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Intelligence and the Prediction of Academic Achievement in Closed-Head Injured Adolescents and Young Adults

Murry G. Mutchnick
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Murry G. Mutchnick entitled "Intelligence and the Prediction of Academic Achievement in Closed-Head Injured Adolescents and Young Adults." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Psychology.

Leonard Handler, Major Professor

We have read this dissertation and recommend its acceptance:

Robert Wahler, Kathleen Lawler, Lawrence James

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Intelligence and the Prediction of Academic Achievement in Closed-Head Injured Adolescents and Young Adults

A Dissertation
Presented for the
Doctor of Philosophy Degree
The University of Tennessee

Murry G. Mutchnick
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DEDICATION

This dissertation is dedicated to young individuals who are challenged with life after head-injury.

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ABSTRACT

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The present study examined the relationship between intellectual, other neuropsychological variables and academic achievement in a sample of closed-head injured adolescents and young adults (N = 61). Specifically, severity of injury, crystallized ability and fluid ability were examined as to their prediction of academic achievement. Severity of injury was measured as length of post-traumatic amnesia. Crystallized ability was measured as the average of WAIS-R Information, Vocabulary and Comprehension subtests (age corrected standard scores). Fluid ability was measured as the average of WAIS-R Picture Completion, Block Design, and Object Assembly subtests (age corrected standard scores). Three mediation models are described examining the importance of crystallized and fluid variables in mediating between severity of injury and academic achievement. Crystallized ability was found to be a significant mediator as determined by a significant change in beta between the unmediated effect of PTA on achievement ([beta] = -.287; SE = .005, $p < .05$) and the mediated effect ([beta] = -.031; SE = .004, $p > .1$. Fluid ability was also found to be a significant mediator as determined by a significant change in beta between the unmediated effect of PTA on achievement ([beta] = -.287; SE = .005, $p < .05$) and the mediated effect ([beta] = -.034; SE = .004, $p > .1$. The difference score between crystallized and fluid variables failed the criteria to be considered as a significant mediator between severity of injury and academic achievement. Implications for these findings are discussed.

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CHAPTER I

INTRODUCTION

Traumatic injury is the primary cause of death in persons under age thirty-eight and is the third most common cause of death in the United States. The highest-risk age group for central nervous system damage sustained in a traumatic injury is adolescents and young adults, primarily resulting from automobile accidents. The head is injured in more than two-thirds of all automobile accidents and is the cause of death in seventy percent of the fatal cases. As one of the most critical problems facing the health care system, head-injury devastates its victims and their families with physical, psychological, and social consequences (Satz, 2001; Perrott, Taylor, & Montes, 1991; Rimel & Jane, 1983).

Given the advanced medical technology available, most victims of head-trauma survive. Thus, there are a very large number of adolescents and young adults who live with the consequences of head-injuries that may include significant functional limitations. Because these individuals were typically attending school prior to their injury, the survivor, the survivor's family and health care professionals are often faced with the question of the survivor's capability to return to school following their trauma. Research is needed to provide information as to the predicted academic success of the head-injured adolescent. Initially, this research must determine the abilities and functional integrity needed for academic behaviors such as reading, spelling, and arithmetic.

Intellectual Deficits Following Head-Trauma

There are no definitively established profiles of strengths and weaknesses of individuals who have sustained closed-head injury. However, neuropsychological assessment commonly reveals deficits in these individuals. These effects are most frequently observed as a generalized weakness resulting in a reduction in mental speed, ability to concentrate, and overall cognitive efficiency even when the measured intelligence rating may be well above average (Kolb & Whishaw, 1985). Whereas, some research shows a decline in overall, verbal and performance intelligence in adolescents following closed-head injury (Slater & Kohr, 1989), other works show that, in children and in adults, "visuospatial and visuomotor tests tended to show more impairment than verbal tests, as reflected in Wechsler Intelligence Scale scores" (Berg, 1986, p. 128).

