured groups, a linear reduction in all WMS-R measures except Attention/Concentration was postulated as severity of head injury increases due to cortical and subcortical damage.

With regard to the CVLT, overall reductions on all memory indices was expected to be found in the head injured subjects compared to normals. Within the head injured group, performance on the CVLT variables was expected to decrease as severity of head injury increased due to damage occurring in severe head injuries which extends beyond the cortex into subcortical regions where encoding and retrieval processes are located. Therefore, memory
functioning in the mildly head injured would reflect consolidation deficits, whereas severely head injured would reflect encoding, consolidation and retrieval mechanisms which would produce significant decreases in recall and recognition compared to head injuries of lesser severity.
Subjects. A total of 30 head injured patients were selected retrospectively from available patient files at the Neuromedical Center of Baton Rouge who met the following criteria: 1) right handedness; 2) PTA of less than 60 minutes which constituted mild severity or PTA of greater than 24 hours for the severe CHI group. All procedures used in the current study were administered as part of a routine comprehensive neuropsychological evaluation. Severity of closed head injury was derived from patient retrospective reports of PTA which is defined as coma plus period of confusion between termination of coma and recovery of continuous memory. Diagnoses of mild and severe head injury were derived from Russell and Smith's (1961) categories based on duration of PTA. Subjects who reported a history of drug and/or alcohol abuse, neurological disease or dementia prior to their head injury were excluded from the study. Demographic and historical data were obtained from routine extensive clinical interviews.

The control group consisted of 15 non-head injured individuals recruited on a volunteer basis from the local community. The control subjects were matched to the experimental groups by age, gender, race and education. Based on the distribution of the mild and severe
CHI groups, four levels of age (17-24, 23-34, 35-44, 45-74) and three levels of education (less than 8 years, 9-12, greater than 12 years) were utilized in matching experimental and control subjects according to age and education. Only those subjects who were right handed and reported no history of open or closed head injury, drug and/or alcohol abuse, neurological impairment, or psychological factors which may affect memory functioning were included in this group.

Group 1 (Mild Closed Head Injury):
This group consisted of 15 individuals, eight males and seven females with a mean age of 39.73 (SD = 12.23) an age range of 18 to 67. The mean number of years of education was 12.33 (SD = 4.06). There were eight blacks and seven whites. Table 1 contains associated deficits for all group members including language, sensory/perceptual, and motor impairments.

Insert Table 1 about here

Group 2 (Severe Closed Head Injury):
Members of this group included 15 individuals, 10 males and 5 females ranging in age from 17 to 52 with a mean age of 28.80 (SD = 10.15). Mean years of formal education was 11.33 (SD = 2.22) and the racial composition was 3 blacks and 12 whites. Associated deficits among the severe
TBI patients are presented in Table 2.

Insert Table 2 about here

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**Group 3 (Controls):**

The control group consisted of 15 subjects, eight males and seven females with a mean age of 38.07 (SD = 17.74) and an age range of 17 to 77. There were 10 whites and 5 blacks, and the mean level of education was 12.87 years (SD = 2.82).

**Materials.** The control subjects were administered the Medical and Psychological Screening for Healthy Adults which was derived from Adams and Victor (1981) to assess the presence of any factors causing memory impairment in these subjects. Factors known to affect memory functioning include such medical disorders as neurological disease, vascular disease, diabetes, epilepsy, dementia, and such psychological disturbances as depression (Adams & Victor, 1981). Both the control and experimental subjects were administered the Lateral Dominance Examination (Reitan & Wolfson, 1985) which assesses the lateral dominance by determining whether right or left side is preferred on tasks that can only be performed using one side. This instrument indicated handedness, footedness and ocular dominance (Appendix B). Both experimental and control subjects also completed the following measures of
intellectual and memory functioning:

**INTELLECTUAL SCALES**

1. **Wechsler Adult Intelligence Scale—Revised** (WAIS-R; Wechsler, 1981). This is an individually administered measure of intellectual functioning consisting of six verbal (Information, Digit Span, Vocabulary, Arithmetic, Comprehension, Similarities) and five performance subtests (Picture Completion, Picture Arrangement, Block Design, Object Assembly, Digit Symbol) which are alternated during administration. Raw scores on the subtests are converted to standard scale scores with a mean of 10 and standard deviation of 3. Scale scores are summed and converted to Verbal, Performance, and Full Scale IQ's.

