Wechsler Adult Intelligence Scale/Wechsler Memory Scale Difference Scores: Their Relationship to Brain Dysfunction and Closed Head Injury

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WECHSLER ADULT INTELLIGENCE SCALE/WECHSLER MEMORY SCALE DIFFERENCE SCORES: THEIR RELATIONSHIP TO BRAIN DYSFUNCTION AND CLOSED HEAD INJURY

by

Don A. Boyd

A Dissertation Submitted to the Faculty of The Graduate College in partial fulfillment of the requirements for the Degree of Doctor of Education Department of Counseling and Personnel

Western Michigan University Kalamazoo, Michigan August 1984
Performance differences between the Wechsler Adult Intelligence Scale (WAIS) and the Wechsler Memory Scale (WMS) were studied. Differences in performance between the WAIS Full Scale IQ Score and the WMS Memory Quotient (WMS discrepancy score) were compared across three groups consisting of a closed head injury group (N = 45), a localized lesion group (N = 25), and a psychiatric group (N = 45) who were unimpaired on the Halstead-Reitan Neuropsychological Battery. Also, WMS discrepancy scores were compared across a long-coma group and a short-coma group and the correlation coefficient between the WMS discrepancy score and neuropsychological impairment rating was obtained.

The WMS discrepancy score was hypothesized to be a marker of diffuse closed head injury; and it was predicted that WMS discrepancy scores would be greater in the closed head injury group, that the long-coma patients would show greater WMS discrepancy scores than a short-coma group, and that WMS discrepancy scores would be related to severity as defined by impairment on the Halstead-Reitan Neuropsychological Battery. Results confirmed the expected differences between groups. The closed head injury group was significantly different from both the localized lesion group and the unimpaired...
psychiatric group on the dimension of WMS discrepancy score. The long-coma group had significantly larger WMS discrepancy scores. The correlation between WMS discrepancy score and neuropsychological impairment rating was only weakly supported. The closed head injury group showed greater WMS discrepancy scores despite the fact that they showed the lowest WAIS scores. Results were interpreted as being supportive of the idea that the WMS discrepancy score may be a marker of diffuse closed head injury.

Implications for the use of the WMS discrepancy score and neuropsychological ratings were discussed. The WMS discrepancy score may be more descriptive of severity in closed head injury than neuropsychological impairment ratings. Despite weaknesses in the use of the WMS as a comprehensive test of memory, it may be of clinical value when used with other tests to highlight specific difficulties in the area of fluid verbal skills or information processing. The systematic inclusion of the WMS discrepancy score in the evaluation of closed head injuries seems warranted. Recommendations for further research were offered.
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Don A. Boyd
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CHAPTER I

THE PROBLEM AND THE BACKGROUND

The Problem

This research was initiated to gain further knowledge regarding the cooperative utilization of the Wechsler Memory Scale and the Wechsler Adult Intelligence Scale. More specifically, it is concerned with the degree of difference between the Wechsler Adult Intelligence Scale (WAIS) full scale intelligence quotient and the Wechsler Memory Scale (WMS) memory quotient. For the remainder of the present study this difference score will be more conveniently referred to as the 'WMS discrepancy score.'

This WMS discrepancy score, when it does exist, is thought to be important due to the fact that Wechsler (1945) constructed the memory scale to be equivalent to the WAIS full scale intelligence quotient score. Therefore, a Wechsler memory quotient significantly below the WAIS intelligence quotient should logically predict difficulties in information processing or memory as measured by the WMS.

The validity of the WMS as a screening device for memory dysfunction has been disputed however (Prigatano, 1978). He suggested that the WMS was not sufficient as a test of memory owing to its emphasis on verbal and language types of memory and its lack of capability to measure functions other than short-term memory processes. Prigatano (1977) also suggested that it is a poor screening test for head injury.
Despite its published shortcomings as a memory test, this researcher has observed deficits in WMS performance in populations of closed head injury patients. In an outpatient rehabilitation setting, a number of closed head injury patients were examined on an outpatient basis who were 2 years or more posttrauma. They seemed to perform poorly on the WMS in relation to the WAIS; a fact that appeared to be confirmed by the subjective impression that the rehabilitation of these individuals was often most hindered by an inability to show the capabilities for short-term memory and retention. Such subjective opinions of memory dysfunction have been formerly documented (Benton, 1979; Black, 1973). This study attempts to show that a comparison of the WMS discrepancy score between closed head injury and nonclosed head injury patients might help to determine if it could be used as a marker or indicator of specific types of short-term memory deficits; particularly those short-term memory processes that may be peculiar to the specific diffuse processes of closed head injury.

Neuropsychological batteries are constructed to be sensitive to the type and severity of head injury. However, these neuropsychological batteries are not satisfactory as brief screening devices for closed head injuries and they do not afford a comparison between memory and nonmemory processes. The WMS has been used in conjunction with the Halstead-Reitan Neuropsychological Battery for years and it has recently been added to the Michigan Neuropsychological Battery (Smith, 1983). Therefore, with the possibility that it may show different sensitivity to different clinical
syndromes, the use of the WMS in neuropsychological batteries needs to be further defined. This would be particularly true in respect to the meaning of the WMS discrepancy score. Logically, the Wechsler memory quotient and WAIS full scale intelligence quotient should show similar sensitivity to those types of brain dysfunction where memory disturbance is not an expected complaint. Conversely, in brain trauma where the damage is diffuse, there should be greater memory impairment of the type measured by the WMS discrepancy score. Also, if the WMS score is truly sensitive to short-term memory disruption following closed head injury, then the more severe closed head injuries should be associated with greater WMS discrepancy scores. Also, since severity of head injury is measured by impairment ratings on neuropsychological tests, then the WMS discrepancy score should increase along with those severity ratings among the closed head injured. Lastly, it is suggested that the closed head injury patients will show greater WMS discrepancy scores than will patients with localized lesions or psychiatric patients who are unimpaired.

This study then proposes to examine the WMS discrepancy score in relation to other severity indicators and also to carry out a comparison of the WMS discrepancy score with brain damaged and non-brain-damaged populations. Such comparisons might greatly extend the usefulness of the WMS as it is coming to be used as an additional neuropsychological technique. Due to its cited difficulties in validity as a memory task or an individual screening technique (Prigatano, 1977), its use within the context of other assessment
measures might prove more useful. Additionally, the early detection and assessment of the information processing and memory deficits of the closed head injured patient might be more meaningful and more simply assessed by a comparison of WMS and WAIS scores than with other phases of neuropsychological assessment. Thus, this investigation may help in the efficient use of measurement techniques already present in neuropsychological batteries. The ultimate detection and rehabilitation of cognitive deficits in the closed head injury patient requires this type of specific description at the earliest diagnostic opportunity.

In summary, the problem addressed by this research involves a greater understanding of the possible short-term memory or information processing deficits in closed head injury patients by the use of a WMS and WAIS comparison score called the WMS discrepancy score. It is attempted in this study to elucidate the meaning or importance of the WMS discrepancy score by correlative or comparative techniques and that the specific diagnostic capability of these deficits in instances of closed head injury could be carried out through already existing neuropsychological techniques which utilizes the WAIS in combination with the WMS.

Review of Literature

The review of the literature will be organized in the following manner: (a) definition and explanation of the diagnosis closed head injury to clarify this trauma as a type of injury process; (b) the definition and explanation of memory process; (c) a review of the
literature with reference to the impact of head injury upon memory processes; (d) the WMS will be described and a review will be presented of its relationship to brain trauma; (e) the WAIS will be reviewed along with its relationship to brain trauma; (f) the WAIS and WMS relationships will be described with emphasis upon their differential sensitivity to brain impairment; and (g) the Halstead-Reitan Neuropsychological Battery will be described with an emphasis upon its sensitivity to brain dysfunction. A brief summary of the literature which attempts to highlight the major findings will be provided at the end of these reviews.

Definition of Closed Head Injury

Closed head injury results from the impact of a blunt object striking the head. It is differentiated from a penetrating or missile wound trauma by the absence of penetration of the brain case. In penetrating head wounds the penetrating object itself may destroy brain tissue and constitute an immediate cause of localized brain lesion. Beyond the superficial fact that closed head injuries do not involve penetration and localized disruption of brain tissue, closed head injuries involve a set of occurrences which qualify it as a type of trauma quite distinct from other brain lesion producing processes.

Ommaya and Gennarelli (1974) have explicated the actual physical process of damage. The brain, as a semigelatinous mass, is seen to distort and move within the brain case under conditions of rotation, sudden acceleration, or sudden deceleration. These movements,
following blows to the head, distort the physical shape of the brain particularly at the frontal and temporal poles. Shearing forces disrupt the longer axon processes within the brain causing microscopic, rather than mass, lesions. Additionally, the force of the brain being pressed against the surfaces of the brain case may produce "bruising." Ommaya and Gennarelli (1974) attributed traumatic unconsciousness also to shear strain which extends to lower brain centers causing a "disconnection of the alerting system of the brain."

Levin, Benton, and Grossman (1982) have cataloged additional features. They described primary traumatic effects which are similar to those just described. These include both contusions and microscopic shearing and stretching of nerve fibers across communicating brain areas. They also cite the presence of intracranial hemorrhage. Raised intracranial pressure due to swelling of damaged tissues and the presence of mass lesions due to subdural bleeds and hematomas are additional effects.

Closed head injury by definition is fundamentally, therefore, a diffuse brain injury in which long axon processes connecting lower brain centers with the cortex, and long axons within the cortex, are disrupted. It is important for the purposes of the present study to understand closed head injury, therefore, as a mostly nonlocalized phenomena which may have superimposed localized affects due to hematomas or hemorrhage. The major aspect of acceleration and deceleration of the brain within the skull and shearing forces are its major discriminating features. These processes differentiate it
from a more local or focalized process resulting from cerebral vascular accidents, penetrating head wounds, tumors, or other pathological process.

Sequelae of closed head injury have been reviewed by Benton (1979). He noted the following symptom picture: (a) impairment of concentration, (b) fatigability, (c) disturbances in memory, (d) emotional instability and lowered tolerance for frustration, (e) personality alteration including either depression or disinhibition and euphoria, (f) some aphasic deficits, and (g) mixed, inconsistent sensory deficits. For the entire range of closed head injuries it would appear that the first three factors are the most prevalent and serious in the report of closed head injuries and that these symptom complexes, which appear to disrupt a client's momentary capacity to attend to stimuli in the environment and to memorize them, create long standing disability. An estimated 40% suffering these disabilities fail to make a satisfactory long-term social and economic adjustment following those injuries (Benton, 1979). The importance of developing an assessment technique to alert clinicians to the presence of disabling deficits in short-term memory is quite obvious given this prevalence.

Definition of Memory Processes

Memory is a very broad concept that encompasses a number of different processes and functions. E. W. Russell (1981) has reviewed the experimental literature and described types of memory
functioning which have applications to clinical neuropsychological use.

E. W. Russell's (1981) description of memory function includes a sensory store which is tied to immediate sensory detection capacity and which fades extremely quickly. Of greater importance is short-term memory also known as "immediate memory." This memory function lasts for 20 to 40 seconds or slightly more. It is determined by specific capacity and is usually related to about seven items; plus or minus two. Short-term memory is considered a "working memory" in that it is strongly associated with ongoing consciousness and the momentary organization of awareness. Therefore, short-term memory is intimately associated with the ongoing process of mental organization as well as being an indicator of momentary "storage." Thirdly, long-term memory has three recognized stages consisting of consolidation, storage, and retrieval. The consolidation stage is said to relate to the period when short-term memory is being transferred to long-term memory storage. During this stage of consolidation, long-term memory processes are particularly unstable and this unstable period may last for minutes to hours. The word recent memory is often used to describe that period of transfer which is longer than actual short-term memory but it is not a true long-term memory phenomenon. Long-term memory therefore extends from the recent memory of a few minutes, to years, depending upon the completeness and the organization of the memory trace.

Future discussions of memory in this paper will be primarily concerned with memory under the above descriptions of short-term
memory or long-term with recent memory being specifically designated as an intermediate and transitional term between the two.

Closed Head Injury and Memory Impairment

Despite the broad range of memory impairments associated with closed head injuries, the actual pattern of recovery of memory functions following closed head injury and the long-term effects are less clearly agreed upon. Conkey (1938) compared closed head injury and control patients on a variety of cognitive tasks starting at 2 weeks post-injury and extending to 50 weeks post-injury. By the time of the fourth test, the performance of the head injured group approximated that of the control group. Conkey claimed, however, in this group that memory performance fell behind the recovery of other intellectual functions, particularly verbal functions. Brooks (1972) tested 27 closed head injury patients on many tests of short-term memory and, when compared with a normal control group, documented difficulties on all measures used. He used a test very similar to the verbal learning and visual reproduction subtest of the WMS and interpreted his results to indicate that the head injury patients showed severe memory deficits by acquiring less information initially and also showed increased forgetting through the process of interference. In a later study, Brooks (1975) studied 30 closed head injury patients whom he classified as "very severe" with most having coma periods of 24 hours or more. He interpreted those results to suggest that long-term memory is more impaired than short-term memory in closed head injury and that it is related to overall
severity as measured by the length of coma. It should be noted, however, that Brooks utilized a simple digit span subtest as one measure of short-term memory which does not require organization of the stimulus material and requires only very brief retention periods. An inability to organize novel stimuli may contribute to difficulties in recent memory as suggested by Brooks. Impairment of memory functioning in 27 closed head injury patients in a task of extremely short recognition memory (10 to 20 seconds) was described by Levin, Grossman, and Kelly (1976). Persistent impairment on this type of task was uncovered in this group several months or more after trauma. They noted that many of the patients tested more than a year following injury were among the most impaired, suggesting rather permanent deficits. Since the present study is concerned with the long-term residuals in memory functioning, this nicely corroborates the presence of the problem with the results of the early study by Conkey (1938) cited earlier, which showed some memory impairments to persist even after recovery of many cognitive functions.

Brooks (1975) specifically attempted to objectify whether short-term memory or long-term memory processes are most affected in closed head injury patients. The 30 patients of his study were alert and well recovered from any recent posttraumatic or acute memory difficulties. The presentation of high frequency words and lists with recall periods ranging from zero seconds to 20 seconds was used in addition to digit span. Brooks noted that head injured patients were near normal in terms of digit span subtests but were
significantly poorer on even very short delayed recall. He interpreted these results to suggest a "long-term" memory deficit. Again these results could be an artifact of the overall complexity of the memory task, with digit span subtests representing the most simple and immediate form of short-term memory.

In another study attempting to find the nature of head injury impairments, Silverstein, Rosenbaum, and Rennick (1979) attempted to determine whether memory impairments were the results of decay in unstable memory traces or whether brain damaged individuals were more subject to greater interference which erased previous memories. Their sample included a mixed group of head injuries, including closed head injuries as well as neurosurgical patients. The results indicated that decay, and impairment of consolidation at the level of immediate memory, was greatest for this group. This implies deficits in the area of short-term memory and favors the hypothesis of rapid decay.

The previous studies suggest that while there is agreement regarding the presence of memory impairment in head injury patients, speculation about the type of memory impaired varies from the short-term memory processes to more long-term memory processes. The actual incidence of memory dysfunction following closed head injury was probably first investigated by W. R. Russell (1932). He calculated that about 36% of the cases following closed head injury develop some type residual memory problem. However, methodological problems with the study were present in that the degree of memory impairment was not reported and the method arriving at "severity"
was not reported. More recently, Lidvall, Linderoth, and Norlin (cited in Schacter & Crovitz, 1977) depended upon the patient's subjective report to determine the incidence of memory impairment and found reported memory difficulties in about 16% of closed head injury cases they reviewed. These cases range from only 2 to 90 days posttrauma, however, suggesting that much of their sample was biased in the direction of very mild postconcussive syndromes. Both of the above studies lack comparative psychometric data or any controls upon the severity of head injury, such as length of coma.