The abilities measured by many instruments used in assessing cognitive function may be characterized by their assessment of "fluid" versus "crystallized" type abilities. Fluid and crystallized intelligence may be described in the following ways:

1. Fluid intelligence, representing processes of perceiving relations, educing correlates, maintaining span of immediate awareness in reasoning, and abstracting in both speeded and unspeeded tasks of a relatively culture-fair kind but involving figural, symbolic, and semantic content.
2. Crystallized intelligence, representing similar processes of perceiving relations, educing correlates, etc., in speeded and unspeeded tasks involving various kinds of content, but tasks requiring considerable pre-training to

acquire techniques representing the accumulated wisdom of a culture. (Horn & Cattell, 1966, p. 268)

Crystallized ability seems much more dependent on over-learned, well established cognitive functions and relates to mental achievements. Fluid abilities, in contrast, relate to adaptation, new learning, and mental operations and processes (Sattler, 1992). Performance on certain neuropsychological and intelligence tests, such as the WAIS-R Vocabulary subtest, depends very much on the prior experience of the individual. Performance on other tests, such as the Block Design subtest, depends very little on the prior learning of the individual. Tests like the Block Design subtest require the ability to learn novel information that is fairly task specific. Factor analytic studies (Corrigan & Hinkeldey, 1988; Earnst, Warner, Hochberg, & Townes, 1988; Konold, Kush & Canivez, 1997; Newby, Hallenbeck & Emberson, 1983; Sattler, 1992; Swiercinsky & Howard, 1982) involving the Wechsler intelligence scales (Wechsler, 1955, 1981, 1991) empirically demonstrate separation between subtests of intelligence in a variety of normal and impaired (e.g. learning disabled and brain injured) populations of various ages. Though more than two factors may be identified, factor loadings across studies consistently show a separation of verbal achievement abilities from essentially non-verbal object manipulations, visual-spatial problem solving, memory/freedom from distractibility and processing speed skills. These two factors may be identified as representing crystallized and fluid abilities, respectively.

Sattler (1992) discussed how crystallized and fluid abilities differ in their relation to brain function changes:

> Fluid intelligence is more dependent on the physiological structures… that support intellectual behavior than is crystallized intelligence. Fluid intelligence increases until some time during adolescence, when it plateaus; it then begins to decline because of the gradual degeneration of physiological structures. Fluid intelligence is also more sensitive to the effects of brain injury. (p.48)

Cullum, Steinman, and Bigler (1983) discussed the importance of conceptualizing abilities in the brain-damaged patient in terms of fluid and crystallized. The crystallized abilities, and test which rely on them (such as IQ), may be relatively unaffected by neurological damage. Age and time since injury seem to be significant factors in predicting the crystallized (or verbal), and fluid (or performance) differential. In adults, it is thought that the tasks that reveal greatest impairment following closed-head injury are those tasks that can be characterized as being of fluid abilities (Winogron, Knights, & Bawden, 1984; Bawden, Knights, & Winogron, 1985). Paniak, Silver, Finlayson, and Tuff (1992), showed severely head-injured adults to have significantly lower Performance IQ than Verbal IQ, but contend that the clinical significance (27% of the sample had PIQs lower than VIQs by 10 points or more) was of question. Parker and Rosenblum (1996) found similar results in mild head-injured adults.

Berger-Gross and Shackelford (1985) found that, in children, Performance IQ was more impaired initially (three to six months), but showed more recovery (at least one year later) than Verbal IQ. This recovery of performance-type skills was also observed in a sample of children and adolescents who sustained closed-head injury

(Filley, Cranberg, Alexander, & Hart, 1987). Beers (1992) reviewed the literature with regard to mild head injury in children in adolescents and found discrepancies in findings related to VIQ and PIQ changes following injury, including many studies that demonstrated PIQ scores *greater* than VIQ scores early in recovery.

Lezak (1995) warns against using VIQ-PIQ discrepancies to determine neuropsychological status. Her summary of an extensive body of literature describes that the averaging across subtests, even within a particular ability area, leads to loss of specificity and diagnostic information.

For a meta-analytic review of the literature regarding VIQ and PIQ differentials in head-injured adolescents, see Appendix A. This research, conducted by this author, suggests that the difference between VIQ and PIQ cannot be fully demonstrated and, at best, is a minimal difference. Further, that research describes limitations in the controlled empirical work that can be analyzed for such comparison.