2. **Wechsler Memory Scale—Revised** (WMS-R; Wechsler, 1987). The WMS-R is an individually administered scale of memory functioning. Mental status items are administered in the Information and Orientation subtest but this score is not used in calculating any memory scores. The scale consists of eight subtests which measure short term recall (Mental Control, Figural Memory, Logical Memory I, Visual Paired Associates I, Verbal Paired Associates I, Digit Span, Visual Memory Span) and four additional subtests (Logical Memory II, Visual Paired Associates II, Verbal Paired Associates II, Visual Reproduction II) which measure delayed recall of both verbal and visual stimuli. Two
composite scores are derived from the eight short term subtests, the Attention/Concentration and the General Memory scores. The General Memory Index is composed of two subscales measuring the the Verbal Memory and Visual Memory. The four delayed recall trials form the Delayed Recall composite. Composites are converted to Indexes each of which has a mean of approximately 100 and a standard deviation of 15.

2). California Verbal Learning Test (CVLT; Delis et al., 1987). The CVLT is an individually administered assessment of recall and recognition of verbal material. A list of 16 items is presented over five trials. Four words from four separate categories comprise the list. A new list of 16 items is then presented as interference for one trial. Short delayed free and cued recall of the original list is then completed. Following a 20 minute delay, free recall, cued recall and recognition of the first list are assessed. According to Delis et al. (1987), the CVLT provides levels of total recall and recognition on all trials, semantic and serial learning strategies, serial position effects, learning rate across trials, consistency of item recall across trials, degree of vulnerability to proactive and retroactive interference, retention of information over short and long delays, enhancement of recall performance by category cueing and recognition testing, indices of recognition performance, perseverations
and intrusions in recall and false positives in recognition. The CVLT Administration and Scoring Software which was used to score all data provides age- and sex-adjusted standard scores. Total Trials 1-5 is based on a T score with a mean of 50 and standard deviation of 10. All of the remaining variables of the CVLT are scaled as standard scores with a mean of 0 and a standard deviation of 1.

Procedure. Retrospective data from 30 closed head injured patients were obtained from available files from the Neuromedical Center of Baton Rouge. Lateral dominance and intellectual functioning as assessed by the WAIS-R, as well as scores on the WMS-R and CVLT were recorded. Demographic data including age, gender, race, education, type of injury and PTA were obtained from routine extensive clinical interviews performed with each patient. Severity of head injury was based on PTA with groups of mild and severe head injury. All subjects were notified that they have been chosen to participate in the current project via mailed informed consent with request to contact the Neuromedical Center if they did not wish to participate and/or regarding questions about the project. Appendix C contains the informed consent for the CHI subjects. No subjects indicated a desire to be withdrawn from the study.

Control subjects consisted of 15 volunteers from the local community. A brief interview was conducted with each
potential subject in which the project was described and demographic information was obtained. A consent form summarizing the study with risks and benefits of participation provided was completed by those chosen to participate in the project (Appendix D). These subjects then completed the Lateral Dominance Examination and Medical Screening Questionnaire. Those individuals meeting the criteria were matched to the experimental subjects according to age, race, gender and education based on the distribution of the CHI groups. They then completed the WMS-R and CVLT during a single session lasting approximately 3 hours.
Chapter III
RESULTS

Homogeneity among the experimental and control groups was examined with regard to demographic variables that may affect memory functioning. Premorbid WAIS-R Full Scale IQ was derived by the use of regression equations which involved demographic variables of age, race, gender, education and occupation (Barona, Reynolds, & Chastain, 1984). No significant differences between the groups were found on age, education, premorbid intellectual functioning or time interval from injury to assessment. A summary of demographic variables for each group is presented in Table 3.