In a very comprehensive review of the literature regarding closed head injuries, Schacter and Crovitz (1977) concluded that most studies of closed head injury substantiate correlations between posttraumatic amnesia, which is the period of absence of continuous awareness following injury, and length of coma to a broad range of memory difficulties. However, they noted that the literature concerning the recovery process ranges from studies that suggest no remaining memory impairment 2 years after closed head injury to those who were able to find correlations between coma and memory deficits as much as 5 years after injury. There is a general tendency for a variety of memory effects to be found in head injuries, especially with longer periods of coma or posttraumatic amnesia. Differences in methods of measurement as well as rather important differences in agreement about what is considered long or short periods of coma prevent meaningful consistencies in conclusions drawn about the overall impact of closed head injury upon later memory functioning. Early as well as later studies, as we have seen,
however, suggest that memory impairment is a remaining deficit of considerable importance.

A major lack of specific comparisons between types of head trauma is conspicuous in the early literature. The next section which more specifically reviews the use of the WMS to measure head injury effects allows examination of more consistent results of a single psychometric instrument.

The WMS and Its Relationship to Brain Trauma

An explanation of the WMS, its content, and its psychometric structure is in order previous to a review of its sensitivity to brain damage effects.

Wechsler (1945) desired to develop a "rapid, simple memory examination." Since he desired that the memory quotient scores be made comparable and equivalent to the then popular Wechsler-Bellevue Intelligence Scale, he calculated correction scores for an age group that could be added to the total score of the WMS so that the patient's memory quotient would be equal to his or her full scale intelligence quotient score. In this way he had hoped that memory deficits relative to the patient's overall cognitive functioning could be estimated.

He included seven subtests. Subtests 1 and 2 are concerned with personal and current information as well as orientation. These subtests essentially determine whether the patient is communicative or oriented to surroundings sufficiently to take the test. A third section, mental control, requires the patient to rapidly execute
overlearned material, such as reciting the alphabet, counting by 3s, and doing other simple tasks under the pressure of time. Logical memory is the fourth section and requires the person to recall a number of items presented in two short-story passages which are read to the patient. The fifth section which is memory span is identical to digit span on WAIS. The sixth section which is visual reproduction requires the person to draw from memory geometric designs after he or she has been shown them for 10 seconds. The seventh section is associate learning which requires a patient to listen to a number of paired words and then to recall the accompanying word when the word list is read. The patient is allowed three trials, and the words are divided into easy words which are logically associated and hard words which have no logical association.

The factor structure of the memory scale was investigated by Davis and Swenson (1970). The factor analytic study produced two factors which they labeled long- and short-term storage and the third factor called "mental control" which they claimed as having much in common with the "freedom-from-distractibility factor" or the ability to maintain concentration under more complex stimulus demand conditions. Kear-Colwell (1977) did a factor analysis of WMS results in 112 patients referred for investigation of possible organic pathology of the brain. While the pathology type was not specified, a similar factor structure emerged. This consisted of (a) the recall of immediate novel information to both visual and auditory modalities, (b) attention concentration and rapid processing of verbal information, and (c) orientation to place and time and the
recall of simple long established verbal information. Their idea of emphasizing a novel learning or "short-term memory" function along with attention and concentration capability is very similar to the earlier study of Davis and Swenson (1970). Still another factor analysis of the test carried out by Dujovne and Levy (1971) compared the factor analytic results of normals to a patient group of mixed psychiatric diagnosis. They extracted three factors for normals which they called (1) general attentiveness, (2) simple learning, and (3) associational flexibility. For patients the relevant dimensions were named (1) mental control, (2) associational flexibility, and (3) cognitive dysfunction. In the patient group, associative flexibility and cognitive dysfunction accounted for the majority of the common variance. The factor of associative flexibility appeared to load on associative learning with the cognitive dysfunction factor loading on visual reproduction, logical memory, and the verbal associates portions of the test. The overall results were interpreted to indicate that, as a whole, the WMS may be sensitive to dysfunctions in "associative flexibility" such that the capacity for analysis and synthesis of complex stimuli and a rather immediate retention of this stimuli was impaired.

This would suggest that the WMS is also sensitive to variables which serve as a platform for short-term memory processes. This would seem to suggest that in a normal sample the WMS was sensitive to a factor of "general retentiveness" that is closely related to verbal intelligence. Therefore, the WMS may be detecting cognitive abnormalities related to concreteness and an inability to rapidly
synthesize information.

Dye (1982) did a factor analysis of the WMS in results obtained from patients over 50 years of age. She reported that the factor structure in this age group was more similar to the patient than the nonpatient population of previous studies. That is, a short-term memory factor of retention and a second factor of attention and concentration that governs rapid organization and input appear to determine the performance in this group as well as in the patient population. These factor analytic studies appear to portray the WMS as an instrument that may not be sensitive to pure memory function, but rather cognitive processes which determine the rapid and flexible acquisition of stimuli.

The more recent validation study by Kear-Colwell and Heller (1978) replicated the presence of the factors of learning and immediate recall of information and attention and concentration in a population of normal subjects divided into a young and an old age group. The overall results obtained were construed to suggest that these two factors were indeed a measure of short-term memory. In the most recent large scale review of most of the literature concerning the WMS, Prigatano (1978) summed up the positive features of the test as including a relatively constant factor structure in the areas of attention and concentration to novel information and general retentiveness in the verbal mode. He noted that it has limitations, however, in that it appears to be a poor measure of nonverbal memory and fails to adequately address a more full range of memory functions, such as recent or long-term memory.
An emergent impression of the WMS based upon the review cited thus far suggests that it is too "narrow" to serve as an actual battery of memory testing. However, its sensitivity to operations requiring flexibility without distractability and its involvement with a general factor of retentiveness would suggest that it has merit in measuring dysfunction in brain trauma syndromes where these types of learning deficits are considered to be key events.

These learning deficits will be shown to be important to the diffuse head injury processes, which are theoretically related to closed head injury, at another point in this study. However, a review of the relationship of the WMS to more specific processes of brain trauma is warranted.

The literature relating the WMS to the effects of brain trauma and closed head injury has shown a great deal of growth within the last 10 years. The WMS (Wechsler, 1945) has been in existence for over 30 years and in its most recent history has been probably the most frequently used instrument for investigating memory deficits in head trauma (Prigatano, 1978). Since it continues to be widely used as a neuropsychological technique, a review of the relationships between this test and head trauma will be carried out here.

In one of the earliest comparison studies, Cohen (1950) compared patients with psychoneurotic difficulties, "organic pathology," and schizophrenics. The organic group was divided into cases of encephalitis, brain tumor, and posttraumatic syndromes. His study lacks completeness in definition of cerebral pathology. The groups were compared in terms of their performance on the WMS, but in
addition, it included the Wechsler-Bellevue full scale intelligence quotient and memory quotient discrepancy score, which is the topic of this study. He found that the memory functioning of these three groups could not be discriminated in terms of WMS subtest scores or deviation from Wechsler-Bellevue intelligence quotient scores. It should be noted that there was no description of the "traumatic" cases. There was no attempt to discriminate closed head injury from other types. Another similar early study by Howard (1950) compared epileptics, various encephalopathies, and 35 paretics. He was not able to distinguish any of these groups from the control group with the exception of some of the paretics. Again, this study lacked a clear definition of cerebral pathology and appeared to exclude closed head injury as a syndrome.

Bachrach and Mintz (1974) compared two groups of neuropsychiatric patients. Group 1 consisted of 42 patients with a clear diagnosis of cerebral dysfunction. These were compared to psychiatric patients with no such diagnosis. They stated that four subtests from the WMS (information, logical memory, designs, and associative learning) significantly discriminated between those impaired and unimpaired patients. These authors did not specify the type of dysfunction that they thought the WMS might be sensitive to. Rather, they hoped it to be a more general tool for the prediction of "mild cerebral dysfunction." This claim is contested by Prigatano (1977). He compared 31 adult patients with confirmed brain dysfunction to 26 adult patients without similar dysfunction. He noted that these patients generally performed poorly on subtests of the WMS, but
these differences drastically decreased when intelligence quotient levels were matched. This suggested that the WMS was a poor screening device for brain dysfunction and that consistent with its previously established norms (Wechsler, 1945) it was not discrepant or additive to cognitive functions as measured by the Wechsler Adult Intelligence Scale (WAIS).

Although the WMS is described in the above studies as being insensitive to undefined cerebral dysfunction, its failure may not necessarily reflect uselessness due to the criticisms inherent in patient selection processes. There is no reason to believe that all organic disorders of the central nervous system will necessarily cause memory dysfunction in the same manner. A unitary concept of brain damage may not be adequate to understand the relationships between memory function and organic brain disorders.

In a factor analytic study in which factor scores were calculated for patients with different types of organic pathologies, Kear-Colwell (1973) investigated the performance of 250 patients on the WAIS and WMS. They located three factors. The first loaded highly on complex short-term memory. The second appeared to consist of mental control and seemed to involve processes of immediate attention, concentration, and the ability to process verbal nonsemantic information. Factor 3 appeared to load primarily on very long-term memory processes. These factors were continuous across groups with the first factor correlating highly with intelligence. The group with mixed head injuries scored significantly different on Factors 1 and 2 with major deficits appearing on Factor 1. These figures
suggest that compared with normal subjects of similar age and intellectual ability, the head injury subjects evidence memory dysfunction on two to three factors described in this study. Their research also appeared to support the conclusion that while some localized and focal lesions do not produce measurable memory defect, diffuse head injury manifestations create greater memory disturbance as measured by the WMS.

In one of the first studies to closely control the type of cerebral pathology, Brooks (1976) examined 82 patients with "severe" head injury (posttraumatic amnesia lasting at least 2 days). He found rather conclusive results in this study that these head injured patients had severe memory difficulties, particularly on logical memory and associative learning. Posttraumatic amnesia and length of coma were related to poor performance, as was increasing age. He also noted, however, that more localizing neurological signs, such as skull fracture or dysphasia, were not related to difficulties in performance.

These results are interesting in the context of the present study because they appear to relate diffuse processes to deficits in WMS performance and suggest that focal signs, when present, are less clearly predictors of poor memory function as defined by WMS performance. Secondly, this study marks very clear-cut results of memory deficit in closed head injuries which are apparently remaining many months after injury. Also, Brooks (1976) suggested that on a long-term presentation (1 hour), retention proved very difficult for head injured patients. On logical memory, head injured patients
were significantly poorer at immediate and delayed recall although their rate of forgetting was not significantly greater than controls. This suggests that the acquisition of the stimuli affects both immediate retention as well as the longer term retention which follows. In general, Brooks observed that patients with a length of coma of 1 week or less were much less affected on memory tasks than patients with a comatose period lasting greater than 1 week. He also suggested that recovery of memory to a stable but low level may take place possibly within the first 4 to 6 months after injury.

In another study of head injured patients, Kear-Colwell and Heller (1980) performed a factor analysis study comparing head injury subjects with a control group from the general population. This study isolated three factors which were persistently identified in other factor analytic studies of the WMS and cited earlier. This involved the learning and immediate recall (short-term memory) of new semantic and complex information. It also included attention and concentration or freedom from distractability with the third factor being the overall orientation to time, place, and the recall of simple long-established information. The differences between the head injured group and the general population were very striking with differences obtained at all three factors, particularly Factors 1 and 2. Although the head injury group produced decrements on all aspects of performance on the WMS, it had a particularly marked effect on tasks that required the immediate learning of new verbal information, i.e., logical memory and associative learning. It was concluded that the WMS has useful validity for describing these
types of cognitive deficits and in identifying these particular types of cognitive dysfunctions in head injured patients.

A rather unique application of the WMS to the measurement of brain damage was carried out by Kljajic (1975). He attempted to compensate for the lack of scale scores on the WMS by comparing "don't hold subtest" on the WMS (the associate learning subtests) with the "hold subtests" (orientation, mental control, and digit span). He was able to discriminate head injured from noninjured groups based upon their performance on these two subtests, with the brain injured group performing much more poorly on the "don't hold subtest" in relation to the "hold subtest." This may point out the susceptibility of the head injured groups to performance deficits on the associative learning subtest. It also demonstrates the apparent difficulty the head injured populations have in dealing with the more complex subtests in terms of the types of material learned. The head injured group correspondingly had a much easier time in the performance of overlearned simple material which did not require the rapid efficient organization of multiple verbal stimuli such as that found in the associate learning subtest.

In another study which did control for the type of pathology, Black (1973) compared WMS performance on groups who have suffered both penetrating missile wounds and closed head injuries. As predicted, the degree of impairment on three tests of memory was significantly greater in closed head injury, as compared to brain damage secondary to penetrating missile wounds. Although there was considerable variation in individual test performance, suggesting
that a "pure" type of head trauma is improbable, the group tendency was very clear. These results suggest that discrete and localized brain trauma does not result in as great a memory impairment as the more diffuse types of head injury processes.

The effects of unilateral lesions on WMS performance was studied by Bornstein (1982). He demonstrated that the WMS was sensitive to the effects of lateralized lesions. As expected, right lesion patients scored poorly on visual reproduction, while left lesion patients scored poorly on logical memory and verbal associate learning. The former finding corroborates the observation of E. W. Russell (1975), who developed a scoring system to test recent memory and found visual reproduction to function well as a diagnostic indicator of right hemisphere lesion. Thus, although diffuse head injury processes result in greater overall decrements in memory processes, it would appear that some modality specific memory deficits can be measured by the WMS if the lesions are specific in regard to laterality. E. W. Russell (1982) used the same revised scoring system of the WMS in a factor analytic study of the Halstead-Reitan Neuropsychological Battery. In the context of that battery of tests sensitive to a variety of dysfunctions, he found five types of memory functions loaded with many nonmemory functions on the same factors. This led him to conclude that the processing of immediate or short-term memory in any given modality (i.e., verbal or visual) is carried out by discrete brain areas, but that these discrete and modality specific storage functions act in a unit for purposes of integrated activity for more consolidated long-term
memory activity. This would explain why highly lateralized and specific lesion processes result in modality specific performance on the WMS. It would also explain why the diffuse head injury process resulting from closed head injuries has an even greater adverse effect upon WMS performance. That is, a disruption of connections between lower brain centers and the cortex as well as intercortical disruption occurs causing impairment of memory processing across modalities with a special impact upon memory processes requiring simultaneous integrating activity.

The studies cited above appear to emphasize the thesis of this study. That is, particular types of memory and acquisitional deficits result from the diffuse process of closed head injury. The bulk of the literature reviewed on the results of head trauma upon WMS performance also suggests that the more complex portions of the WMS, or those requiring the simultaneous integration of complex verbal stimuli, are also areas of particular susceptibility in diffuse closed head injury trauma. A discrepancy between these more complex types of short-term memory processes with other cognitive functions which require less efficiency or adaptation to complex novel information would seem likely. In a following section, a review of the WMS and WAIS relationships may attempt to clarify this possibility by examining the relationship between the WMS and the WAIS for both normal and brain damaged populations. It would seem logical that, if the WAIS contained many cognitive tasks which do not require rapid acquisition of new memory, the pathological
affects of closed head injuries would be less noticeable on portions or all of the WAIS than it is on the WMS.

The WAIS and Its Relationship to Brain Trauma

The WAIS will be reviewed in terms of the most recent and important literature in regard to the performance of brain damaged individuals on the WAIS. Previous to that review, however, a functional description of the test is provided such that the construction of the subtests will be understood along with a shared understanding of the domains of behavior measured by the subtests. A description of those subtests will be provided by paraphrasing the originator of the test (Wechsler, 1958).

Since Wechsler (1958) believed that intelligence was the net result of interaction between various factors of intelligence, he constructed his intelligence scale to be a battery of tests in order that those factors might be measured separately. In choosing subtests he used criteria which consisted of an analysis of standardized tests already in use. An attempt was then made to evaluate the validity of each subtest on the basis of correlations with other recognized tests and empirical ratings of intelligence. An attempt was then made to relate these tests to the clinical experience of practitioners. Following the selections of subtests, some 2 years were devoted to experimental work on individuals with known intelligence levels. He originally selected 12 tests and later dropped one of the subtests called cube analysis.
The following is a listing and description of the subtests following the most important elements in Wechsler's (1958) descriptions. A first subtest called the Information Subtest examines an individual's range of information by accessing the amount of common information an individual has the opportunity to acquire. The Comprehension Subtest requires an individual to furnish his or her answer to questions requiring problematic but practical thinking. These subtests, however, are presented at different levels of complexity, such that the most complex requires some abstract thinking.