Severity of Injury and Time Since Injury

Neuropsychological test performance may vary greatly among individuals who sustain head-trauma. There are factors that are identified to account for much of this inter-patient variability in cognitive test performance, though there remains controversy regarding their individual contribution to prediction. Two of these factors are severity, as measured by either the duration of coma or post-traumatic amnesia (PTA), and time since injury (Long & Webb, 1983). Level of coma has also been shown to be a predictor of cognitive, emotional, and hyper-arousal levels following traumatic brain injury in adults (Rapoport, McCauley, Levin, Song, & Feinstein, 2002). Functional outcome has also been predicted by coma duration in head-injured children and teenagers (Stover & Zeiger, 1976). When considering the relationship between neuropsychological tests and academic achievement, one must consider how severity and the time since injury influence test performance.

There is considerable controversy as to the use of coma duration in understanding cognitive outcome from head-trauma. Coma duration seems to be useful to the physician in his/her judgments regarding “medical” outcome. To the psychologist, however, the relationship of coma duration and cognitive and emotional sequelae is not clearly understood. The reliability of reported coma is often problematic to the psychologist; patients often report coma duration as secondarily gained information from family members or medical staff.

Post-traumatic amnesia (PTA) is a period following head injury during which a patient cannot consolidate, or store recent events over time. These individuals revealed significantly impaired memory test performance and general disorientation. PTA duration of greater than twenty-four hours is indicative of some permanent impairment in the patient (Russell, 1932). PTA is thought to be a more accurate predictor of the time required for the patient to return to work (Long & Webb, 1983). Based on the work of Russell (1932), Ruesch (1944) and Tooth (1947), Long and Webb suggest four severity groups based on post-traumatic amnesia: Mild, PTA from zero to one hour; Moderate, PTA from one to twenty-four hours; Severe, PTA from one to seven days; and Very Severe, PTA of seven days or greater.

Though coma and post-traumatic amnesia are commonly used, and have an important function in the determination of the severity of injury the reliability of these measurements remains largely undetermined.

Brain-injured individuals generally reveal some form of cognitive recovery. Long and Webb (1983) propose that this recovery typically is dramatic initially and then becomes less rapid during the "chronic phase" of recovery (see Figure 1). In the early stages of recovery from head injury, a patient may regain consciousness at some level. Then, the memory loss associated with post-traumatic amnesia becomes apparent. At approximately this time of initial recovery, which is during or following PTA, the patient is often discharged from the acute medical setting barring no further medical complications. However, the patient may, and likely does, continue to reveal cognitive dysfunction following PTA. It is during these later stages of recovery, continuing to approximately two years following the injury, that an individual continues to recover from cognitive deficits as well as possible post-concussion symptoms (fatigue, dizziness, lowered frustration tolerance, headaches, etc.).

The course of cognitive recovery seems to vary with regard to various abilities. For example, verbal, or crystallized oriented tasks are more stable with brain injury, are not as sensitive to the effects of trauma, as are more performance, or fluid, oriented abilities. The more crystallized abilities recover more rapidly than do fluid abilities. Thus, a "medically stable" patient is not necessarily ready to resume pre-morbid responsibilities due to neuropsychological factors and their difficulties may be psychogenic and/or neurogenic.

Measurement of Academic Success

The majority of investigations examining academic success describe the relationship between a score on a cognitive test and academic success, defined by