Insert Table 3 about here

Nineteen dependent variables were involved in the current study: three intellectual scores, five scores of memory functioning from the Wechsler Memory Scale - Revised and 11 scores from the California Verbal Learning Test. Appendices E-H contain the correlations between all dependent variables. Table 4 contains the means and standard deviations for the mild head injured, severe head injured and control groups on each dependent variable.
Three separate one-way univariate analyses of variance (ANOVA) tests were utilized to examine differences in intellectual functioning between the three groups. Three IQ scores obtained from the WAIS-R including Full Scale IQ, Verbal IQ and Performance IQ were examined. Performances on memory tasks from the WMS-R were compared using five separate one-way ANOVA's with the verbal index, visual index, general memory index, attention/concentration index, and delayed recall index as dependent variables. Additional separate one way ANOVA's were performed on 11 variables from the CVLT which are as follows: sum of words recalled over trials 1-5, number of words recalled on Trial 1, number of words recalled on Trial 5, short delay free recall, short delay cued recall, long delay free recall, long delay cued recall, semantic learning, serial learning, consistency of recall over trials 1-5, and number of hits on a delayed recognition trial. Tukey's Studentized Range Tests were subsequently performed to control for experimentwise error rate. The results from the Analyses of Variance and Tukey's tests for each ANOVA are found in Table 5.
Analyses of variance revealed group main effects for all measures of intellectual functioning: Full Scale IQ, $F(2,42) = 4.02, p > .02$; Verbal IQ, $F(2,42) = 3.64, p > .03$; Performance IQ, $F(2,42) = 3.93, p > .02$. Tukey's tests indicated that the severely head injured subjects scored significantly lower on Full Scale, Verbal and Performance IQ than controls. Although WAIS-R scores were found to be in the expected direction, no significant differences were found between severe and mild head injured subjects and between controls and mildly head injured subjects on these measures.

Significant group main effects were also found on four of the five memory indexes from the WMS-R: Verbal Memory, $F(2,42) = 5.57, p > .007$; Visual Memory, $F(2,42) = 6.24, p > .004$; General Memory, $F(2,42) = 4.63, p > .01$; and Delayed Recall, $F(2,42) = 12.28, p > .0001$. For verbal memory, visual memory, and delayed recall measures, Tukey's tests indicated significantly greater performance for controls than for mildly head injured and for controls than for severely head injured subjects. Although verbal and general memory scores were slightly higher in the mild head injured compared to severely head injured, these differences were not significant. The mildly head injury
subjects achieved lower performance than the severe subjects on a recall test of visual stimuli, but these results also were found to be nonsignificant. With regard to general memory index, normals achieved significantly better scores than severely head injured individuals. Although in the expected direction, no significant differences were found between controls and mild head injured and mild and severe head injured on this variable. A univariate one-way ANOVA yielded no significant group main effect for the Attention/Concentration index of the WMS-R.

Eleven variables from the CVLT were examined using separate one-way analyses of variance. A significant group main effect was found for sum of words recalled in Trials 1-5, $F(2,42) = 9.81, p > .0003$, as well as number of words recalled on Trial 1, $F(2,42) = 8.52, p > .0008$ and number of words recalled on Trial 5, $F(2,42) = 10.37, p > .0002$. Tukey's tests indicated that controls recalled more words over five trials and on Trial 1 than the severe head injured did. The performance for controls was also greater than that for the mild head injured subjects and the mild greater than the severes, but these differences were nonsignificant for these two measures. Total number of words recalled on Trial 5 was found to be significantly greater for controls than that for either mild or severely head injured individuals. In addition, Tukey's tests
revealed significantly better performance by the mild head injured group than by the severe group for this variable.

Significant group main effects were also found for the following delayed recall measures: short delay free recall, \( F(2,42) = 14.25, p > .00001 \); short delay cued recall, \( F(2,42) = 9.72, p > .0003 \); long delay free recall, \( F(2,42) = 12.75, p > .00001 \); long delay cued recall, \( F(2,42) = 10.06, p > .0003 \). Tukey's tests indicated that the number of words recalled following a delay of either several minutes or delay of 20 minutes was significantly greater for controls than either mild or severely head injured subjects. Mild subjects also scored significantly higher than severe subjects on both variables. When cuing was provided following a short delay and long delay, normals again performed higher than the severes, but not significantly greater than the mild subjects. Although the mild subjects recalled more words than the severes, differences on these two variables were nonsignificant.