The Arithmetic Subtest was added to access computational skills involving practical calculations which must be done without the aid of written reference. The Digit Span Subtest, which is used both on the WMS and the WAIS, is one of the most specific subtests in terms of the type of ability it measures and was included to estimate attention and retentiveness. The Similarities Subtest requires individuals to associate elements or concepts in terms of their common elements and thereby stresses concept formation and to a certain degree is controlled by the "logical character of the subject's thinking processes." The Picture Arrangement Subtest, which begins the performance section of the WAIS, requires individuals to sequentially understand disarranged picture stories and to correct the order. It is supposed to measure the subject's ability to access a total situation as well as its parts in sequence. The Picture Completion Subtest requires analysis of a visual scene with the intent of identifying a specific missing part thereby measuring speed in visual analysis and attention detail. The Block Design Subtest is
basically a task of imitation requiring a person to assemble colored blocks to match geometric patterns. It requires spatial perceptual skills and ability to visually analyze form. The Digit Symbol Subtest requires a subject to associate certain symbols with numbers in a manner which requires visual speed and accuracy along with dexterity. The Object Assembly Subtest consists of four figure form-boards consisting of an elephant, a maniken, a hand, and a face and profile. These are presented to the subject in disarray with the instruction to assemble them into a finished object. It thus has a puzzle-like quality but visual discovery is important on the more difficult items. The Vocabulary Subtest is basically a measure of a person's ability to define words presented both verbally and visually. It simply calls for a defined response to presented words.

The above subtests comprised the verbal portion of the battery (Information, Comprehension, Vocabulary, Similarities, Arithmetic, and Digit Span). The "performance" section of the battery includes Block Design, Picture Arrangement, Picture Completion, Digit Symbol, and Object Assembly. A group intelligence quotient score is obtained for the verbal subtest, as well as the performance subtest, and then these scores are combined to obtain an age corrected full-scale intelligence quotient.

A discussion of the subtests on different factors obtained in factor analysis is beyond the scope of the present review. However, it should be noted that Wechsler (1958) described three factors which are currently identified. These are a verbal comprehension factor, a nonverbal organizational factor, and a general intellectual
factor. Most of the verbal subtests load heavily on the verbal comprehension factor with performance subtests loading highly on the nonverbal organizational factor. Besides the general factor of intelligence which shows relatively good correlations with most of the subtests, a fourth factor has also emerged which is termed by Wechsler to be "memory" or freedom from distractability. The methods section contains a review of the basic normative data that pertains to the WAIS (and its more recent form the WAIS-Revised Form).

Studies reflecting the effect of head trauma or organic brain syndrome upon the WAIS have frequently been preoccupied with pathology affecting either the right or left hemispheres. More recently, researchers have attempted to contrast actual pathology types, such as comparing closed head injury to other specific types of wound processes. Representative studies which relate recovery of intellectual functions, as measured by the WAIS, to closed head injury have been relatively recent. A range of this research will be covered presently to help elucidate the meaning of the WAIS in the context of measurement of brain dysfunction and to survey the most recent relevant research of the psychometric properties of the WAIS in respect to brain injury.

It has long been typical for studies to compare groups of brain damaged persons with known lesions in either the right or left hemisphere on the WAIS. In this manner, several reports appear indicating that lesions of the left cerebral hemisphere were related to impaired ability to deal with language and right hemispheric lesions have been associated with impaired ability in the area of
visuo-spatial tasks (Fitzhugh, Fitzhugh, & Reitan, 1962). Other relationships of WAIS performance patterns to type of cerebral dysfunction became apparent, however. Fitzhugh and Fitzhugh (1964) compared patients with lateralized cerebral dysfunctions to those with diffuse cerebral dysfunction. In addition to the more simple relationship of right and left hemispheric effects, they discovered that the performance subtests were more impaired in the diffuse lesion groups than were verbal subtests. Heilbrun (1956) also called attention to the possibility that the performance subtests are a more "heterogeneous" group of subtests and speculated that they may not be truly "nonverbal."

Parsons, Vega, and Burn (1969) compared bilateral lesions (both hemispheres involved) with unilateral lesions (only right or left hemisphere damage). They did support the hypothesis that left hemisphere damage results in impairment of language abilities and right hemisphere damage results in decrement of visuo-spatial ability. They investigated this hypothesis using only Vocabulary as a language score and Block Design as a performance score, however. Using this technique, they could not discriminate a group with bilateral head injury from a unilateral lesion group. They did not specify the nature of the bilateral head injury subjects used in the study.

Zimmerman, Whitmyre, and Fields (1970) investigated differences in the factor structure of the intelligence scores in right, left, and "diffuse" cerebral dysfunction patients. In this group only a minor portion of the diffuse dysfunction group were closed head injuries. However, they did find that the greatest similarity in
factor structure appears between the right hemisphere injury group and the diffuse injury groups. They interpreted these findings to mean that the lowering of performance scores may be more predictive of cerebral involvement than the lowering of verbal scores, though performance scores, overall, are less predictive of the question of unilateral versus diffuse cerebral dysfunction. Their study did, however, support the presence of a "verbal factor, performance factor and memory efficiency or freedom from distractability factor."

Simpson and Vega (1971) also studied the effects of unilateral brain damage on the WAIS and attempted to control the confounding effects of advancing age by using age corrected scaled scores to study patterns of intellectual deficits associated with damage to one or the other cerebral hemispheres. They achieved the expected results. That is, brain damaged groups show more impairment than controls in overall levels of function. However, they noted that there was no significant difference between right hemisphere brain damage, left hemisphere brain damage, and bilateral hemisphere brain damage groups on the performance subtests. Woo-Sam (1971) offered partial experimental verification that age compensated scores achieve spurious results due to the affect of aging factors on the performance subtest. He compared 21 subjects identified as right hemisphere damaged and 15 subjects considered as left hemisphere damaged within a single age group (ages 30 to 36) and failed to report clear differences between right brain dysfunction and left brain dysfunction in respect to verbal or performance intelligence factors. His study, however, again does not consider overall
severity of injury. It does not include a description of localization of dysfunction or type of trauma.

In a group of mostly chronic brain damaged subjects, E. W. Russell (1972) demonstrated that while WAIS performance is affected by brain damage, its basic factor structure is not. He confirmed a factor of general intelligence, verbal intelligence, and visual-organizational intelligence along with memory and freedom from distractability factors. He substantiated the reported history that Digit Symbol was particularly affected by a variety of brain damage conditions, but suggested strongly that laterality of brain damage was not related to verbal and performance factors in these more chronic brain damaged cases. The study suffers again from the heterogeneity of the brain damaged types in the population study.

Lansdell and Smith (1975) studied 268 head injured servicemen divided between cases of penetrating head wounds, closed head injuries, and mixed cerebral damage. They applied factor analytic methods and found a verbal factor loading on the Vocabulary Subtest with a second factor loading on the Object Assembly Subtest which was apparently linked to visual organizational skills. The patterns of ability uncovered are similar to other studies. They interpreted their results to indicate a resiliency for a verbal factor and a tendency toward remaining impairment for nonverbal factors after brain damage. They hypothesized that the WAIS performance intelligence quotient may contain a verbal component, making it more vulnerable to impairment in all types of brain damage.
In a similar vein, Todd, Coolidge, and Satz (1977) investigated WAIS functioning in 335 patients. These were split between psychiatric controls, 69 "diffuse" brain damaged cases, 46 right lateralized brain damaged cases, and 68 left lateralized brain damaged cases. Like other studies, their data for localization was based upon standard neurological procedures; however, their patient group was again very mixed. The categories of brain damage included head trauma, cerebral vascular accidents, tumors, degenerative diseases, epilepsy, and a large unclassified group. They applied the WAIS verbal intelligence quotient/performance intelligence quotient discrepancy index. This is the degree of difference between the performance intelligence quotient and the verbal intelligence quotient. The results suggested that the verbal intelligence quotient/performance intelligence quotient discrepancy not be used as a diagnostic screening tool due to the fact that these discrepancy scores were not consistently related to status or type of lesion. In all groups they noted that mean performance intelligence quotients were significantly lower than mean verbal intelligence quotients.

The above studies concerning the lateralized indicators of brain damage have much in common. They often use clearly heterogeneous populations. For the purposes of this study it is important that closed head injury as a distinct traumatic phenomenon is largely ignored. While the same factors of intelligence are present and substantiated for most control groups consisting of normal populations, these studies also substantiate that the clear and simple use of verbal intelligence quotient/performance intelligence
quotient discrepancy scores or differences are not easily relatable to localization of trauma or type of brain damage. Also, on the whole, they yield findings indicating a greater susceptibility of the performance intelligence quotient factor to most types of brain trauma with the exception of some cases showing highly localized unilateral dysfunction.

These findings also generally lend support to Wechsler's (1958) claim that brain damage to either or both hemispheres significantly lowers the performance intelligence quotient but does not affect the verbal intelligence quotient as dramatically. Moreover, these results lend further credence to Smith's (1966) results. He found that over 65% of his left hemisphere damaged group had a higher verbal intelligence quotient than performance intelligence quotient. He suggested that his findings indicated that impairment secondary to a wide number of brain trauma types causes impairment in performance intelligence quotient. Smith's subjects also varied dramatically in the type and recency of their brain damage. So while the general tendency of liability of performance intelligence quotient appears in Smith's study, the same criticism of mixed patient groups apply.

A WAIS performance comparison between brain damaged populations and neurotic adjustments was done by Ladd (1964). His brain damaged group consisted of 50 male patients with undefined cerebral disease. Also he purposely excluded grossly impaired brain damaged individuals. Interestingly, like many previous studies his results showed that the brain damaged group was significantly lower in full scale
intelligence quotient and performance intelligence quotient but they were not lower than the neurotic group in verbal intelligence quotient. Within group comparisons in that study suggested that verbal intelligence quotient and performance intelligence quotient were roughly equivalent; however, the verbal intelligence quotient and performance intelligence quotient discrepancy in the brain damaged group was significantly larger. There was no particular pattern of individual subtest deficits in this heterogeneous group. This particular study raised the question of whether any particular pattern of subscore variation could be used in individual diagnosis of brain damage. Similar general results were obtained by Vogt and Heaton (1977). They studied patients with extreme values on the impairment index of the Halstead-Reitan Neuropsychological Battery. These are a large group of tests which are sensitive to a variety of cerebral dysfunction. When comparing impaired groups with unimpaired groups on that index, they found that the impaired group did worse on all 11 WAIS subtests. Compared to the nonimpaired group, however, impaired subjects appeared to do relatively poorer on Block Design and Object Assembly and did relatively better on Information, Comprehension, Vocabulary, and Picture Completion. These results are similar to other results and suggest a greater sensitivity of the performance subtest to impairment. In addition to using the Halstead Impairment Index as a definition of impairment, however, this study is important from the standpoint that it appears to support Wechsler's (1944) idea of a "deterioration quotient."
In developing that deterioration quotient, Wechsler hypothesized "don't hold" and "hold" subtests. He suggested that, under conditions of deterioration of brain function, "hold" subtests would be less subject to performance decrements; and the "don't hold" subtests would be more subject to performance decrements following any condition of deterioration. He hypothesized "don't hold" subtests to be Digit Span, Digit Symbol, Arithmetic, and Block Design. "Hold" subtests are Information, Object Assembly, Picture Completion, and Comprehension. The above results generally support Wechsler's contention with the exception of Object Assembly. It is seen in the present review that Object Assembly appears to be part of a perceptual organizational factor which is managed very poorly by brain damaged individuals.

In another study which compared WAIS performance with the Halstead-Reitan Neuropsychological Battery, Logue and Allen (1971) confirmed a correlation between Wechsler full scale intelligence and predicted category errors. The Categories Test on the Halstead-Reitan Neuropsychological Battery is its single most valuable indicator of cerebral dysfunction. It is basically a concept formation task involving higher level problem-solving skills. It requires flexibility in judgment, problem solving, and analysis. Its relationship to the Wechsler Adult Intelligence Scale full scale intelligence quotient is documented and the above authors developed a table that would enable direct comparison scores to evaluate Category Test performance while correcting for intelligence quotient. The nature and description of the Halstead-Reitan Neuropsychological
Battery and the specific indicators on that battery will be reviewed.

Mandleberg (1975) and Mandleberg and Brooks (1975) studied WAIS performance as indicators of cognitive recovery after severe head injury. Unlike other studies, they selected rather carefully for the diffuse damage which results from the pathophysiological effects of closed head injuries. Their findings are instructional from the standpoint that they documented remarkable recovery in overall WAIS intelligence quotient for their group of patients with severe head injuries (posttraumatic amnesia greater than 1 week). During posttraumatic amnesia they discovered that verbal ability appeared to be relatively intact, while nonverbal skills were extremely poorly executed. It should be realized, however, that they tested individuals during a period where they were oriented but not necessarily capable of responding to complex stimulation, including test instructions. Over the period of serial testing, verbal subtest scaled scores showed less initial impairment and were faster to recover than were all nonverbal subtest scores. Verbal intelligence quotient scores for a head injured group approached that of a comparison group within about 1 year following the injury, while the performance intelligence quotient continued to be deficient for a period lasting over at least 3 years. They also noted that the pattern of impairment on the WAIS for this closed head injury group corresponded to that typically displayed by the right hemisphere or bilaterally damaged groups. That is, the discrepancy between verbal and performance subtests continued to be present, with the performance subtest being more poorly performed. Mandleberg (1976) also
related WAIS performance to length of posttraumatic amnesia. While verbal intelligence deficits were related to posttraumatic amnesia duration at 3 months, performance intelligence quotient deficits continued to be correlated to posttraumatic amnesia after 6 months. These relationships had disappeared by 30 months after injury. In a study of a similar nature, Becker (1975) had administered the WAIS to 10 patients who had sustained closed head injuries in auto accidents. This head injured group displayed initially severe deficits with subsequent improvement on the performance subtests, especially Digit Symbol, Block Design, and Object Assembly. The susceptibility of perceptual organizational skills to diffuse head injury was reinforced by the fact that Digit Span and Block Design appeared to be the most sensitive indicators of improvement.

Other systematic studies of diffuse and closed head injuries syndromes were carried out by E. W. Russell (1979, 1980). In both studies, E. W. Russell was concerned with patterns of brain damage as defined by the WAIS subtest profile. As has been the case with much of the review of the literature, he suggested that diffuse degenerative brain damage has about the same pattern of WAIS performance as does right hemisphere damage. He concluded that the WAIS has defects from the standpoint of neuropsychological testing in that the verbal portion does not have subtests that are highly sensitive to brain damage. On the other hand, Digit Symbol, Block Design, and Object Assembly, which constitute a majority of the performance subtests, are all sensitive to brain damage.
The effects of brain dysfunction on the performance of the WMS and the WAIS have been reviewed in separate sections previously. While they are different in regard to sensitivity to brain dysfunction, they have rather high intercorrelations as, indeed, they were intended to (Wechsler, 1945). Libb and Coleman (1971) used outpatients with disability groups including mental retardation, psychiatric disorders, and physical problems to study WAIS and WMS relationships. They found significant correlations and a very close relationship between the WAIS full scale intelligence quotient and Wechsler memory quotient. This was true for all three groups, none of which showed or documented memory disturbance or brain damage, however.

In a study which did correlate Wechsler memory quotients with the Wechsler Adult Intelligence full scale intelligence quotient, Fields (1971) found that in a brain damaged population, a similar high and significant correlation between the WMS and the WAIS. However, this study also failed to control for the effects of qualitatively different types of pathology. This research population was mixed to include focalized and nonfocalized lesions in an extremely heterogeneous sample. Field (1971) argued that the WMS and WAIS measured the same factor of "general intelligence." Likewise, Hall and Toal (1957) suggested that the overlap between the WMS and the Wechsler-Bellevue Intelligence Scale was so large as to not justify giving both tests. Hall and Toal (1957) also noted occasional
subjects who achieved very low intercorrelations between the WMS subtests. This was interpreted as low reliability due to the brevity of the test. An alternative explanation, however, may be found in the fact that all the subtests are combined to achieve a memory quotient. Owing to the fact that the previously cited factor analytic studies of the WMS have noted a complex audio-verbal factor and an attention and concentration factor, it is likely that the Wechsler memory quotient often is masking true variability in different facets of memory performance and, hence, eliminating consistent differences when compared to the WAIS. A more pervasive and sweeping difficulty in attention or concentration among brain injured might more favorably highlight WAIS and WMS differences. That is, the freedom from distractability factor may not be as important in normals or mixed patient groups as it is in amnestic neurological disabilities, particularly closed head injury.