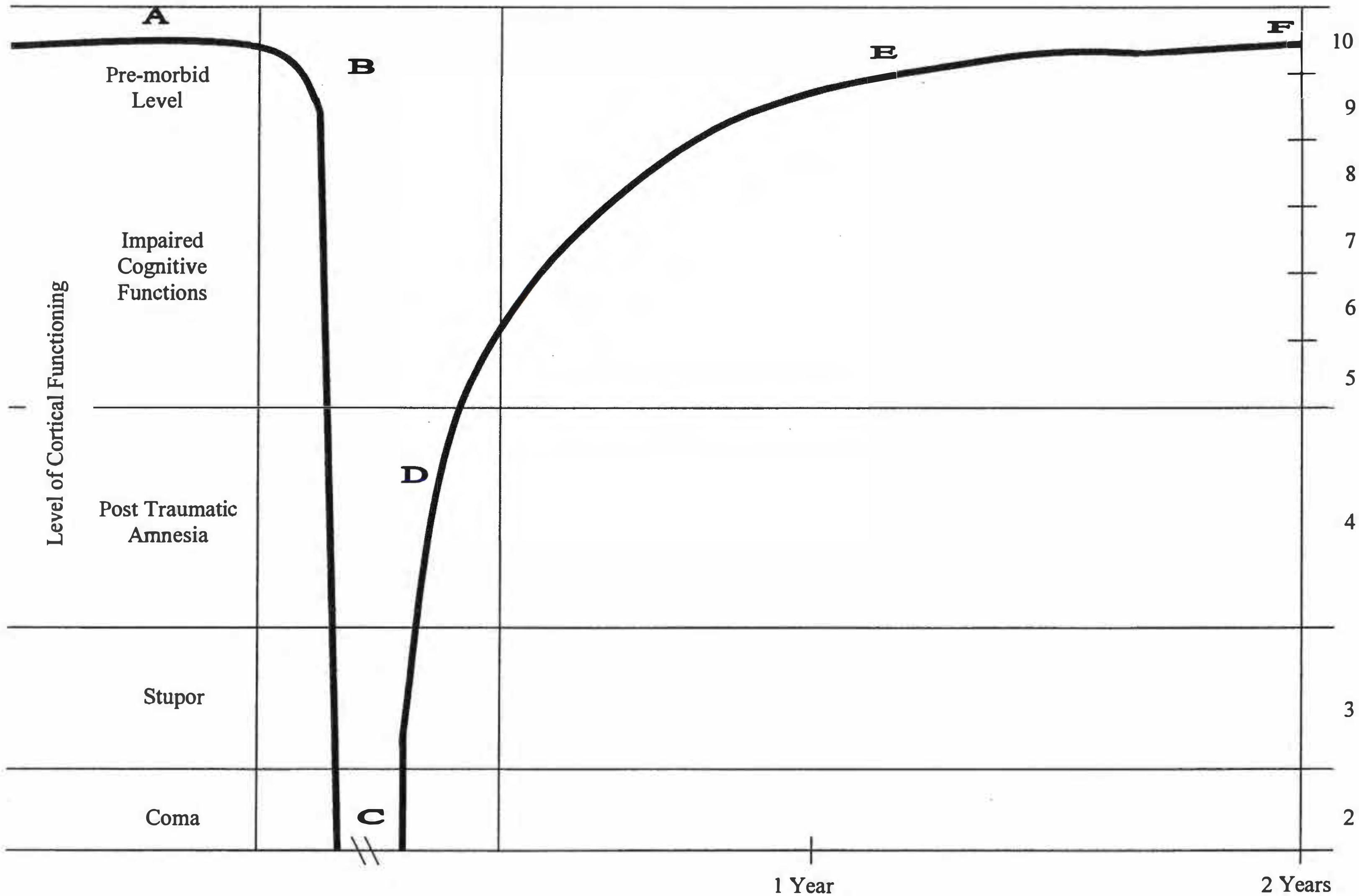

Figure 1. Head injury recovery curve (Long and Webb, 1983). Level of cortical functioning as a function of time since head trauma: (A) premorbid level, (B) retrograde amnesia, (C) coma, (D) post-traumatic amnesia, (E) recovery of cognitive functions, and (F) final level of recovery.

achievement test scores (Applebaum & Tuma, 1982; Hale & Foltz, 1982; Reschly & Reschly, 1979; Rourke & Finlayson, 1978; Stevenson & Newman, 1986). However, some studies employ more observable behaviors of a student that are thought to be indicative of academic success. Examples of this "behavioral" approach to the definition of success involve teacher ratings of social competence, social compliance, cognitive compliance, motivation, self-concept, and anxiety and peer ratings of compliance, intrusiveness, dullness and friendliness (Greenwald, Harder & Fisher, 1982; Stevens & Pihl, 1982). Other studies use grades achieved in particular courses or overall grades as a dependent measure of choice (Dhaliwal & Sharma, 1976; Kundu, 1975; Pentecoste & Lowe, 1977; Troutman, 1978). More recent research, striving for more comprehensive assessment of academic success, included, but was not limited to, behavioral rating scales, counselor ratings; student involvement in school societies, etc.; disciplinary action taken against the student; grade-point average (Lambert, 1972; Light, et al. 1998).