Univariate analyses of variance revealed a significant main effect for the use of semantic learning strategy, \( F(2,42) = 5.22, p > .009 \). Controls were found to employ semantic techniques to a greater extent than severes, but no significant differences were found between controls and milds and between milds and severes on this measure. A univariate ANOVA yielded no significant main effect among the three groups for serial learning. Consistency of recall
over trials 1-5 was found to be significantly different among groups, $F(2,42) = 6.24, \ p > .004$. Tukey’s test revealed that both controls and milds consistently recalled the same words across repeated presentations of the same list as compared to severes. No significant differences were noted between controls and mild head injured subjects on this measure. Significant differences were also revealed with number of hits on a recognition task following a 20 minute delay, $F(2,42) = 6.32, \ p > .004$. Controls performed significantly higher on the recognition trial than either mild or severe subjects. No significant differences were found between mild and severe performance.
Chapter IV

Discussion

The purpose of this study was to assess memory functioning with the WMS-R and CVLT to examine the effects of severity of head injury on encoding, consolidation and retrieval mechanisms. Due to strong convergence between the two measures and their assessment of reportedly different aspects of memory, the Wechsler Memory Scale – Revised and the California Verbal Learning Test used in conjunction offer a complementary and thorough approach to the assessment of memory (Delis et al., 1988). Previous studies have employed either the WMS-R or the CVLT in the assessment of memory following closed head injury. However, these two tests have not been applied in unison to this clinical population despite preliminary results suggesting their increased utility when used together in assessing memory. The results of this current study indicate that the WMS-R is effective in providing information regarding memory functioning across head injury, but it is insensitive to severity of head injury. In contrast, the CVLT was shown to be a significantly more sensitive measure of memory functioning. Overall results indicated that closed head injury produces severe deficits in learning and recall of both verbal and nonverbal stimuli, with degree of impairment related to severity of injury (PTA). That is, individuals with severe closed head injury exhibited
greater deficits in both amount of information learned and the strategies and processes used in recall of information.

Although not the primary focus of this current study, intellectual functioning in both the head injured and control subjects was assessed using the WAIS-R. Persons with severe head injury exhibited significantly lower scores on Verbal, Performance and Full Scale IQ as compared to controls. Although previous research by Mandleberg and Brooks (1975) found that intellectual functioning of severely head injured individuals returned to normal levels three years following CHI, results of the present study are consistent with studies which found residual deficits in Verbal, Performance and Full Scale IQ as compared to controls following considerable interval between injury and assessment (Drudge, Williams, Kessler, & Gomes, 1984). In addition, no significant discrepancy in verbal-performance functioning was noted within the severely head injured group. These results are consistent with previous studies which found that although the Verbal IQ was greater than Performance IQ during the acute stages of brain damage, this discrepancy disappears approximately 12 months following injury (Mandleberg, 1976; Drudge et al., 1984). The mean time interval in the current study from date of injury to assessment for the milds and severes was 17.2 months and 14.53 months respectively, which was not found to be significantly different. No significant
difference in intellectual functioning was found between the mild and severe head injured subjects or between mild head injury and controls. These results support the argument offered by other researchers that the WAIS-R is not sensitive to subtle cognitive changes following TBI and lack of impairment in WAIS-R scores does not indicate lack of cognitive deficits in other areas (Miller, 1986; Levin et al., 1982).

In contrast to the WAIS-R, the Wechsler Memory Scale-Revised detected more subtle differences in cognitive functioning between head injury and control subjects. Significant differences between severe head injured and controls, as well as between mild head injured and controls were found on three out of five WMS-R variables. On immediate recall of verbal material in the form of paragraphs and verbal paired associates, controls scored significantly better than mild and severe head injured. Similar results were found with immediate recall of visual stimuli summing across subtests of visual reproduction, visual paired associates and recognition of figures. Controls scored significantly greater than both mild and severe head injury subjects for this overall visuospatial variable. Differences in performance disappeared between mild head injured and controls for the General Memory Index. The General Memory Index is a composite of both verbal and visual memory scores, but it provides a more
accurate description of verbal memory functioning as opposed to visual functioning. Loring (1989) points out that out of the 193 raw score points which form the General Memory Index, 124 are from verbal subtests and only 69 points are from visual subtests. The fact that this index is more heavily weighted toward verbal functioning can cause intergroup differences in performance to disappear if the verbal index is higher than the visual index. Findings of the current study support Lezak's (1988a) argument that global measures are often insensitive to various performances exhibited by brain damaged individuals. Therefore, specific performances on the Verbal and Visual Indexes should be examined rather than drawing conclusions from the General Memory Index in assessing particular facets of memory functioning.