Thus, while memory quotient and full scale intelligence quotient are highly correlated in individuals of average intelligence and in mixed pathology (Hall & Toal, 1957; Libb & Coleman, 1971), it would be important to investigate whether there are memory quotient and intelligence quotient differences in individuals with syndromes which are clearly expected to evidence these differences based on history or neuroanatomical evidence. In a group of 15 patients with Wernike-Korsakoff Syndrome (a syndrome known for short-term memory difficulties), Victor, Herman, & White (1959) found that memory deficits as measured by the WMS did exist when compared with normal verbal intelligence. The Korsakoff patients had mental
quotients that were generally in the 70s and well below their intelligence test scores. Interestingly, alcoholic patients without the Korsakoff Syndrome did not show the Wechsler full scale intelligence quotient and memory quotient discrepancy effect (Parsons & Prigatano, 1977).

In one of the most specific studies of intelligence quotient and memory quotient difference scores, Zaidel and Sperry (1974) compared those scores in eight patients who had undergone complete or partial commissurotomy. These patients, who underwent separation of the hippocampal commissure, showed memory quotient scores which were always 12 points or more below their obtained intelligence quotient scores. Wide ranging memory deficits were reported by individuals who lived with those patients. Case reports of individuals with known lesions of the hippocampus (Victor, Angevine, Mancall, & Fisher, 1961) also show that those patients, who have expected memory deficits by virtue of anatomical evidence, show rather clear-cut intelligence quotient and memory quotient difference scores with the latter being inferior.

Quadfasel and Pruyser (1955) compared scores from the Wechsler-Bellevue Intelligence Scale and the WMS in 38 epileptic patients. More than half of these manifested abnormal anterior temporal lobe electroencephalogram (EEG) recordings. They were compared to another 19 subjects with no focal abnormalities but with generalized EEG abnormalities. The temporal lobe abnormal group showed a significantly greater memory quotient discrepancy than the group with the generalized abnormal EEG. At that time Quadfasel and Pruyser

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(1955) suggested that memory deficit would be said to exist when it is 11 or more points below the intelligence quotient. The research also suggested the WMS to be a test which was sensitive to dysfunction in the temporal lobe, as well as being an instrument sensitive to deficits in audio-verbal memory. A similar conclusion was reached by Milner (1975), who suggested that a WMS quotient about 12 points below the full scale intelligence quotient is indicative of a verbal memory impairment.

The above studies link aspects of pathophysiology that are expected to produce brain impairment to actual deficits on the WMS in relation to intelligence quotient. Other studies, as noted before, have, however, shown less clear-cut discrepancy between full scale intelligence quotient and memory quotient. Note that Howard (1950) failed to find a memory quotient that could discriminate encephalitics from epileptics and paretics. Also, Cohen (1950) sought to use the memory quotient discrepancy index to define memory impairment in tumor, encephalics, and posttraumatic cases. He found no clear discrepancy between full scale intelligence quotient and memory quotient in these groups. He did not suggest, however, why he may have expected to find memory difficulties as a specific syndrome in this mixed group.

In 1974, Prigatano (cited in Prigatano, 1978, p. 823) compared WAIS full scale intelligence quotient scores minus memory quotient scores in 15 head injured patients who sustained coma after head trauma. He compared these with a psychiatric control group without coma. Average discrepancy scores for the head trauma group were
significant in showing a nearly 10-point discrepancy, on the average, of memory quotient below intelligence quotient. The psychiatric patients manifested no similar relative lowering of the memory quotient score and, in fact, showed somewhat higher memory quotient scores as opposed to intelligence quotient scores. Interestingly, he also found that there was a very high correlation between estimated time of unconsciousness and discrepancy scores. At that time Prigatano (1978) suggested that was a preliminary sign which needed to be evaluated further.

A summary of WMS quotient and WAIS quotient comparisons in brain damaged individuals would suggest that memory quotient is sensitive to highly specific lesions which are expected to produce memory deficits, as reviewed. Also, we have seen that in groups of mixed brain damage regular discrepancy scores are less frequently obtained. Thirdly, the material reviewed suggests a probable intelligence quotient/memory quotient discrepancy in diffuse head injury cases caused by closed head injury. Prigatano (1978) suggested that low memory quotient scores should be expected in any patient with diffuse brain dysfunction who shows overall cognitive impairment. To this end, it would seem logical to compare cognitively impaired closed head injury patients with individuals manifesting impairment from localized lesions and to study the degree to which the full scale intelligence quotient and memory quotient discrepancy correlates with severity. These hypotheses will be more specifically stated along with an integration of the literature review in the final
section following a review of the sensitivity of the Halstead-Reitan neuropsychological indicators.

The Halstead-Reitan Neuropsychological Battery

The Halstead-Reitan Battery serves as a measure of brain impairment severity in this study. This section is devoted to a description of its historical development and the research relevant to its sensitivity as a measure of brain dysfunction.

Neuropsychological testing and the Halstead-Reitan Battery grew out of attempts to understand the nature of intelligence. Halstead (1947) sought to set forth a new conception of intelligence. At that time he hypothesized that there were three categories of intelligence which included psychometric intelligence, clinical intelligence, and neurological intelligence. He considered the concept of "psychometric intelligence" to stem largely from the investigative efforts of psychologists. This was presumed to include such things as "judgment," "abstract thinking," and other measures of adaptability as manifested by quantitative testing and scoring methods. He felt that "clinical intelligence" was a product largely of clinical investigations and involved those clinical descriptions oriented toward describing the effectiveness of an individual's behavior. Neurological intelligence was associated primarily with the effects of brain lesions on human beings and lower animals. Halstead (1947) believed that deficiencies existed in each of these explanations. Halstead proposed the concept of "biological intelligence" which he achieved through a factorial analytic study that utilized several
newly developed tests. He found four factors to be the central integrative field factor, the abstraction factor, the power factor, and the directional factor.

Besides Halstead's concept of "biological" intelligence, the importance of his early work was the development of a battery of tests which he applied to brain damaged and control subjects in an attempt to define the basic attributes of adaptive brain functioning.

A very large portion of Halstead's Battery was adopted by Reitan (1955a) for his early research on brain dysfunction. The majority of the early Halstead tests of biological intelligence became the foundation of the Halstead-Reitan Neuropsychological Battery. In his earliest attempt to validate Halstead's tests of biological intelligence, Reitan (1955a) compared persons with symptoms of cerebral damage with a normal control group. He found that composite scores based upon a number of Halstead's tests were extremely sensitive to organic brain damage. In particular, he found that Halstead's category test differentiated clinical groups nearly as well as the total impairment index from all of the other nine subtests. This subtest will be described shortly. Later Reitan (1956) administered the Wechsler-Bellevue Scale of Adult Intelligence as well as Halstead's 10 tests again to 50 brain damaged patients and 50 control subjects. He found that the Wechsler-Bellevue variables were much more highly intercorrelated than were Halstead's measures. He also found that Halstead's tests were much more sensitive to brain damage than the Wechsler-Bellevue subtests although there was considerable overlap. Reitan concluded that while there
was a relationship between "psychometric" and "biological" intelligence, the latter did indeed appear to be more related to the integrity of the central nervous system and he continued on a span of research into tests sensitive to brain dysfunction which has lasted to the present.

Before revealing the sensitivity of the Halstead-Reitan Battery that has been shown in more recent research, a description of that battery will be provided. The following descriptions are paraphrased from Reitan (1967).

The **Category Test** utilizes a projection apparatus (or more currently a booklet form). The subject is told to select one of four pictures which appears either on the page or the screen. Only one response is allowed for each selection and he or she is given feedback regarding whether his or her selection is right or wrong after each trial. He or she is simply told that he or she has to learn a "principle" that will allow him or her to select correctly one of the four designs. The first group requires the matching of numerals. In the second group the subject must learn to select one of four numbers corresponding to the number of items appearing on the screen. In a third group of items the subject must learn to select one figure which is unique from the other three. In this section the task becomes quite a bit more complex as it progresses through different shapes, sizes, and colors of figures such that the stimulus field constantly changes while the subject is required to maintain a response consistent with an underlying principle. Additional principles must be learned as the subject proceeds through the seven
subtests. The Category Test is therefore a nonverbal measure of complex concept formation which requires an abstract ability to note similarities and differences in constantly changing stimulus material while postulating hypotheses to serve as selection principles.

The Tactual Performance Test is a three-part test in which a subject sits in front of a large board blindfolded. The "form board" has a number of recessed shapes into which a specific shaped block will fit. The subject's task is to fit the blocks into their proper spaces using first his or her preferred hand, then his or her nonpreferred hand, and finally both hands together. It requires the development of a visualization of the spatial configuration of the board without actually viewing it. Later, the patient is required to draw the entire board from memory and place the shapes in their respective correct locations. It therefore has a time, memory, and localization component.

The Rhythm Test is a subtest of the Seashore Test of Musical Talent requiring the subject to differentiate 30 pairs of rhythmic beats. This requires sustained perceptive attention in the auditory modality and auditory differentiation.

The Speech Sound Perception Test consists of 60 spoken nonsense words with four nonsense words spoken on each trial period. The subject's task is to discriminate the spoken word, and in doing so, select that word from four closely sounding alternatives. It is a test of audio-verbal receptivity and audio-verbal attention.

The Finger Oscillation or Tapping Test is a test of pure visual motor speed using the index finger on the preferred and nonpreferred
hand in five consecutive 10-second trials.

The Trail Making Test consists of two parts, (a) and (b). Part (a) consists of 25 circles distributed over a white sheet of paper and numbered from 1 to 25. Part (b) consists of 25 circles numbered from 1 to 13 and lettered from A to L. The subject is required to connect these circles in consecutive order according to the numbers or letters in rapid sequence. It requires a maintained sense of sequence, attention and memory to the most recent point of departure, and rapid visual scanning.

In the Fingertip Number Writing Perception Test, the subject is required to report numbers which are written upon the fingertips of each hand. It requires the tactile recognition of symbolic form.

On the subtest called Tactile Finger Recognition, the subject is required to call out a number which is assigned to each finger.

In Tactile Form Recognition, the test requires the subject to identify by touch alone: pennies, nickles, and dimes. Additionally, the nonvisual and tactile recognition of shapes is also required.

In addition to the above tests, the neuropsychological battery consists of a brief aphasia screening battery, a spatial relation score which is derived from the Block Design of the WAIS in conjunction with a Creek cross drawing, and sensory perceptual examination which tests the sensory intactness on the face and upper extremities. An indication of grip strength is also obtained.

Finally, the Digit Symbol subtest of the WAIS is included as a separate subtest that contributes to the impairment index.
Since the previously cited studies (Reitan, 1955a, 1956), a large amount of research has occurred in regard to the Halstead-Reitan Battery aimed both at evaluating its sensitivity in the detection of various types of cerebral pathology and in attempts to understand patterns of test scores indicative of types of lesions or pathological processes. Reitan (1958a) administered the Halstead Battery and the Wechsler-Bellevue Scale to 50 brain damaged patients and 50 controls to assess whether that battery would show qualitative differences between the brain damaged and control groups or whether simple quantitative differences would occur. His results suggested that while brain damaged patients tend to show impaired abilities, their manner of failure, as defined by types of errors on a variety of subtests, are of the same type as normals. In particular, Reitan discovered that the Category Subtest was extremely sensitive to brain damage despite the fact that the distribution of error scores for brain damage was similar to the distribution for errors for normal groups.

Reitan (1959a) more directly compared the effects of brain damage on the Halstead Impairment Index with the Wechsler-Bellevue Scale. The brain damaged group consisted of mixed cerebral pathology. The Halstead impairment index was found to be significantly more sensitive to brain damage than was the Wechsler-Bellvue intelligence quotient. All of the Halstead-Reitan subtests proved to be more sensitive with the exception of two subtests called Critical Flicker Frequency and Time Estimation. Later Reitan dropped both of these subtests from the battery. Although, overall, the intelligence
quotient tends to be lowered by brain damage, it showed a smaller magnitude of effect regardless of the Wechsler-Bellevue Scale selected for comparison. In this study Reitan also found that the Category Subtest was almost as sensitive as the entire neuropsychological battery in discriminating cerebral dysfunction regardless of the type of dysfunction present.

Other validating research on the Halstead-Reitan Neuropsychological Battery was carried out with the aim of attempting to make correct predictions regarding the presence or absence of brain damage through statistical methods. Three studies (Wheeler, 1964; Wheeler, Burke, & Reitan, 1963; Wheeler & Reitan, 1963) indicated that correct classification of individual subjects in accordance with neurological criteria ranged from 98.8% to 81%. The brain damaged subjects included bilateral, unilateral, and diffuse brain damage. In spite of these impressive levels for correct prediction of the presence or absence of brain damage, they are scarcely better than those obtained by impairment criterion based on simple cutting scores on the Halstead-Reitan Battery (Reitan, 1967).

Other cross-validation studies have been done. Vega and Parsons (1967) attempted to revise the nature of the impairment index. The impairment index that was originally used was based on cutting scores which defined either impairment or nonimpairment on any particular subtest. Halstead's impairment index required that the 7 out of 10 subtests be within the impaired range resulting in the necessity of a score of .7 to indicate impairment. Vega and Parsons (1967) substituted T scores for each subtest, then calculated average
T scores. Using such a modified index, they were able to produce nearly 80% correct classifications with a variety of established brain damage types ascertained through neurological methods.

The Halstead-Reitan Neuropsychological Battery as a test which is potentially usable to specify lateration, localization, and process aspects of brain lesions was studied by Filskov and Goldstein (1974). Their validational study attempted to compare diagnostic statements obtained by a clinical interpretation of the Halstead-Reitan Neuropsychological Battery to diagnostic statements based on commonly used physical diagnostic procedures. They claimed a perfect success rate for the Halstead-Reitan Neuropsychological Battery, demonstrating the contention that a neuropsychological diagnostic approach, when combined with a clinical/actuarial approach, was preferable to either clinical or actuarial approaches used alone. Other research suggests that a subtest interpretation approach is usable in identifying static versus rapidly growing brain lesions resulting from tumors (Fitzhugh, Fitzhugh, & Reitan, 1961).

As successful as the Halstead-Reitan Neuropsychological Battery has been for the detection and the specification of brain damage, another subtest, in addition to the Categories Test, has shown to be very highly sensitive to the variety of brain damaged conditions. The Trail Making Test, as described previously, was very successful in differentiating a mixed group of brain damaged patients from controls (Reitan, 1955b). In later studies, Reitan (1958b, 1959b) administered the Trail Making Test to patients with brain damage and achieved highly significant differences in performance of normals.
and brain damaged groups. It was noted that brain damaged individuals usually do very well on Part (a) but have a great deal of difficulty on Part (b) of Trail Making.

Reitan (1959b) computed correlation coefficients between the Trail Making Test and the WAIS variables. These showed generally significant correlations and at that time Reitan suggested that the WAIS be used to establish expected levels of performance so that the performance requirements for the Trail Making Test could be established that would more specifically ascertain the presence or absence of brain damage. In a study of Trail Making Test performance in normal and brain damaged children, Reitan (1971) noted that not only were brain damaged children more impaired than normals on Trail Making, but also the factor of brain damage was a far more potent predictor of test results than was chronological age among children. This is a rather important indication of its selective sensitivity to the effects of brain damage.

The Trail Making Test, like the Category Test, requires a degree of alertness and visual comprehension of stimulus material, interpretation of symbols in sequence, and a large degree of purposeful visual scanning. It also requires the patient to maintain a memory of sequence simultaneously. In this respect, Part (b) of Trails seems somewhat similar to the requirements of the Halstead Category Test in which the patient must assimilate information from one stimulus figure after another in an effort to grasp an organizing principle which applies to the series. It is little wonder, in light of the literature reviewed, that these two indicators are of
special significance in terms of being powerful single indicators of brain lesions.

Summary of Literature Review

In this section an attempt was made to highlight the major findings of the literature reviewed and to draw tentative conclusions which lend themselves to the researchable hypotheses regarding the relationship of the WAIS, the WMS, and closed head injury.