It can be seen from the research that determining or measuring academic success is difficult and results in little agreement among investigators. Measuring performance in the school setting involves subjective factors that encompass grades, social behavior, etc., and makes the need for standardized assessment apparent. Researchers who examine standardized achievement test results bypass much of the subjectivity that accompanies grade assignment or other measurements. However, these scores may have limited generalizability to the actual school setting. The many aspects of academic performance may need to be examined individually before complex interactions can be further determined.

Academic Performance of the Traumatically Brain Injured

Intellectual dysfunction following head injury seems to lead to poor academic performance in many individuals, as compared to their peers (Slater & Kohr, 1989). There are many problems that head-injured children may experience in the educational setting:

> Children who experience head injury are at greater risk for intellectual impairment, behavioral disorders, and emotional adjustment difficulties. These children often require special educational services. Sometimes parents and teachers may not be aware of the neuropsychological sequelae of a head injury.... Recent changes in academic functioning, behavioral patterns, or emotional adjustment should be reason enough to investigate the possibility that head injury has occurred. (Franzen & Berg, 1989, p. 32)

Filley, Cranberg, Alexander, and Hart (1987) support Franzen and Berg's observations in finding that children and adolescents demonstrated reading, spelling and arithmetic deficits following closed head injury. Berger-Gross and Shackelford (1985) demonstrated that children who have sustained head injury had significantly more difficulties in arithmetic than in reading or spelling, unaffected by intelligence of time-in-coma variables. As a somewhat contrast to the views previously mentioned, Satz, Zaucha, McCleary, Light, Arsanow and Becker (1997), following a comprehensive review of the literature pertaining to mild head injury in children, found that there were none to minimal effects on academic and psychosocial outcomes.

Intelligence and Academic Achievement

The relationship of intelligence test results to achievement test results is a strong one. In attempts to understand the relationship between the intelligence test performance and academic performance, Applebaum and Tuma (1982) examined psychiatrically hospitalized adolescents using the Wechsler intelligence Scale for Children-Revised (WISC-R) and the Peabody Individual Achievement test (PIAT). Correlations of these measures indicated that Verbal and Full Scale IQs (FSIQs) are significantly related to all PIAT measures, with Verbal IQ being the best predictor of achievement. More achievement subtests were strongly correlated with Verbal IQ compared to their correlations with Performance IQ in this non-neurologically-impaired population.

Intercorrelations between the WAIS Full Scale IQ and the WRAT subtests range from .82 to .87. Generally, Verbal subtest correlations are higher than Performance subtest correlations with achievement scores (means = .66 and .51 respectively; Jastak and Jastak, 1978; see Table 1). Jastak and Jastak (1965) pointed out, "Comprehension and reasoning tests of the WISC and WAIS tend to be less highly correlated with the WRAT subtests than the more reconstructive subtests of vocabulary, information, digit span, and coding (p. 19)." WISC-R summary score and the WRAT subtest correlations were found to range from .39 to .65 and were all significantly different from zero ($p<.001$; Wright, 1987). In individuals with psychiatric complaints (including some with histories of head injury and/or substance abuse), referred for neuropsychological testing, the WAIS-R FSIQ and WRAT scores were significantly correlated ($p<.001$; Warner, Ernst, Townes, Peel, and Preston,

Table 1

Correlations Between WRAT Reading Standard Scores and WAIS Scaled Scores (Jastak & Jastak, 1978)