Performance for delayed recall of verbal and visual stimuli was significantly decreased in mild and severe head injury subjects compared to controls. No difference in recall was found between mild and severe subjects which highlights the insensitivity of this index to severity of brain injury. In addition, no significant differences in attention and concentration were found among any of the groups in the current study. These results are consistent with Crossen and Wiens (1988) who found significant impairment on all composite Indexes with the exception of the Attention/Concentration Index in severely head injured
subjects compared to controls. These authors found much
greater deficits on the Paced Auditory Serial Addition
Test, a more demanding task of information processing and
sustained attention and concentration, than on the WMS-R
Attention/Concentration Index. Therefore, additional
measures of attention and concentration are recommended to
avoid potential false negative diagnoses in clinical
settings.

Results from the present study with the California
Verbal Learning Test with head injured subjects are
consistent with previous research (Crosson et al., 1988;
Crosson et al., 1989). The CVLT was found to be the most
sensitive measure in highlighting memory deficits between
head injury and controls and between level of severity of
head injury. Encoding of information is reflected by
immediate recall following presentation of the stimuli.
Recall of stimuli following the first presentation was
found to be significantly deficient in the severely head
injured subjects. In addition, the severely injured
subjects exhibited significant difficulty in consistently
recalling the same items across repeated presentations of
the same list. That is, the severe subjects responded to
each presentation of the list as if it were a new list,
abandoning one recall strategy for another. No significant
impairment was found in mild head injured subjects
regarding recall following Trial 1 or consistency of recall
over the five trials. Therefore, these results indicate that only persons with severe head injury exhibited difficulty with encoding of information. Deficits in encoding were predicted to occur within the severely head injured due to damage sustained in the subcortical regions, whereas persons with mild head injury exhibited no difficulty with encoding due to DAI occurring in cortical regions.

Consolidation and/or retrieval of information is indicated by free recall of that information. Total information recalled was significantly decreased with severe head injury compared to controls. Recall of information on Trial 5 was found to be significantly impaired for both mild and severe subjects compared to normals, with severe head injured exhibiting significantly greater deficits than the mild individuals. Recall of information following both short and long delays were significantly impaired for mild and severe head injured subjects compared to controls. The severe individuals showed greater deficits in free recall than did mild subjects.

To differentiate retrieval from consolidation of information, facilitation of cuing in free recall processes can be utilized. The performance of the severe head injured subjects was found to improve with the use of categorical cues which provides them with a strategy with which they
can search long term memory. These results suggest that persons with severe head injury may exhibit difficulty with retrieval of information. In contrast, recall was not facilitated by cuing in the mild head injured subjects which suggests that the information was never adequately consolidated into long term memory. Therefore, mild head injured subjects exhibited only consolidation deficits, whereas the severe subjects exhibited both consolidation and retrieval difficulties. Consolidation is associated with cortical regions (temporal lobe) and these deficits were predicted in both the milds and severes due to damage sustained in the cortex in both of these injuries. Retrieval processes are dependent on the integrity of subcortical areas (basal ganglia) and were predicted to occur only in the severe head injured group.

In addition to free recall, recognition of information can be used to determine consolidation of information. Recognition of stimuli was impaired in both the mildly and severely head injured subjects compared to controls. Due to the lack of retrieval demands, recognition is a more accurate assessment of actual content of long term memory compared to free recall. Therefore, these results suggest that both the mild and severe head injury subjects exhibited deficits in consolidation of information.

Lastly, strategies of learning including semantic and serial processing were assessed in the head injury and
control subjects. No differences in serial learning were noted among the groups. However, severe subjects appeared to utilize semantic clustering in recall of information to a significantly lesser degree than controls. The inability to use an active learning strategy of reorganizing the target words into categorical groups, along with the inability to consistently recall the same items across repeated presentations, indicates that severe subjects are employing haphazard, disorganized styles of learning, with difficulty formulating or maintaining a learning plan.

One major limitation of the present study is the use of retrospective self-report estimates of posttraumatic amnesia (PTA). Research has shown that when patients are queried about their head injury and resulting confusion, it is often difficult for them to describe accurate experiences following TBI as opposed to information family members provided to fill in memory gaps (Levin et al., 1982). Other research has shown wide discrepancies in patients' estimates of amnesia and return of continuous memory compared to direct measurement of amnesia during their hospitalization (Gronwall & Wrightson, 1980).