It was initially stated that memory was documented as a rapidly plateauing variety of cognitive dysfunction and this is probably related to severity in closed head injury. It was seen as a possibly more vulnerable and long standing residual deficit following closed head injury, especially in respect to short-term memory.

The WMS was reviewed and it was suggested that while it is not a complete measure of memory functioning, it has repeatedly been factored into short-term complex audio-verbal memory, attention concentration, and freedom from distractability factors; and to a certain extent, a third factor occurs which includes orientation and access to simple overlearned information. A review then of the impact of brain lesions and trauma upon the WMS, with some exceptions, indicates that the above factors are also likely significant in the poor performance obtained by closed head injury patients. These patients performed more poorly than normals or patients with some forms of localized brain lesions. This appears to be especially true for complex audio-verbal tasks, i.e., Logical Memory and Paired Associate Learning subtests. An inability of closed head injury
patients to adapt to novel and complex stimuli was suggested by these findings.

Unlike the WMS, the WAIS was introduced and shown to be more refractory to the effects of diffuse head trauma or closed head injury. While the WAIS was seen as being sensitive to some forms of highly localized lesions, at least the verbal portions are less impaired following diffuse or closed head injury. Also, WAIS performance was seen to improve to higher levels with time and recovery. This was more true for the verbal subtests, however, and it is suggested that the performance subtests, by virtue of their active processing requirements, are more vulnerable to a variety of trauma effects. Therefore, neuropsychological indicators which also demand novel or active integrative capacity are more likely to parallel performance intelligence quotient scales.

A review of the direct WMS quotient and WAIS quotient comparisons was presented. While the WMS quotient is discrepant and low in comparison to the WAIS on diffuse and closed head injury groups, less clear discrepancy scores were obtained for mixed pathological populations. The WMS may be most sensitive to temporal lobe lesions and verbal memory deficiencies.

Finally, the Halstead-Reitan Neuropsychological Battery was introduced in terms of its sensitivity to a wide variety of brain damage aspects. It was reviewed in terms of its sensitivity and capacity for discrimination on a wide variety of organic brain syndrome features. This was particularly true of the Categories and Trails (b) subtests. Its universal sensitivity appears to be a
factor that apparently discriminates it from the WAIS as a measure of residuals of brain trauma.

The above-stated differences in sensitivities of the Wechsler Memory Quotient and Wechsler Adult Intelligence Quotient may present the unique opportunity to use them in concert in cases of closed head injury or other cases of brain trauma where impairment of short-term memory or impairment of active audio-verbal processing is a suspected deficit area.

Much of the value in comparing the WMS to the WAIS may lie in the long recognized differences between fluid and crystallized intellectual abilities.

Halstead (1947) postulated the existence of two general forms of intellectual abilities, calling them psychometric and biological intelligence. Cattell (1943) used a similar concept even earlier when he named two forms of intelligence to be fluid and crystallized intelligence. Both of these theories can be explained by emphasizing that fluid (biological) intelligence involves active mental processing of new material while crystallized (psychometric) intelligence is composed of well learned historically developed abilities.

It is possible that sensitivities of the WMS and WAIS are different by virtue of the fact that the verbal portions of the WAIS and some portions of the performance aspect of the WAIS measure crystallized abilities. Hence, they recover more quickly following specific types of brain damage and are more refractory to impairment as a long-term residual of closed head injury. Conversely, neuropsychological indicators, as discussed previously, are more sensitive
to the process of rapid perceptual integration or novel problem solving which could be considered to be more of a fluid ability. This concept would not only explain the differences between the WMS and WAIS in response to brain damage but also would explain the historical difference between the verbal subtests and the performance subtests with the latter being considered as fluid abilities and hence more chronically impaired under conditions of diffuse cerebral trauma.

From a previous review, Horn (1976) advanced this hypothesis directly by suggesting that most of the performance subtests of the WAIS indeed measured right hemispheric, but also fluid abilities. This made them more susceptible to impairment. E. W. Russell (1980) tested this hypothesis specifically and found that in diffusely organically damaged subjects the performance subtests were indeed more affected than the verbal subtests. At that time E. W. Russell commented that a test of fluid verbal abilities was not in common use.

In addition to being a measure of short-term memory function, the WMS may indeed be a measure of more fluid verbal abilities. Its demands for new learning, concentration, and active mental processing of verbal material would possibly make it separate from the verbal subtests of the WAIS in terms of its overall requirements. This interpretation would be consistent with the literature review carried out in this study which showed generally good correlations between the WAIS and WMS except in some brain damage or special populations. This observation has been supported in other research.
The known feature of closed head injury as previously discussed emphasizes a disruption of the integrative aspects of brain functioning. With such a hypothetical disruption of integrative functions and memory difficulties as outlined previously, it is possible that the WMS's discrepancy (that is, the WMS quotient below the WAIS full scale score) would be an important measure both in estimating the nature of neuropsychological disability and as screening information regarding processing defects of specific types, such as fluid verbal abilities and related memory functions.

Smith (1983) has recently included the WMS in the Michigan Neuropsychological Battery and he has suggested that it be used along with the Digit Symbol Modalities Test as an indicator of deficits in rapid and fluid processing capabilities.

General Research Hypothesis

The general research hypothesis will be stated here in three parts reflecting, therefore, the three major hypotheses to be tested.

**Hypothesis 1:** The WMS memory quotient score will be lower than the WAIS full scale score in closed head injury patients. Such a WMS performance discrepancy will not be present in a group of localized brain damaged patients and a psychiatric control group.

**Hypothesis 2:** The short coma group will show a smaller WMS discrepancy score than will the long coma group. That is, the less severely head injured will have more equal WAIS and WMS performances.
Hypothesis 3: Large WMS discrepancy scores will be associated with large impairment ratings on the Halstead-Reitan Neuropsychological Battery in the closed head injury group. Conversely, low WMS discrepancy scores will be associated with lower impairment ratings on the Halstead-Reitan Neuropsychological Battery.

Limitations of the Study

A limitation of this study derives from the fact that a number of separate events in nature are studied that are not subject to scientific control. The study relies upon pathological groups. In this case, a closed head injury group, a localized trauma group, and an unimpaired psychiatric control group were formed from existing clinical populations. This does not provide confidence that each group has unity in terms of the exact dysfunctions assumed or measured. Every effort has been made to analyze presenting pathology so that the truly localized brain syndrome patients and closed head injury patients qualified for their respective groups. However, dependence upon posttrauma information gathering is a liability as is the absence of experimental controls over a number of unseen variables which may contribute to these naturally occurring phenomenon.

A second limitation rests in the weaknesses inherent in static-group comparison designs and correlational studies. An unknown number of factors could contribute to the traits in each group in a predetermined way or these effects might be independent of the named pathology groupings.
CHAPTER II

DESIGN AND METHODOLOGY

Subjects

The total subject population in the present study consisted of 115 inpatients and outpatients from a large inpatient psychiatric and rehabilitation facility. All subjects were referred specifically for neuropsychological evaluation. The closed head injury group, localized injury group, and unimpaired psychiatric group did, however, differ slightly in terms of the source and reason for referral.

The Unimpaired Control Group

The unimpaired psychiatric control group consisted of 25 males and 20 females. The age range of the control group was 18 to 56 years old with a mean age of 28.4 years and a median age of 25 years. An initial pool of 71 inpatients was identified who had been referred for neuropsychological testing. From the original pool of 71 cases, 18 were excluded due to incomplete test files or data. Four of the original pool were excluded due to a stated history of mild closed head injuries which had occurred in their distant past but were noted to have resulted in at least some notable residuals, hospitalization, or a diagnosis of head injury. Two others were excluded from the original pool due to actual neuropsychological ratings which placed them within the defined range of impairment.
One additional case was dropped due to an inability to read and a history of learning disability. An additional case was excluded due to the presence of a cerebral vascular accident in recent history. The total number of excluded subjects was 26 leaving 45 for a total number in the group.

"Pure" clinical histories were difficult to obtain for the psychiatric unimpaired group as well as the closed head injury group and localized trauma group. It should be noted that the psychiatric control group evidenced a number of individuals (nearly half of those sampled in all groups) to have suffered minor blows to the head which they claimed resulted in very transient effects with no stated residuals, posttraumatic amnesia, or confusion of any type. It is assumed that these very transient head injuries are ubiquitous in the general population and no attempt was exhaustively made to screen out every individual who reported some blow to the head at sometime in their personal history. Three persons in the psychiatric control group showed abnormal EEGs at sometime in their personal history. This group also included two cases with possible encephalitis.

All individuals in the unimpaired control group were referred largely from an inpatient psychiatric facility. At the time of referral, the treating clinician usually attempted to screen out subtle processes of thought disorder, memory difficulties, or other difficulties, such as concentration. A large variety of the referrals were motivated by histories of alcohol or street drug abuse.
Referrals with this type of history constituted almost half of the referred group.

The Closed Head Injury Group

The closed head injury group consisted of 45 cases. These were drawn from an original data pool of 59 cases who were examined neuropsychologically. Nine of these cases were dropped due to incomplete testing or missing scores. Two were excluded due to equivocal histories of head injury. That is, it could not be ascertained either in their history or from their report whether they had a diagnosed history of head injury with any resulting symptomology. One was excluded due to a coexisting learning disability and reported birth trauma which influenced intellectual development. An additional case was dropped due to a long standing history of hearing impairment which lowered the verbal intelligence quotient. One additional case was dropped due to penetrating head wound which coexisted with closed head injury.

Of the remaining 45 cases in the closed head injury group, 16 showed some additional localizing effects. That is, their histories were positive for hemiparesis, focal signs, hematomas, or some signs of abnormal EEG or seizure activity. Four of the group were neurologically suspected of suffering an anoxic effect. Fifteen to twenty percent of the cases had head injuries severe enough to show decerebrate posturing at the time of emergency room admission. There were 35 males and 10 females with a mean age of 30 years, range of 16 to 54 years, and a median age of 27.5 years. It was
predominately a young sample. Twenty-two of the 45 cases fell below age 26. There were 13 cases over 40 years of age and 10 cases were in their 30s.

In terms of recency of injury, the closed head injury group showed a mean of 45 months post-injury. There were four cases where the head injury was very remote, that is, 12 years or more. When these were excluded from the 45 cases, the average recency of injury dropped to 30.6 months post-injury. Recency of injury ranged from a high of 20 years to a low of approximately 9 months.

In terms of length of coma, the head injury sample showed a median length of coma of 14 days. This ranged from zero days to 90 days. Seventeen of the cases had comas of 5 days or less. Seventeen cases had comas of 28 days or more. An additional 13 cases had comas ranging from 14 to 28 days. In those cases with zero days of coma, there were documented confusional stages, memory impairment, or posttraumatic amnesia, such that even though coma was not present, rather clear stated or documented residuals from the head injury occurred.

The Localized Trauma Group

The localized trauma group consisted of an original pool of 39 non-closed head injury patients who suffered some localized lesion. From this data pool four were dropped due to incomplete measures or data. An additional two cases were dropped due to the confounding presence of closed head injury in their history.
The localized lesion group, since it contained many stroke patients, was a more aged group. They had a median age of 60 with a mean age of 54.9 years. The ages ranged from 29 to 78 years. The group consisted of 15 males and 10 females. Of the total group 19 suffered either cerebral vascular accidents or aneurysms. Six suffered tumors. In terms of lateralization, seven of the sample has lesions clearly lateralized to the left hemisphere. Nine members of the sample had lesions clearly lateralized to the right hemisphere. An additional nine individuals showed equivocal lateralization based on their neurological history, and some were unable to report specific localizing data.

Table 1 summarizes the sex and age comparisons between the groups. Also, Table 1 provides a comparison of the mean neuropsychological impairment ratings. This variable was included here to afford a direct comparison of the level of severity of each group in terms of measured deficits. As might be expected, the unimpaired psychiatric group was very nearly average in terms of their group performance (an average, or unimpaired, score is 1.0).

The localized lesion group is clearly oldest and most impaired. Group comparisons in terms of educational level are not tabulated. Although the educational level for all groups is estimated to be near high school completion, the closed head injury group and the psychiatric group evidenced lower levels of occupational and educational attainment. This is likely associated with the high number of serious drug abusers and troubled adolescents comprising the psychiatric group and the large number of very young adults and
teenagers in the closed head injury group who had educational and occupational progress interrupted by their injuries.

Table 1

Comparison of Closed Head Injury Group, Localized Lesion Group, and Psychiatric Unimpaired Group by Sex, Mean Age, and Mean Neuropsychology Impairment Rating

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Sex</th>
<th>Mean age (yrs.)</th>
<th>Mean neuropsych. impairment rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed head injury group</td>
<td>45</td>
<td>35</td>
<td>10</td>
<td>30.0</td>
</tr>
<tr>
<td>Localized lesion group</td>
<td>25</td>
<td>15</td>
<td>10</td>
<td>54.9</td>
</tr>
<tr>
<td>Psychiatric unimpaired</td>
<td>45</td>
<td>25</td>
<td>20</td>
<td>28.4</td>
</tr>
</tbody>
</table>

Subject Selection and Group Assignment

The subjects utilized in the present study were patients who had undergone either clinical treatment or formal assessment to understand, rehabilitate, or treat clinically presenting conditions. Therefore, the three groups, which consisted of the psychiatric unimpaired group, the localized lesion group, and the closed head injury group, in many ways constitute naturally occurring phenomenon. Therefore, the clinical entities, which comprise the three groups are not considered to be "pure." Also, the lack of purity in clinical syndromes is a recognized liability in such group comparisons.
As was noted in the description of the subject composition for each group, it was difficult to find patients with absolutely no other confounding factors in their history which might have contributed some measurable type of brain dysfunction. It is likely that these events are commonplace in nature such that minor blows to the head, high fevers, history of fainting spells, abnormal EEGs, or other features would be impossible to rule out.

Subject selection criteria relied upon patient history and any accompanying neurological data. An effort was made to be very conservative and not to include subjects in any group for which the self-report or accompanying neurological history or data was uncertain.

Individuals in the closed head injury group were required to have suffered a head injury for which they were treated and which resulted in some residuals which were brought to the attention of treatment personnel. Self-report was used as a criterion in a minor portion of the closed head injury cases. In this instance patients had to exhibit a clear recognition of whether coma exceeded 5 days. Cases where self-report was equivocal of this regard, or where other data were not present, were omitted. Those cases with no clear evidence of coma were referred due to posttraumatic confusion and to ascertain cognitive dysfunction which was residual and persisting from the time of trauma.

The localized lesion group had a neurological history of either cerebral vascular accident, aneurysm, or tumor. They were included in this group regardless of severity or localization of the injury.
In this group all individuals were referred to ascertain the possible residuals of these events. It was important with this group to demonstrate the absence of diffuse brain damage history or closed head injury. Therefore, patients with any such history were dropped from consideration as noted in the description of that population. A number of those individuals who were reporting extremely minor head injuries were retained if it was clear that there were no reported immediate or retained sequelae to these injuries. Since these events were considered to be frequent in the population, exclusion criteria to rule out the most minor of head injuries would seriously have limited candidates for inclusion in a non-closed head injury sample.

Subjects included in the psychiatric control group were included if they had no history of stroke or localized lesion. Also, it was required that they have no known closed head injury. The criterion for the inclusion of this group was an unimpaired rating of the Halstead-Reitan Neuropsychological Battery. Therefore, it serves as a contrast which requires subjects not to have lesions of the type involved in the other two groups. A cut-off of an impairment rating of 1.55 was utilized. That is, individuals obtaining scores of 1.56 or higher were excluded and defined as impaired following the subtest averaging method described by E. W. Russell, Neuringer, and Goldstein (1970). These authors considered an impairment rating of 1.55 to be the dividing line between the average range of functioning and the mildly impaired range of functioning. In the present study three cases with an impairment rating of 1.58
were included due to the fact that the examiner in the individual case offered the clinical judgment of nonimpairment. Thus, it was not felt that these three cases would harm the integrity of the assumption of nonimpairment for the control group. There was no attempt made to control for education, age, or other demographic factors. The possible confounding effects of group selection variables and their limitations for interpretation will be discussed at a later time.