WAIS Subtest	Reading		Spelling		Arithmetic	
	Males	Females	Males	Females	Males	Females
Information	.80	.74	.76	.73	.74	.71
Comprehension	.57	.64	.53	.59	.55	.59
Arithmetic	.66	.68	.66	.69	.74	.72
Similarities	.59	.66	.55	.59	.55	.65
Digit Span	.62	.61	.61	.58	.55	.50
Vocabulary (Short)	.79	.83	.75	.78	.68	.72
Digit Symbol	.55	.53	.59	.56	.66	.54
Picture Completion	.49	.57	.43	.49	.48	.58
Block Design	.58	.59	.58	.55	.66	.65
Picture Arrangement	.41	.49	.40	.43	.46	.54
Object Assembly	.37	.45	.36	.37	.44	.42

1987). These correlations were .67 for Reading, .44 for Spelling, and .72 for Arithmetic subtests. Upon replication, the correlations were .62, .69 and .70 respectively. With regard to moderate and severely injured adolescents, Butterbaugh, Roochvarg, Slater-Rusonis, Miranda, and Heald (1993) reported findings that demonstrate the importance of time since injury when understanding the relationship of intelligence and achievement in this population. They revealed that severely brain impaired adolescents performed significantly worse than controls on PIQ, VIQ, FSIQ, WRAT-R Reading, Spelling, and Arithmetic at one month post injury, but only performed worse on VIQ and WRAT-R Reading at 18 months post injury. The moderately impaired group in this study performed worse than controls on PIQ and FSIQ at one month following their injuries, but did not differ from either the severely injured group or the controls on other measures at both time points post injury. There is further published support that suggests the association between "fluid" abilities and academic performance is dependent on time since injury in children (Chadwick, Rutter, Brown, Shaffer, & Traub, 1981). Other research examined effects of lateralized damage on academic skills in children, and found language skills, specifically reading, more sensitive to left hemisphere damage (Barnes, Dennis, & Wilkinson, 1999).

Full Scale IQ scores are composite measures and may not adequately represent the strengths and weaknesses revealed through subtest analysis as well as analysis of other tests of cognitive functions. Particular subtests may be sensitive to the effects of head trauma and may offer explanation of academic performance in this population. In addition, other neuropsychological data may be important in understanding academic achievement.

Neuropsychology and Academic Achievement

Following traumatic brain injury, it is believed that the student's pre-morbid cognitive and academic abilities, the available financial and social supportive resources, the availability of specialized academic re-entry or individualized assistance, his/her general psychological adjustment, and emotional factors, such as the motivation of the student, may be only some of the non-organic variables thought to relate to the head-injured student's success in academic performance (see Figure 2). The importance of pre-morbid functioning, for example, seems crucial in understanding possible changes following trauma. Haas, Cope and Hall (1987) reported that up to fifty-percent of a sample of eighty severely head-injured patients showed poor pre-morbid academic performance (as measured by multiple failed subjects, diagnosis of learning disability or school dropout). The first step to understanding or predicting a student's behavior, however, may be to gain a more complete, or comprehensive understanding of the cognitive status of that individual. Attempting to identify and understand all of the possible factors that influence success in the school setting can be a very timely and complex task. In addition, the neuropsychologist must make decisions concerning a head-trauma victim's school re-entry based primarily, if not solely, on cognitive test results. Many intelligence tests, such as the WISC-R, do measure a wide range of abilities and will usually reflect impairment sustained from brain injury (Rutter, Chadwick & Shaffer, 1983). However, Chadwick, Rutter, Shaffer and Strout (1981) described how tests concerned