Results of this study have shown that the WMS-R is useful in indicating the amount and type of information retained by head injured patients as it provides assessment of both verbal and visual memory functioning. In addition, it is effective in highlighting memory deficits between
head injured individuals and non-head injured persons. The CVLT was found to be more sensitive in identifying differences not only between head injury and no head injury, but also differences in strategies and processes utilized between mild and severe head injured subjects. However, the CVLT involves assessment of verbal memory functioning only. Therefore, in a clinical setting, using the WMS-R and the CVLT in conjunction when assessing memory functioning offers a more thorough assessment of both content and process of memory following closed head injury. In addition, when interpreting results from the WMS-R, it appears advisable to examine the specific Verbal and Visual Indexes rather than the General Memory Index due to its greater dependence of verbal functioning. Differences noted in verbal and visual memory functioning may be disappear suggesting global measures are insensitive to subtle differences in performance.

In addition, the inability of the Attention/Concentration Index on the WMS-R to detect impairment in sustained attention and concentration in head injured individuals calls for the need to incorporate additional measures in a neuropsychological assessment. More demanding tasks of information processing and attention such as the PASAT are needed to obtain a accurate assessment of attention and concentration as opposed to relying on the WMS-R alone.
Results of this study also have implications for rehabilitation of patients suffering from closed head injury. Their inability to employ semantic learning strategies and lack of consistency in the learning and recall of information highlight the need to instruct these individuals in such memory techniques as clustering, subjective organization and category search (Levin & Goldstein, 1986).

Conclusion

Significant memory deficits were found in individuals following both mild and severe closed head injuries. Degree of impairment in memory functioning was related to the severity of the injury. While mild head injured persons exhibited deficits in consolidation of stimuli, patients with severe head injury show significant impairment in encoding, consolidation and retrieval. They also demonstrated less use of semantic learning strategies and consistency of recall. These individuals utilized less effective strategies in recalling information and demonstrated haphazard, disorganized styles of learning. Therefore, memory deficits in encoding, consolidation and retrieval were demonstrated in the severely head injured which are consistent with damage sustained to the cortex, extending inward to involve subcortical regions. Results from the mild head injury subjects involving consolidation processes were also consistent with predictions indicating
damage to cortical regions.

The clinical utility of the WMS-R and the CVLT in the assessment of memory functioning following head injury has been shown. Each measure offers distinct information and can provide a clearer description of memory functioning than either test used alone. Future research employing both of these assessment techniques with different clinical populations is warranted.
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### Table 1

**ASSOCIATED DEFICITS FOR MILD HEAD INJURED SUBJECTS**

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*Language = dysnomia*

*Sensory/perceptual = tinnitus, hearing loss*

*Motor = decreased left grip strength*
Table 2

**ASSOCIATED DEFICITS FOR SEVERE HEAD INJURED SUBJECTS**

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*Language = dysarthria, dysnomia*
*Sensory/perceptual = visual acuity, hearing loss, tinnitus*
*Motor = reduced extremity strength*
Table 3

MEAN SUBJECT DEMOGRAPHIC VARIABLES

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<th>Time From Injury (months)</th>
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**Mean Scores on Intellectual and Memory Tests for All Groups**

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Summary of Results from ANOVA's and Tukey's Tests

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*Grp 1 = Mild Head Injured  
Grp 2 = Severe Head injured  
Grp 3 = Controls
APPENDIX
APPENDIX A

MEDICAL AND PSYCHOLOGICAL SCREENING FOR HEALTHY SUBJECTS

Subject# __________________________ Date _________

1. Have you ever been hospitalized or treated for an infection of the brain, spine or other nerves?

2. Have you ever been hospitalized for a head injury of any type?

3. Have you ever been knocked unconscious? If yes, how long did you remain so?

4. Have you ever been treated for or hospitalized for high blood pressure, heart problems, a stroke or other blood circulatory problems?

5. Do you now or have you ever had sudden uncontrollable body tremors, muscular twitches or convulsions?

6. Have you even noticed a brief loss of awareness?

7. Do you now have or have you ever been treated for vitamin deficiencies, diabetes, glandular problems or any other condition related to your body chemistry?

8. Have you ever been diagnosed to have a brain tumor or growth?

9. Has a medical doctor ever suggested that you might have premature aging of the brain (senility)?

10. Can you think of any medical problems that you have had in the past or currently suffer from that I did not ask you about?