Criteria Instruments

The three measures used in this research were the WAIS, the WMS, and the Halstead-Reitan Neuropsychological Battery. An additional variable was length of coma. The origin, description, and validity data relative to these instruments were provided in appropriate sections of Chapter I. The major reporting data regarding their structure and validity, however, will be summarized.

The WMS has repeatedly been shown to be sensitive to factors of very short-term registration memory, attention and concentration, and associational flexibility despite its weakness as a measure of the wider variety of memory functions (Dye, 1982; Kear-Cowell, 1977; Kear-Colwell & Heller, 1978; Prigatano, 1978). It was designed to be comparable to the Wechsler-Bellevue Intelligence Scale (Wechsler, 1945), and in the absence of severe cerebral dysfunction, it is not usually discrepant from the WAIS (Prigatano, 1977). This instrument is included here to serve as a screening instrument for the types of short-term memory and attentional deficits noted in the diffuse
closed head injury.

The WAIS has been shown to be sensitive to four major factors of intelligence. These are a verbal comprehension factor, a non-verbal or visual organizational factor, a general intellectual factor, and a freedom from distractability factor (E. W. Russell, 1972; Wechsler, 1958). Furthermore, rather consistent findings in the literature suggest that while the verbal and performance intelligence quotient scores are sensitive to left hemisphere and right hemisphere lesions, respectively, many types of brain damage, and more particularly diffuse brain injury, result in greater impairment of the performance intelligence quotient score (Lansdell & Smith, 1975; Smith, 1966; Todd, Coolidge, & Satz, 1977). The Wechsler Adult Intelligence Scale and its replacement version, the Wechsler Adult Intelligence Scale-Revised Form (Wechsler, 1981), is the most widely standardized individual intelligence test currently used. In the standardization of the Wechsler Adult Intelligence Scale, large stratified samples were used based on the census data so that scores would be representative of the race, geographic region, age, sex, and occupational variety reflected in the United States census calculations.

Wechsler (1981) reported reliability and validity data in his manual. Split half reliability and test-retest reliability coefficients were obtained. The test-retest reliability coefficient for the verbal intelligence quotient is reported to be .95. The performance intelligence reliability quotient is reported to be .88, and the full scale intelligence reliability quotient score is
reported as .96.

Validity studies have been undertaken to compare WAIS results with global indicators of intelligence, such as level of education, as well as job and school performance. Such correlations are typically on the order of .50 (Woo-Sam, 1971; Zimmerman et al., 1970).

A comparison of average intelligence quotients reveals the WAIS intelligence quotient to be about eight points higher than the corresponding intelligence quotient of the WAIS-Revised Form (Wechsler, 1981). To make WAIS-Revised Form scores comparable to WAIS scores, eight points were subtracted from the full scale WAIS-Revised Form score. In this manner, all subjects who were assessed with the WAIS-Revised Form were given an adjusted full scale intelligence quotient score.

The Halstead-Reitan Neuropsychological Battery has been previously reviewed, as a part of this study, detailing its sensitivity to various types of brain damage (see Chapter I). It has been normed on clinical populations with known types and degrees of cerebral trauma. It was shown to be more sensitive to brain damage than the Wechsler-Bellevue intelligence quotient (Reitan, 1953). It was also shown to discriminate brain damage from non-brain-damaged individuals with a correct classification of 81% to 98.8% (Wheeler, 1964; Wheeler et al., 1963). That the Halstead-Reitan Neuropsychological Battery is potentially usable to specify lateralization, localization, and process aspects of brain damage has been affirmed by Filskov and Goldstein (1974).
Research Design

Data Collection Procedure

Data were collected in the present study through a review of neuropsychological data which were collected in a private psychiatric and rehabilitation facility beginning in 1976 and ending in November of 1983. The subjects tested before 1976 could not be utilized as they were not administered the WMS in conjunction with neuropsychological testing. All subjects were tested by psychometric technicians who had formal training in the administration of the Halstead-Reitan Neuropsychological Battery. Each case was also subjected to a clinical interview which was part of the testing review and report writing procedure. With each neuropsychological case which was eligible for the data pool, a formal intake questionnaire was utilized. This is a self-report format which was individually administered and accessed the client's history in terms of important signs of cerebral trauma or pathology. Additional data were often gathered by referral sources. In many cases of closed head injury, additional historical data were accomplished through interview or questions directed at family members. Therefore, data collection involved the ongoing collection of suitable candidates and a record of relevant data as they became available. It also involved a review of previously stored cases by category of injury. In most cases, the type of cerebral pathology was very clear-cut. In some cases, as was described in the section on subject selection, equivocal results were obtained and this resulted in exclusion.
Design of the Study

The current study is an ex post facto analysis utilizing static group comparisons. In naturalistic observations, such as the brain trauma subjects involved in the present study, it is necessary to test variations and alternative aspects of the hypothesis to add strength to the tentative conclusions gained from lack of control over independent variables (Kerlinger, 1973). Therefore, in the present study the WAIS and the WMS discrepancy score was related to closed head injury both by comparing it to groups chosen to hypothetically contrast in terms of their discrepancy score outcome and by testing for correlation with other measures which relate severity of closed head injury to the WMS discrepancy score.

These alternative hypotheses are not claimed to compensate for threats to internal validity or generalizability of results inherent in this design (Campbell & Stanley, 1966). Rather the analysis was used to determine what relationship may exist between severity of closed head injury as defined by performance on the Halstead-Reitan Neuropsychological Battery and the WMS discrepancy score.

The statistical analysis used to test Hypothesis 1 was a one-way analysis of variance (ANOVA) to determine if there was a significant difference between the localized trauma group, the closed head injury group, or the unimpaired psychiatric group. The protected least squares difference procedure was applied to this three-group ANOVA. This was done to determine which of the three group means were significantly different from each other. The expected
result for Hypothesis 1 would be a significant difference between the mean WMS discrepancy score of the localized lesion group, the closed head injury group, and the unimpaired psychiatric control group. More specifically, it should also be found that the mean WMS discrepancy scores for the closed head injury group are significantly different from the mean WMS discrepancy scores of the localized lesion group and the psychiatric control group. If large WMS discrepancy scores are truly unique to closed head injury, it would also suggest that there will be no difference between the mean WMS discrepancy scores of the localized lesion group and the unimpaired control group.

The statistical analysis used to test Hypothesis 2 was a one-way ANOVA to establish $F$ probability. This was used to determine if the short coma group was significantly different from the long coma group in regard to the WMS discrepancy score. The expected quantitative outcome for Hypothesis 2 is a significant difference between the mean WMS discrepancy scores for the long and short coma groups. This difference between groups should account for the greatest proportion of the discrepancy score differences. Specifically, the short coma group should have smaller discrepancy scores than the long coma group.

The expected result of Hypothesis 3 is a linear relationship between the magnitude of the Halstead-Reitan Neuropsychological Battery severity score and the magnitude of the WMS discrepancy score. That linear relationship should be positive. Increases in neuropsychological severity rating should occur with increases in
discrepancy score.

An alpha level of .05 was used to test all of the null hypotheses against their respective alternate hypotheses.

Additional statistical procedures used to clarify outcomes are presented along with results of those procedures in Chapter III.

Research Hypotheses (Operational Hypotheses)

The three central hypotheses in the current study are presented here in terms of specific parameters. The specific hypothesis to be tested (the null hypothesis) will accompany each hypothesis.

**Hypothesis 1:** There will be a significant difference between the mean WMS discrepancy score of a closed head injury group from the mean WMS discrepancy scores of an unimpaired psychiatric control group and a localized lesion group.

Null hypothesis: There will be no difference between the mean WMS discrepancy scores of the closed head injury group, the localized lesion group, and the psychiatric unimpaired control group following analysis of variance.

**Hypothesis 2:** The mean WMS discrepancy score of a short coma group will be significantly less than the mean WMS discrepancy score of a long coma group.

Null hypothesis: There will be no difference between the means of a short coma group and a long coma group following analysis of variance.

**Hypothesis 3:** There will be a significant positive correlation between severity of head injury as measured by the Halstead-Reitan
Neuropsychological Battery impairment rating and the size of the WMS discrepancy score.

Null hypothesis: The Pearson product-moment correlation coefficient between the Halstead-Reitan Neuropsychological Battery impairment rating and the WMS discrepancy score will be zero.
CHAPTER III

DATA ANALYSIS

This research attempted to investigate the relationship between the WMS discrepancy score and closed head injury. Conceptually, it was hypothesized that closed head injury results in deficient WMS performance relative to WAIS performance. This hypothesized deficit in short-term memory processing is explored by comparing a less severe head injury group with a more severe head injury group as defined by length of coma, comparing closed head injury WMS discrepancy scores with other impaired and unimpaired groups, and finally, by correlating WAIS discrepancy scores with a neuropsychological test battery severity score. Data are presented in this chapter that will portray these comparisons. Initially presented are data from the entire research population that are descriptive. Research data pertaining to group difference and hypothesis testing will follow. Additional statistical analysis will then be presented.

Analysis of Population Data

The descriptive data for the entire research population are presented in Table 2, where the mean, range, and standard deviation scores are presented for the WAIS, WMS, Halstead-Reitan impairment rating, and the WMS discrepancy scores.

As can be noted, the mean scores for both the WAIS and the WMS are within the average range. However, the range and standard
deviation for the WMS are comparatively large with a range of 91 points and a standard deviation of 19 points. Thus, relative variability in WMS performance is suggested with the implication that it is more subject to individual differences within the whole population. The widely varying discrepancy score (standard deviation, 11.61) is also likely associated with the wider variance in WMS scores.

Table 2


<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Range</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAIS</td>
<td>99.30</td>
<td>66.00</td>
<td>12.34</td>
</tr>
<tr>
<td>WMS</td>
<td>94.53</td>
<td>91.00</td>
<td>19.00</td>
</tr>
<tr>
<td>Halstead-Reitan</td>
<td>1.67</td>
<td>2.91</td>
<td>.79</td>
</tr>
<tr>
<td>impairment rating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WMS discrepancy score</td>
<td>4.77</td>
<td>56.00</td>
<td>11.61</td>
</tr>
</tbody>
</table>

The average neuropsychological severity rating is close to the nonimpaired cut-off score of 1.55 with an average severity rating of 1.67 and a standard deviation of .79 points. While the range of severity scores is from .42 (superior) to 3.33 (moderately impaired), they suggest a less variable distribution across the entire sample than do scores associated with the WMS. These descriptive observations may be due to the fact that both the Halstead-Reitan test and the WAIS assess a wide variety of individualized cognitive functions.
and are therefore less likely to evidence extremes in range and variance in their composite scores. It would appear important to note, however, the rather extreme range and variance in the WMS scores as compared to other performance measures obtained.

Hypothesis 1: In order to test Hypothesis 1, an ANOVA was computed to test the null hypothesis that there would be no difference between the means of the unimpaired psychiatric control group, the localized lesion group, and the closed head injury group. Additionally, the protected least squares difference test was applied to ascertain which group differences were significant. The ANOVA did reveal significant differences between the groups, $F(2, 112) = 6.241$, $p = .0027$ (see Table 3). Therefore, the null hypothesis of no difference between group means could be rejected at the established .05 level of confidence.

The least squares procedure confirms the expected group differences. That is, only the null hypothesis of no difference between the means of the closed head injury group and the other two groups could be rejected at the .05 level. At the .05 level of confidence a null hypothesis of no difference between the psychiatric unimpaired group and the localized lesion group could not be rejected.

Hypothesis 2: The null form of Hypothesis 2 states that there will be no difference in the mean WMS discrepancy scores between a short coma group and a long coma group. Hypothesis 2 was tested by computing a one-way analysis of variance and values are shown in Table 4.
### Table 3
ANOVA for Three Ranges of WMS Discrepancy Scores
(Closed Head Injury Group, Localized Lesion Group, and Psychiatric Unimpaired Group)

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>1540.90</td>
<td>2</td>
<td>770.45</td>
<td>6.241</td>
<td>.0027</td>
</tr>
<tr>
<td>Within</td>
<td>13827.22</td>
<td>112</td>
<td>123.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>15368.12</td>
<td>114</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>X</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psychiatric unimpaired group</td>
<td>45</td>
<td>2.00</td>
<td>11.82</td>
</tr>
<tr>
<td>Localized lesion group</td>
<td>25</td>
<td>1.50</td>
<td>12.77</td>
</tr>
<tr>
<td>Closed head injury group</td>
<td>45</td>
<td>9.33</td>
<td>9.23</td>
</tr>
</tbody>
</table>

### Table 4
ANOVA for Two Ranges of WMS Discrepancy Scores by Length of Coma

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>336.56</td>
<td>1</td>
<td>336.56</td>
<td>4.237</td>
<td>.0456</td>
</tr>
<tr>
<td>Within</td>
<td>3415.43</td>
<td>43</td>
<td>79.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3752.00</td>
<td>44</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>X</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short coma group</td>
<td>17</td>
<td>5.82</td>
<td>8.00</td>
</tr>
<tr>
<td>Long coma group</td>
<td>28</td>
<td>11.46</td>
<td>9.41</td>
</tr>
</tbody>
</table>
The obtained $F$ value is $(1, 43) = 4.237, p = .0456$. These values are sufficient to reject the null hypothesis at the .05 level of confidence. It does support the conceptual hypothesis of differences in WMS discrepancy scores between these long and short coma groups.

**Hypothesis 3**: The null form of Hypothesis 3 states a zero Pearson product-moment correlation coefficient between the neuropsychological impairment rating and the WMS discrepancy score in a group of closed head injured.

The obtained correlation was $r = .3236, p < .05 (p = .030)$. The null hypothesis could, therefore, be rejected at the .05 level of confidence. The conceptual hypothesis of a linear positive relationship between the size of WMS discrepancy score and the neuropsychological impairment rating is supported.

**Additional Statistical Analysis**

In order to further examine the relationships between type of cerebral trauma, intelligence, and WMS performance, additional statistical procedures were run in an attempt to clarify the sensitivity of specific instruments to type of cerebral trauma.

In order to examine the specific sensitivity of the WAIS to the three groups, a one-way analysis of variance was computed, along with the protected least squares procedure to determine any differences between groups on the WAIS full scale IQ score. The values for the analysis of variance are presented in Table 5. The result would suggest a rejection of a hypothesis of no difference between
those groups, $F(2, 112) = 7.511, p = .0009$. Computed results of least square tests further indicate, however, that significant differences are present between only the psychiatric unimpaired group and the closed head injury group.

Table 5

ANOVA of WAIS Full Scale Scores for Closed Head Injury Group, Localized Lesion Group, and a Psychiatric Unimpaired Group

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>2054.36</td>
<td>2</td>
<td>1027.18</td>
<td>7.511</td>
<td>.0009</td>
</tr>
<tr>
<td>Within</td>
<td>15315.98</td>
<td>112</td>
<td>136.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17370.34</td>
<td>114</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>$N$</th>
<th>$\bar{X}$</th>
<th>$\text{SD}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psychiatric unimpaired group</td>
<td>45</td>
<td>104.22</td>
<td>10.23</td>
</tr>
<tr>
<td>Localized lesion group</td>
<td>25</td>
<td>98.76</td>
<td>13.04</td>
</tr>
<tr>
<td>Closed head injury group</td>
<td>45</td>
<td>94.68</td>
<td>12.26</td>
</tr>
</tbody>
</table>

An ANOVA and protected least squares test was also computed for the WMS to determine differences in performance between the closed head injury, localized lesion, and psychiatric unimpaired groups. ANOVA results suggest a rejection of the null hypothesis of no difference between groups based on WMS performance also, $F(2, 112) = 10.73, p = .0001$. The accompanying protected least squares procedure suggested a significant difference between the psychiatric unimpaired group and the closed head injury group in addition to the significant

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difference between the localized trauma group and the closed head
injury group (.05 level). Those results are presented in Table 6. These results are suggestive that performance on WMS in the closed head injury population is impaired in comparison to the localized trauma group and the psychiatric control group.