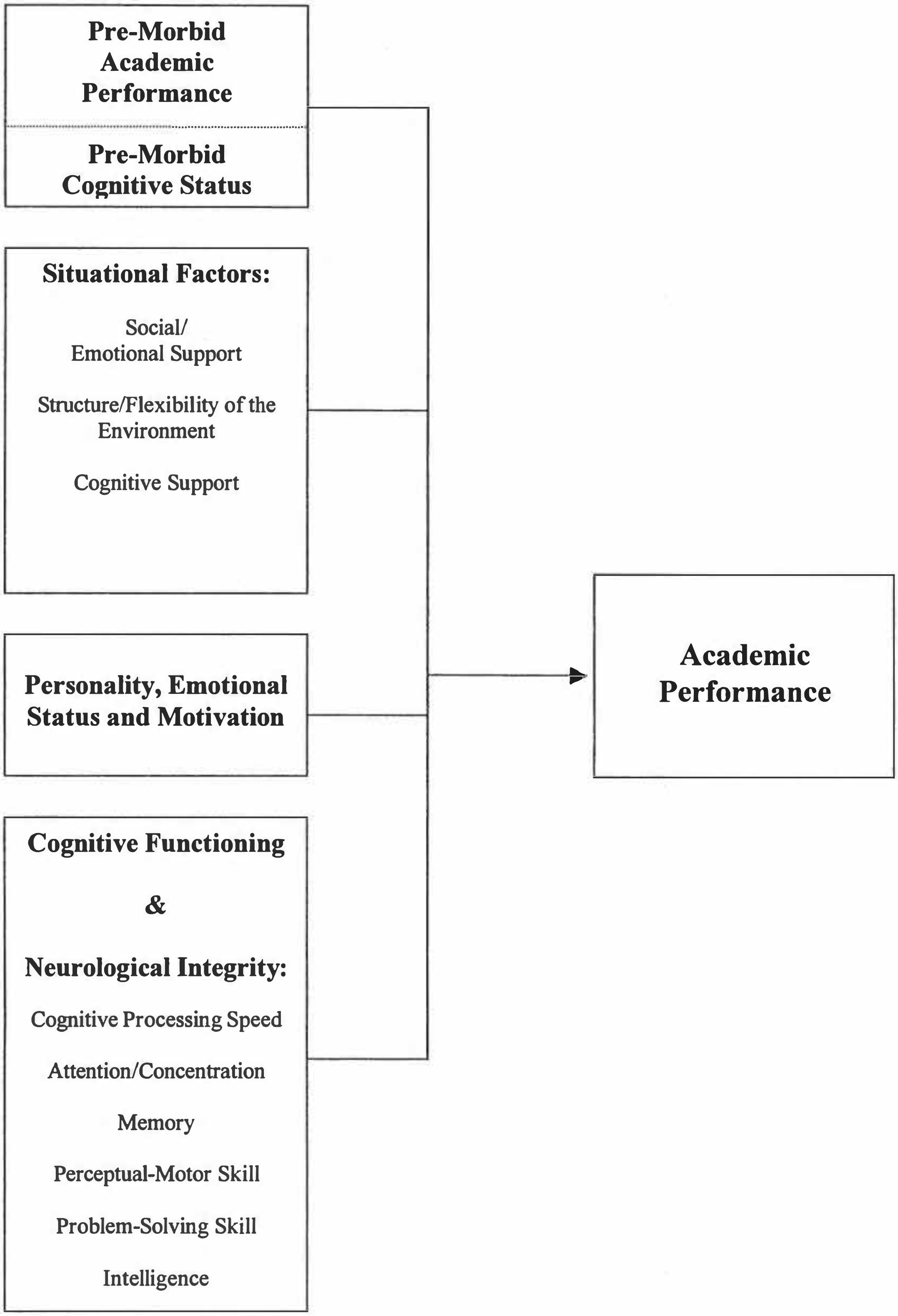

Figure 2. Diagram outlining the factors that may relate to academic achievement in head-injured patients.