11. Have you ever been admitted to a mental hospital for any period of time?

12. Are you currently seeing, or have you ever seen, a mental health professional for personal difficulties?

13. Do you suffer from a tingling, numbness, or burning pain in your feet or hands?

NOTE: Any and all affirmative answers to the above questions will be explored in greater detail to determine if the subject has evidence of a condition warranting exclusion from the study.
APPENDIX B
LATERAL DOMINANCE EXAMINATION

Subject # ___________ Date ______________

1. Show me your right hand ___; left ear ___; right eye ___

2. Show me how you:
   throw a ball __________
   hammer a nail __________
   cut with a knife __________
   turn a door knob __________
   use scissors __________
   use an eraser __________
   write your name __________

3. Write your full name ___________
   preferred hand (_____): ________ seconds
   non-preferred hand (_____): ________ seconds

4. Show me how you look through a telescope. _____ eye
   Aim this gun at the tip of my nose. _____ shoulder _____ eye

5. Show me how you kick a football. ________ foot
   Show me how you step on a bug. ________ foot
APPENDIX C

INFORMED CONSENT - MEMORY SUBJECTS

The psychology department at Louisiana State University and the Neuromedical Center of Baton Rouge are conducting a study of memory following head trauma. The primary investigators of this project include Linda M. Brown, MS and W. Drew Gouvier, Ph.D. of the psychology department at LSU and John Bolter, Ph.D. of the Neuromedical Center. This study involves the examination of your previous testing regarding memory functioning obtained through Dr. John Bolter and Linda M. Brown at the Neuromedical Center of Baton Rouge. All information obtained in this project will be used only in connection with the study and all participants will remain anonymous. We are hopeful that this project will contribute significantly to the understanding and treatment of head trauma and gratefully ask for your full cooperation in this project. Should you have any questions or concerns regarding this project, please do not hesitate to contact Dr. John Bolter, 2237 S. Acadian, Suite 400, Baton Rouge, LA 504/928/5972. Thank you for your participation in our study.
APPENDIX D
INFORMED CONSENT - CONTROL SUBJECTS

The psychology department at Louisiana State University and the Neuromedical Center of Baton Rouge are conducting a study of memory following head trauma. We are asking for volunteers to complete the Weschler Adult Intelligence Scale - Revised, the Weschler Memory Scale - Revised and the California Verbal Learning Test. In addition, individuals participating in this study will be asked to complete two other questionnaires. Completion of these forms in conjunction with measures of memory will allow us to determine how factors affect memory performance in head injured patients compared to persons with no head trauma. This project is being directed by Linda M. Brown, MS and W. Drew Gouvier, Ph.D. of LSU and John Bolter, Ph.D. of the Neuromedical Center of Baton Rouge.

All information collected in this study will be kept strictly confidential. Information obtained in this project will be used only in connection with the study and participants will remain anonymous. Participation is voluntary and will require approximately three hours. You may withdraw from the study at any time and your questions will be answered to your satisfaction. You may at any time elect not to answer a question if you do not wish to answer it. Results of the study will be furnished by mail upon request.

_________________________________________  ________________
Participant Signature                      Date

_________________________________________
Name

_________________________________________
Telephone Number

_________________________________________
Witness Signature
APPENDIX E

CORRELATIONS BETWEEN WAIS-R AND DEPENDENT VARIABLES

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*  .05  
** .01
### APPENDIX F

**CORRELATIONS BETWEEN WMS-R AND DEPENDENT VARIABLES**

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* * .05
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## APPENDIX G

### CORRELATIONS BETWEEN CVLT AND DEPENDENT VARIABLES

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# APPENDIX H

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* .05  
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VITA

Linda Marie Brown was born in New Orleans, La. She received a bachelor of science degree from Louisiana State University with a major in psychology and minor in sociology. Following her undergraduate studies, she attended the University of Southwestern Louisiana and received a master of science degree in general experimental psychology. She then pursued her doctoral degree at Louisiana State University in psychology with a specialization in neuropsychology. Particular areas of clinical and research interest included cerebrovascular accident and closed head injury. A clinical internship was completed at the Veterans Administration Medical Center in New Orleans, La. Ms. Brown is currently employed by the Department of Neuropsychology and Behavioral Medicine at the Rehabilitation Institute of New Orleans with primary duties involving cerebrovascular patients.
Candidate: Linda Marie Brown

Major Field: Psychology

Title of Dissertation: The Effect of Severity of Closed Head Injury on Memory Functioning

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

November 6, 1990