Table 6
ANOVA of WMS Quotients for Closed Head Injury Group, Localized Lesion Group, and a Psychiatric Unimpaired Group

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>6618.57</td>
<td>2</td>
<td>3309.28</td>
<td>10.73</td>
<td>.0001</td>
</tr>
<tr>
<td>Within</td>
<td>34538.07</td>
<td>112</td>
<td>308.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>41156.64</td>
<td>114</td>
<td></td>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>( \bar{X} )</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psychiatric unimpaired group</td>
<td>45</td>
<td>102.20</td>
<td>16.09</td>
</tr>
<tr>
<td>Localized lesion group</td>
<td>25</td>
<td>97.24</td>
<td>21.28</td>
</tr>
<tr>
<td>Closed head injury group</td>
<td>45</td>
<td>85.35</td>
<td>16.70</td>
</tr>
</tbody>
</table>

An additional analysis of variance was computed for the WAIS by the length of coma. These results suggest no significant difference in WAIS performance between short and long coma groups, \( F(1, 43) = 2.113, p = .1533 \). Computed values are provided in Table 7.
Table 7
ANOVA of WAIS Full Scale Scores for Long and Short Coma Groups

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>310.27</td>
<td>1</td>
<td>310.27</td>
<td>2.113</td>
<td>.1533</td>
</tr>
<tr>
<td>Within</td>
<td>6313.36</td>
<td>43</td>
<td>146.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6623.64</td>
<td>44</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>X</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short coma group</td>
<td>17</td>
<td>98.05</td>
<td>11.76</td>
</tr>
<tr>
<td>Long coma group</td>
<td>28</td>
<td>92.64</td>
<td>12.32</td>
</tr>
</tbody>
</table>

The suggestion of no significant difference between the long and short coma groups on the WAIS variable was unlike the results of the analysis of variance for the WMS quotient between short and long coma groups. Significant difference was obtained between the short and long groups beyond the .05 level, \( F(1, 43) = 5.063, \ p = .0296 \) (see Table 8). These results would confirm that while the WAIS may not be sensitive to the length of coma variable, the WMS quotient is more sensitive to that dimension of severity.

Pearson product-moment correlation coefficients were computed to obtain additional information about the degree of relationship between the Halstead-Reitan Neuropsychological Battery impairment rating and other variables, including the WMS memory quotient, WAIS, and WMS discrepancy score. These correlations were computed for both the localized trauma group and the closed head injury group.
Table 8
ANOVA of WMS Quotients for Long and Short Coma Groups

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>1293.14</td>
<td>1</td>
<td>1293.14</td>
<td>5.06</td>
<td>.0296</td>
</tr>
<tr>
<td>Within</td>
<td>10983.16</td>
<td>43</td>
<td>225.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12276.31</td>
<td>44</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>X</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short coma group</td>
<td>17</td>
<td>92.23</td>
<td>14.65</td>
</tr>
<tr>
<td>Long coma group</td>
<td>28</td>
<td>81.17</td>
<td>16.71</td>
</tr>
</tbody>
</table>

The WAIS full scale IQ score correlates with the neuropsychological impairment rating at \(-0.75\) \((p = .00)\) in both the closed head injury group and the localized lesion group. The WMS memory quotient shows a correlation with the neuropsychological impairment rating of \(-0.73\) \((p = .00)\) in the closed head injury group, and a correlation of \(-0.66\) \((p = .00)\) in the localized lesion group. The correlation between the WMS discrepancy score and the neuropsychological impairment rating in the localized lesion group is \(0.33\) \((p = .105)\). Recall that this is nearly the same as the correlation coefficient between the WMS discrepancy score and the neuropsychological impairment rating in the closed head injury group \(0.32\) \((p = .03)\).

The above correlations do permit the rejection of the null hypothesis of a zero correlation between the WMS discrepancy score
and the neuropsychological impairment rating. These correlations do not lend strength, however, to the corollary hypothesis that such a relationship is unique to closed head injury.

Discussion

Hypothesis 1 predicts a difference in the WMS discrepancy score between the closed head injury group, the localized lesion group, and the unimpaired control group. This hypothesis was strongly supported by the results. ANOVA did reveal differences between the groups on the dimension of WMS discrepancy score. The null hypothesis of no group difference was rejected at a confidence level of .05. Furthermore, the nature of those group differences were as hypothesized. The closed head injury group was significantly different from both the unimpaired psychiatric control group and the localized lesion group. The results of the protected least squares difference procedure could not support an assumption of difference between the psychiatric unimpaired control group and the localized lesion group on the WMS discrepancy dimension.

A clear difference is seen on the examination of the mean WMS discrepancy scores for each group. The mean WMS discrepancy score in the closed head injury group is nearly 9.5 points. The psychiatric unimpaired group and the localized lesion group show mean WMS discrepancy scores of 2 and 1.5 points, respectively. Not only are these WMS discrepancy scores low in comparison to those obtained by the closed head injury group, but the small differences between the psychiatric unimpaired group and the localized lesion group are
suggestive of similarity in terms of WMS performance.

Two other ANOVAs were performed to ascertain what differences there might be in WAIS and WMS performance between the three groups. The ANOVA and protected least squares difference test revealed only a significant difference (at the .05 level) between the closed head injury group and the unimpaired psychiatric group on the measure of WAIS full scale IQ. However, an ANOVA and protected least squares procedure reveal significant difference (.05 level) between the closed head injury group and both other groups on the dimension of WMS memory quotient performance.

The comparisons of WAIS and WMS performances by group are supportive of the conceptual hypothesis of greater WMS deficits in closed head injury and, hence, the occurrence of the WMS discrepancy score. Some other descriptive data have a bearing upon this hypothesis also, and it is revealing of the differential sensitivity of the WAIS and the WMS to brain damage.

The closed head injury group, the localized lesion group, and the psychiatric control group show mean WAIS scores of 94.6, 98.7, and 104.2, respectively. All groups are within the average range (not considering the correction factor of adding eight points to the WAIS-Revised Form). This is true even of the two groups with ascertained brain damage. To have an average WAIS full scale IQ even within the low average range in a diffuse closed head injury group might testify to the relative resistance to impairment of overall WAIS performance in the closed head injured.
In contrast, the data indicate that the WMS is affected by the diffuse closed head injury process. The mean WMS memory quotient is nearly equal to the WAIS full scale IQ in the localized lesion group as in the psychiatric unimpaired group. They are about two points below the WAIS intelligence quotient in both instances. However, the WMS performance in the closed head injury group is inferior. The mean WMS quotient in the closed head injury group is nearly 12 points below the mean WMS quotient of the localized trauma group and nearly 17 points below the mean WMS quotient of the psychiatric unimpaired group.

An interpretation that localized lesion groups do not evidence low WMS scores is not warranted, however. This group shows the greatest overall variability in WMS performance with a memory quotient range extending from a low of 73 points to a high of 143 points.

Hypothesis 2 conceptually stated that there would be a larger WMS discrepancy score for the long coma group (more than 5 days) than in the short coma group (5 days or less). The null hypothesis of no difference between the group means of the long and short coma groups was rejected at the .05 level of confidence following an ANOVA.

The above results are supportive of the hypothesized increase in the size of WMS discrepancy scores with a longer period of coma. Additional data portray the effect of length of coma on both the WMS and the WAIS. The WMS scores and the WAIS scores were both subjected to an ANOVA. The results suggested only a tendency for the
WAIS mean IQ scores to differ between the short and long coma groups with the probability level of mean differences being $p = .153$. In contrast, the results of ANOVA of WMS memory quotient scores between the short and long coma groups yielded a significant probability of difference, $p = .029$.

These results would tend to suggest that while both measures are affected by length of coma, the WMS is more sensitive to that indicator of severity.

An inspection of the mean WAIS IQ score and the mean WMS memory quotient for both the long and short coma groups reveals other descriptive information. In the short coma group there is about a six-point discrepancy when the WAIS mean score is compared to the WMS mean score. When these same scores are compared in the long coma group, the difference between the WAIS score and the WMS score increases to more than 11 points. Also, while the mean score for the WAIS in the long coma group remains in the low average range (92.6), the mean WMS score for the same group is a low score (81.2).

The present data regarding the WMS discrepancy score, and its relationship to closed head injury severity as measured by length of coma, is convergent. It is supportive of greater WMS discrepancy with larger periods of coma. It would appear that not only is the WMS deficient in relation to the WAIS following closed head injury, but also this WMS discrepancy increases after longer periods of coma.

Data pertaining to Hypothesis 3 suggest that a linear relationship exists between the WMS discrepancy score and the neuropsychological impairment rating in the closed head injury group.
However, a number of results indicate that this relationship is not strong. Moreover, the relationship between the WMS discrepancy score and the neuropsychological impairment rating is not unique to the closed head injury group. The correlation between the neuropsychological impairment rating and the WMS discrepancy score in the closed head injury group was .32. The same correlation in the localized trauma group was .33. The smaller sample size in the localized trauma group likely prevented a smaller probability than the value obtained, $p = .105$.

A number of interactions between the psychometric variables could act to prevent a higher correlation between the neuropsychological severity rating and the size of the WMS discrepancy score. There is a higher negative correlation between the WAIS full scale IQ and the neuropsychological severity rating (-.75 for both the closed head injury group and the localized lesion group). Despite the high negative correlation of the WMS memory quotient (-.73 for the closed head injury group), such a correlation between the WAIS IQ and the neuropsychological impairment rating obscures the sensitivity of the WMS to neuropsychological impairment. That is, as WMS scores decline with severity, so do WAIS scores. In light of the high negative correlations obtained between the neuropsychological impairment rating and the WAIS, it is remarkable that a significant correlation was obtained between the neuropsychological impairment rating and the WMS discrepancy score.

The above data suggest, therefore, that the WMS discrepancy score and neuropsychological impairment ratings are somewhat related.
but probably measuring quite different processes. This should not be surprising. A neuropsychological impairment rating is based on an extremely wide range of deficit types and it would logically show a higher correlation with the WAIS battery than to a more specific measure such as the WMS. These equivocal results also likely stem from the widely varying pattern of deficits and dysfunction found even within a single patient population. The assumption of a linear relationship and a high significant correlation between WMS discrepancy score and neuropsychological impairment rating presupposes that these two measures would be consistently sensitive to the same attributes in every brain damaged subject. While the WMS may be more uniform in terms of the abilities or attributes tested, certainly the neuropsychological battery will be influenced by a much wider variety of specific dysfunctions which are not related to WMS performance.

Hypothesis 3 is only equivocally supported, therefore. While the size of the WMS discrepancy score is related to neuropsychological impairment ratings in a moderate and positive way, this relationship is not unique to closed head injury and is probably overshadowed by stronger linear relationships between the neuropsychological impairment rating and other more diverse cognitive measures.
CHAPTER IV

FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The goal of the present research was to understand the relationship between the WMS and the WAIS in the context of brain damage. It is hypothesized that short term auditory memory, which is emphasized on the WMS, is more impacted by diffuse brain injuries that are secondary to closed head injury. Thus, the WMS is presumed to show a relative deficiency when compared to the WAIS in a group of closed head injury patients. This research investigated the contention that the WMS memory quotient, when significantly below the WAIS full scale IQ (WMS discrepancy score), signals the diffuse injury characteristic of closed head injuries.

Prigatano (1977) has stated that the WMS is a poor screening device for a wide range of head injuries. At the same time, its factor structure, consisting of the recall of immediate complex information and attention and concentration (Kear-Colwell, 1973), suggests that it might be used in concert with the WAIS to assess the severity of closed head injury or to screen for the presence of diffuse closed head injury. Also, it would be an important indicator of verbal short-term memory difficulties experienced clinically by people suffering closed head injuries. Theoretically, therefore, WMS discrepancy scores should be related to the head
injury process as a distinctive feature. That is, it should be related to severity of the head injury as defined by the length of coma (Brooks, 1976). The WMS discrepancy score would also logically be related to the severity of closed head injury as defined by neuropsychological severity indicators. Its increasing use as a screening technique, both singly and in neuropsychological batteries, warrants further knowledge about these relationships. Thirdly, to assume that deficient WMS performance in comparison to WAIS performance is a distinctive factor of closed head injury, WMS deficits should be greater for closed head injury groups when measured against comparison populations.

The use of WMS in the context of neuropsychological evaluations is increasing (Smith, 1983). Therefore, the WMS discrepancy score was studied as a variable which is relevant to a number of psychometric dimensions and patient types. The fact that the WMS was developed to be a memory test which could be directly comparable to the WAIS full scale IQ score (Wechsler, 1945) adds to the value of understanding the conditions under which WMS performance will vary. Although the WMS is known to be deficient among closed head injury patients (Prigatano, cited in Prigatano, 1978), the exclusivity of this pattern of discrepancy is less well established. In summary, the hypothetical problem of deficient WMS performance in relation to WAIS performance is important from the standpoint of understanding the types of head injury in which these scores are comparable and what parameters of brain injury or dysfunction underlie inferior WMS performance. If the WMS alone is ineffective as a screen for brain
damage, then possibly the WMS discrepancy score might be used as a brain damage screen, at least in closed head injury populations.

The sample population for this research consisted of 115 patients who had undergone complete neuropsychological evaluations but who had also been given the WMS. Their neurological histories were used to divide them into three groups according to category and type of trauma. They were divided into a rather small localized group of patients who had undergone an ascertained brain trauma secondary to a stroke, aneurysm, or tumor; compared to a group who had suffered a closed head injury; compared to a group of psychiatric controls who were referred for the suspicion for brain dysfunction but who developed normal neuropsychological battery test results.

The statistical analysis used to test Hypothesis 1 was an ANOVA to assess any differences between group means of the psychiatric unimpaired group, the localized lesion group, and the closed head injury group. Analysis of Hypothesis 2 was also an ANOVA to test for differences between group means of the short coma group and the long coma group. The statistical analysis of Hypothesis 3 was carried out utilizing the Pearson product-moment correlation coefficient.

Findings

All three null hypotheses were rejected and the theoretical hypotheses for the WMS discrepancy score were supported. The results suggest that it is at least a common feature of closed head
injury and it may be a marker of closed head injury so far as it is related to severity. Hypothesis 1, which theoretically predicted larger WMS discrepancy scores in the closed head injury group than in the unimpaired psychiatric group or the localized lesion group, was supported. Hypothesis 2, which conceptually predicted larger WMS discrepancy scores for the long coma group, was also supported. Hypothesis 3 predicted a significant and positive correlation between the size of the WMS discrepancy score and the magnitude of a neuropsychological impairment rating. While this hypothesis was technically supported, the strength of the finding was substantially weakened by the low order of the correlation and the fact that the localized lesion group showed a similar correlation. Neuropsychological impairment ratings were interpreted as being too diverse in range of measurement to correlate highly with a singular condition verbal short-term memory deficiency.

Additional statistical analyses were carried out which subjected scores on the WAIS and the WMS individually to an ANOVA procedure. It was found that there were significant differences in the dimension of WAIS full scale intelligence quotient only between the closed head injury group and the unimpaired psychiatric group. However, on the WMS memory quotient measure, the closed head injury group was significantly different from both the localized trauma group and the psychiatric unimpaired group.

It was discovered that the WMS discrepancy score showed a significant correlation with the neuropsychological impairment rating in the closed head injury group. These findings are inconclusive,
however, due to the much higher negative correlations obtained between the neuropsychological impairment rating and the WAIS and WMS in both the localized lesion and closed head injury groups. Overall, the findings are summarized to suggest that the WMS discrepancy score is found to persist to a greater degree in closed head injury populations. This was true despite the fact that the WAIS also shows the greatest level of impairment in the population of closed head injury subjects used in this study.

Conclusions

In concept, this study has been directed toward affirming the conceptual hypothesis that the WMS, as a measure of both short-term audio-verbal memory and "fluid" verbal abilities, would be particularly sensitive to the diffuse effects of closed head injury. More specifically, it was hypothesized that the WMS might be used in concert with the WAIS to identify those individuals who suffer the types of injuries which put them at high risk for deficits which involve fluid verbal abilities and the other performance factors of the WMS which include short-term verbal memory, attention, concentration, and the freedom from distractability factor. It was also hypothesized that closed head injury as a pathological process would involve diffuse cerebral disruption and cortex/midbrain disruptions which are important in causing short-term memory impairment. The WMS discrepancy score is also investigated due to the supposed comparability of the scores in normals (Wechsler, 1945). In diffuse head injuries, as the literature has supported, there tends to be a
predominance of performance intelligence quotient score deficits in closed head injuries (Mandleberg, 1975; Mandleberg & Brooks, 1975). The WMS was hypothesized to be a more sensitive indication of fluid as opposed to crystallized verbal abilities. The use of the WMS could therefore be evaluated by understanding the manner in which the WMS might be deficient to WAIS performances. Additionally, it might solve the problem of measuring fluid verbal capabilities and associated short-term verbal memory problems. It therefore could serve as a valuable addition to the WAIS which measures mostly crystallized verbal abilities which are refractory to diffuse head injuries (E. W. Russell, 1980).

In the present study the relationship of head injury to the WMS discrepancy score was established. The relationship of the WMS discrepancy score to length of coma was clearly supported. The present study only differentiates short from long coma groups, but it does nicely corroborate the findings of Prigatano (cited in Prigatano, 1978, p. 823). The discrepancy of the WMS from the WAIS in increasing severity as defined by length of coma is not only supported by Prigatano's study but also the average WMS discrepancy score of 10 points established in his study is highly consistent with the present study. These findings do support the general conceptual hypothesis that increasing severity of diffuse closed head injury results in a disproportionally greater decrease in the more fluid and memory based aspects of verbal processing as measured by the WMS.

The relationship between neuropsychological severity scores and WMS discrepancy scores was investigated to further support the
notion that, with increasing severity, WMS discrepancy scores would be more characteristic of closed head injuries as compared to localized head injuries and a psychiatric control group. This hypothesis was supported but seems considerably weaker. The closed head injury group performance showed a significant correlation between the WMS discrepancy score and neuropsychological severity ratings. While these findings certainly are in the expected direction, they are not strong in supporting conclusively that WMS discrepancy is unique to closed head injury with increasing severity. In fact, the localized lesion group also showed correlation between WMS discrepancy score and neuropsychological severity score approaching significance. Difficulties in sample size in the present study may have prevented more conclusive results regarding this hypothesis.

Possibly the most conclusive evidence in the present study is the obtained significant differences which discriminate the closed head injury from both the localized trauma group and the unimpaired control group on the measure of WMS discrepancy score. While the closed head injury group was different from both of the comparison groups, the localized trauma group and the unimpaired control group were not different from each other. Therefore, except for possibly the most severe of localized lesions, group differences in the discrepancy scores are most notable. It is possible that as localized pathological process such as tumors or strokes become more generalized they begin to overlap on the dimension of WMS discrepancy with the diffuse head injuries. This may be due to multiple lesion sites, the more widespread involvement of the cerebral cortex, or by the
radiating effects of more widespread brain damage. This observation certainly would be in line with the observation of Smith (1966), who found that 65% of left hemisphere lesion patients showed the contradictory findings of having higher verbal intelligence quotient scores.

However, the present study has much less to say conceptually about memory difficulties or WMS discrepancy in regard to localized lesions. The fact that WMS discrepancy was less typical of the group does not obviate the fact that some localized lesion subjects showed markedly inferior WMS scores. The use of the WMS discrepancy scores with localized lesion groups will obviously remain a matter of individual clinical neuropsychological assessment. Given the extremely large range of WMS scores in that group, it would demand that the neuropsychology clinician be sensitive to the potential variance among localized lesion groups on the dimension of memory function. The fact that localized lesion patients as a group do not show a regularly occurring pattern of short-term memory deficiency only requires greater vigilance to those numbers of cases who may show such a condition. These observations tend to reinforce the importance of the present findings in terms of using a technique in addition to the WAIS to screen for deficits in the area of memory processes regardless of the site of lesion.

Another observation which can be derived from results of this study pertains to the differences in deficit pattern between the closed head injury group and the localized lesion group. The localized lesion group showed the greatest overall neuropsychology
impairment rating. Despite this fact, they showed higher WAIS scores and much smaller WMS discrepancy scores. It is tempting to speculate that the Halstead-Reitan Neuropsychological Battery, by virtue of its specific sensitivity to cortical areas, may underestimate or overestimate total brain dysfunction depending upon the type of lesion process. If that were true, then it could be possible that the neuropsychological impairment rating may underestimate diffuse lesions and overestimate focal lesions in terms of their total impact upon a patient's adjustment and cognitive capacities. While this possibility is a matter for further research, it suggests clinical caution when using neuropsychology impairment ratings as estimates of difficulty in living.

A number of important features emerge from the present findings. Despite the fact that WAIS performance was most devastated in the closed head injury group, the discrepancy effect remained. That is, although closed head injury patients showed the greatest disruption of intellectual processes as measured by the WAIS, they still show the largest relative WMS discrepancy effects.

This researcher believes this effect further underscores the importance of assessing interaction effects among subtests when carrying out neuropsychological evaluations. This observation certainly is not new to neuropsychology. The field has long depended upon the differential sensitivity of subtests to estimate brain dysfunction. This is most true of those subtests constructed to be sensitive to specific sites of dysfunction within the cortex. The addition of memory testing to neuropsychological batteries, however,
provides a new dimension. That is, it supplies the examiner with information about the rate and nature of information processing and retention. Memory processing and other rapid integrative activity are most frequently not the product of activity within a well localized field of the cortex. The interactions between neuropsychological subtests which test more localized cortical functions and those which are more globally sensitive to diffuse brain dysfunction need to be compared. WMS and WAIS performance comparisons may therefore be most important not because of any specific ability to discriminate memory deficiency; rather, they may provide a set of interactions or comparisons which can be used to discriminate localized from diffuse injury processes or even to estimate subcortical brain damage effects which have a bearing upon memory, arousal, attention, and other fluid adaptive capacities.

The present study discloses closed head injury to have an average WMS discrepancy score of almost 9.5 points. Other authors (Milner, 1975; Prigatano, 1978; Quadfasel & Pruyser, 1955) have reported, from studies of groups with lesions known to produce memory deficits, discrepancy scores of 12 points, 10 points, and 11 points, respectively. Zaidel and Sperry (1974) reported a WMS discrepancy score of nearly 12 points in a group of patients with known short-term memory impairments secondary to hippocampal commissurotomy. This places the average discrepancy score for the closed head injury group in the present study (9.33) to be close to those groups with known memory producing lesions. The discrepancy of the localized trauma group and the unimpaired psychiatric control group were
1.5 and 2.0 points, respectively. They do not approach the level of WMS discrepancy required for defined memory impairment as suggested by the previous authors and further confirm the overall tenant of the present study.

The findings of the present study have some important implications for clinical assessment of brain dysfunction following closed head injury. Although the population of closed head injured subjects used in the present study were not selected on the basis of known memory dysfunction, they manifested a distinct tendency to resemble memory impaired groups on the WMS discrepancy score measure. This was true of the present closed head injury population despite the fact that it contained a substantial percentage of "mild" head injuries as defined by length of coma. Clinical neuropsychologists cannot afford to ignore the dimension of relative short-term memory impairment, especially when evaluating closed head injury. This implies that an absence of a memory measure, which could be used to contrast with intelligence and neuropsychological findings, would jeopardize the applicability of neuropsychological battery findings. The present study does not imply that only the WMS be used as a measure of short-term memory. Rather, it would suggest that an instrument be developed or used which requires rapid assimilation of new information. Also, the information to be assimilated should vary according to modality and complexity.

One interpretive danger to the present study consists of the fact that it has failed to control for the amount of time following injury. Although most of the subjects in the present study are past
the 6 months critical period of restitution (Mandleberg, 1975), it should be recognized that a very few individuals with less severe closed head injuries had relatively recent injuries which would tend to emphasize abnormally low WMS in those groups who were still recovering function.

Recommendations

The following recommendations include suggestions for both further research and clinical practice. Initially some points will be discussed which may have some importance for further research and then a general discussion of the relationship of the present findings to clinical practice will be offered.

Future research should be aimed at avoiding methodological weaknesses in the present study as well as being directed toward extending the understanding of the WMS discrepancy score. A criticism of the present study might be a failure to control in an exacting way for the site, location, and severity of lesion in the localized lesion group. The availability of more definitive data which describes the exact site and location of lesions in this group would have provided valuable additional data regarding the impact of those specific lesion sites on the discrepancy score. It is possible that a different magnitude of WMS discrepancy score will occur in right sided as opposed to left sided lesions. Also, there may be further relationships between the exact localization of these lesions within a functional territory of the cortex and the discrepancy score. For example, temporal lobe lesions could be compared with frontal or
posterior lobe lesions in a way that furthers the understanding of ways in which some localized lesions might be more similar to closed head injury or diffuse lesions in terms of discrepancy scores and memory deficits. Such research obviously requires the availability of large numbers of patients on whom data can be gathered in a highly systematic and ongoing fashion. This approach, however, appears to be indispensable for highly specific research involving the clinical correlates of brain lesions.

It would be important to investigate the discrepancy score on subjects with known levels of premorbid functioning. This could provide a description of the relative deficits on the WMS performance or an increase in the WMS discrepancy score following any specific lesion type. Again, it requires data collection which is specific and concurrent rather than a post hoc analysis.

The present study found rather conclusive evidence that severity of closed head injury as defined by length of coma correlates highly with WMS discrepancy score. That is, as length of coma increases, so does relative WMS discrepancy score. It would be a substantial clinical benefit to record specific length of coma or posttraumatic amnesia such as number of days and to relate increasing length of coma to WMS discrepancy. While the effects of generally worsening WMS performance with increasing severity of head injuries has been documented by Mandleberg and Brooks (1975), it will be important to know if there are specific benchmarks in terms of length of coma or posttraumatic amnesia which cause greater corresponding increases in WMS discrepancy. The current suggestion of coma state lasting 5 days
or more as an indicator of severity producing memory results certainly seems to be established.

It would be important for further research to aim at the understanding of the relationship between closed head injuries and the most severe types of localized lesion. Overall, the localized lesion group and the closed head injury group were dissimilar for purposes of the WMS score and the WMS discrepancy score. At the same time, many localized lesion individuals showed very poor WMS performance. This may suggest that, as localized lesions become more involved, they more closely resemble closed head injury in terms of memory performance. A similarity in performance on the WMS discrepancy score between closed head injury and more severe localized lesions would not only be an important clinical finding but also would be theoretically important for understanding the sufficient pathophysiological causes of memory impairment.

This study continues to be heuristic in supporting the notion that a fluid verbal factor is present and may be in fact measurable by such tests as the WMS. While the concept of fluid as opposed to crystallized abilities in both verbal and visually based skills has long been theorized, the concept has been most recently applied in test construction by Kaufman and Kaufman (1983). The effects of closed head injuries on fluid and crystallized intelligence deserve further study.

In addition to these more general research suggestions, specific research ideas are generated by the findings in the study. The WMS discrepancy score has been shown to be psychometrically
associated with closed head injury. It would enhance the WMS discrepancy score concept and allow more specific clinical description if modality specific comparisons between the WMS and WAIS could also be made. For example, the WAIS verbal IQ score could be contrasted with the paired associates or logical memory subtests. Similarly, figural memory could be contrasted with the WAIS performance IQ score. Such a study might provide both a visual and verbal memory discrepancy score. This could provide an index of "fluid" and "crystallized" abilities in both visual and verbal spheres and provide important additional information in the context of a neuropsychological assessment. To best carry out such a research project, the exact locus of lesion should be specified in control groups. In this way, more specific comparisons can be made regarding the effect of lesions on discrepancy scores.

An immediate problem which needs to be solved if WMS discrepancy scores are to be useful is the problem of establishing WMS and WAIS-Revised Form (WAIS-R) comparisons. As discussed, the WAIS-R understates IQ level in comparison to the older WAIS. A more broad study of WAIS-R/WMS differences would provide descriptive information about comparisons between the WAIS-R and WMS in different populations, but more importantly it would help establish a new WMS discrepancy score "benchmark" so that the WMS could more predictably be used with the newer version, the WAIS-R.

The current study focuses almost entirely on short-term memory processes. In light of the current findings it would be beneficial to investigate the discrepancy effect utilizing recent memory, or
even longer periods of retention. In such a study, WAIS-R performance could be contrasted with short-term memory and then, in turn, contrasted with memory requiring retention of 30 minutes or more. This would carry the benefit of measuring more pure memory functions in addition to performance skills requiring attention and arousal. E. W. Russell's (1979) multiple scoring system utilizing the WMS would lend itself nicely to such an investigation.

Many computer software programs are currently marketed to offer cognitive retraining that is claimed to improve memory capabilities in the head injured patient. The WMS discrepancy could be used in a test-retest fashion to investigate whether true short-term memory gains are occurring or whether improved memory performance is really an aspect of more general cognitive improvement. This study emphasizes the problem of short-term memory in the closed head injured, and more specific evaluations of the conditions of "true" memory improvement in this group are required.

The present study was unconvincing in regard to WMS discrepancy scores and their correlation with neuropsychological outcomes. It is likely that the extreme diversity of neuropsychological subtests which contribute to global impairment ratings will not have a predictable relationship to the WMS discrepancy score. It would remain desirable to be able to use the WMS discrepancy score in conjunction with neuropsychological indicators to estimate diffuse or severe dysfunction. Such comparisons could be made possible by research which investigates the relationship between the WMS discrepancy score and those neuropsychological subtests which require integrative
ability. Specifically, on the Halstead-Reitan Battery, the Categories Test and the Trails (b) Test might be used in concert with the WMS discrepancy score as a marker of diffuse head injury. Again, this research would be most valuable if such inter-test comparisons are made utilizing the strictest control possible over the type of lesions which comprise comparison groups. Such specific comparison of lesion types will be most important in future research aimed at understanding the complex interactions of neuropsychological assessment instruments.

In terms of clinically relevant indications from the present studies, it clearly shows that clinicians should be very aware of verbal processing deficits in cases of closed head injury. Moreover, this is even true in cases where a normal verbal intelligence score is obtained. That is, the rather regular deficiencies on the WMS (even with its strong component of audio-verbal processing) suggests that deficits in verbal or auditory learning may exist as hidden features which significantly compound the treatment and rehabilitation of the diffusely involved closed head injury patient. Specifically, the WAIS alone should not be used as an indicator of restored verbal capacity.

The study suggests that the actual treatment of the closed head injured should be oriented toward a reduction in the complexity and rate of verbal processing demands. The repetition of written language and the use of visual as well as spoken verbal messages may be used simultaneously to enhance memory traces for instructional or therapeutic purposes. The hidden deficits relative to verbal
efficiency and fluency may be responsible for a great deal of the concreteness and inflexibility and adjustment observed in closed head injury patients who have difficulty adapting even after normal verbal intelligence quotient scores are obtained.

The results of the study do not suggest that the WMS discrepancy score be used as a screening tool for organic brain dysfunction. While the score is certainly more descriptive than the WMS scale alone, it would appear that it is much too variable to be used as a reliable indicator of the presence of a lesion. This would appear to be especially true in those categories of brain dysfunction that do not involve closed head injury or diffuse dysfunction.

If a shortened screening battery for closed head injury patients were required, the WMS discrepancy score would be best used along with a global test of impairment, a test of spatial relations, and an aphasia screening tool. In this manner, intelligence, short-term memory, fluid processing capabilities, visual spatial organization, and language functions could contribute to a functional description of deficits. Such a combination of instruments still could not be used to infer the site of a lesion, however.

The WMS should probably be included in most batteries attempting to generate information relevant to rehabilitation or treatment. This is obvious due to the immediately preceding comments about hidden deficiencies in verbal fluency and acquisition. Prigatano's (1978) general criticism of the WMS as a general test of memory may still be true. However, with E. W. Russell's (1979) complex scoring system, it may still be possible to assess immediate and fluid
verbal processes as well as recent memory of up to 30 minutes. Additionally, it would be possible to gauge the type of memory difficulties which are specific to an individual or to achieve information regarding modality specific memory deficits. This approach may solve the problem of addressing fluid as opposed to crystallized verbal functions while also retaining the capability of measuring qualitative disruptions in the memory process proper and enabling the clinician to describe more specifically the type of breakdown in memory processes in the individual patient.

It is not likely that the results of the present study are strong enough to indicate that the WMS discrepancy score can be used in individual patients to describe the severity of closed head injuries. Too many factors are involved in the idiosyncratic pathological makeup of each injured patient. However, the systematic inclusion of the WMS in cases which use neuropsychological batteries or the WAIS for screening purposes might provide an additional valuable point of analysis which can be combined with other psychometric features and clinical judgment in managing the diagnosis and treatment following head injury.
APPENDIX

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