with speed of visuomotor or visuospatial functioning do allow for the identification of deficits in head-injured children who have normal intelligence scores. Ewing-Cobbs and Fletcher (1987) stated, "Intelligence tests are often more sensitive to the behavioral effects of brain injury. However, these procedures do not evaluate all aspects of a child's cognitive functioning. For example, the WISC-R provides a limited and largely indirect assessment of memory and attention skills, which are frequently impaired in head-injured children. Therefore, it is not surprising that the use of intelligence tests with brain-injured children is often unfair and may prevent entry into necessary special education classes" (pp. 529-530). The wide acceptance of intelligence tests, specifically the Wechsler intelligence scales, may relate to their availability and resulting over emphasis in certain settings. Broader assessment, including neuropsychological evaluation, is needed in the educational planning with head-injured children (Ewing-Cobbs & Fletcher, 1987). Cullum, Steinman, and Bigler (1983) indicate the importance of utilizing other neuropsychological tests that measure fluid abilities to better predict a patient's "functional" IQ, as compared to an actual measured IQ score. Those authors described the case of a thirty-five year old, Ph.D. college professor who suffered a severe closed-head injury in a motor vehicle accident. This patient reported to be unable to lecture due to being unable to keep his thoughts organized. However, his IQ scores were as follows: VIQ = 143, PIQ = 117, and FSIQ = 134. The authors continue to describe the significance of using "other" fluid based tests, such as the Halstead Category Test (HCT):

> Despite the intactness of his IQ scores, granted the significant VIQ-PIQ difference, his HCT error score was 84 – well into the impaired range…from

> the obtained HCT score, we would have predicted a PIQ of approximately 87. In evaluating the cognitive status of this patient, the predicted PIQ of 87 from his distinctly impaired HCT error performance of 84 is certainly more in line with his actual deficit in ability. (pp.173-174)

Other Developmental Considerations

There are difficulties when examining the effects of head injury on individuals of specific developmental stages. One of these difficulties seems to be the large variance in how researchers study the relationship of age to neuropsychological outcome. Many studies report the examination of children, which may include adolescents (i.e., 9 to 13 yr. olds), or describe adults while including adolescents, etc. This may be a problem while considering the possible developmental considerations that may be lost when combining groups. Satz, et al. (1997) hypothesize that the varying findings across chronology may have a developmental basis:

> Children differ from adults in aspects of life experience that may produce a different impact on the course of recovery following mild head injury. Because children live in dependent circumstances, they, in contrast to adults, have yet to experience many of the personal adversities, as well as successes, that may later moderate one's recovery course after mild head injury. (pp. 128-129)

Ewing-Cobbs, Levin, Eisenberg, and Fletcher (1987) suggest that their observation, of written language being more affected in younger head-injured children, may relate to the hypothesis that the neuropsychological skills that are rapidly developing are more sensitive to the affect of neurological insult than those that are well consolidated.

Other Neuropsychological Data and Head-Injured Adolescents

Appendix B presents a brief review of the literature on other neuropsychological data and head injury in adolescents.

Ecological and Treatment Considerations

There is quite an array of reported consequences of head trauma on the student who returns to school following such an injury. These consequences have been described as behavioral/conduct problems, poor academic performance, interpersonal adjustment difficulties, personality changes, learning difficulties, language deficiencies, impairment in motor, memory and attention, poor judgment, unrealistic expectations and perception of self, and very variable performance across time and between ability areas (Blosser & DePompei, 1989; Light, Asarnow, Satz, Zaucha, McCleary, C., & Lewis, R., 1998; Telzrow, C.; 1987).

The unique deficits, strengths, perceptions, awareness and abrupt and continuing changes of the head-injured adolescent require unique considerations and services upon their re-entry into school. Though these students possess characteristics of other learning disabled children, mentally retarded children, or children with other handicapping conditions, they are in need of specific and specialized responses from the educational system (Blosser & DePompei, 1989; Ewing-Cobbs, Fletcher, & Levin, 1986; Savage, 1987). Savage (1987) suggests that several areas be addressed as the student returns to the secondary education environment, including: involving the school and the hospital in the transition from one to the other; in-service training of school staff regarding head injury; a team approach by school personnel; integration of cognitive, affective and psychomotor domains to address the students needs; careful educational placement (needs are not met in placements designed for learning disabled, mentally retarded or emotionally disturbed children); understanding the common problems of head-injured students including poor attention and concentration, memory and learning difficulties, problems with organizing, abstracting, adapting thinking, exhibition of high levels of frustration, irritability, inappropriate behaviors and difficulty re-associating with peers; use of teaching methods that focus on cognitive processing as skills are learned, and on teacher-student interaction; and a projection of needs on a long-term basis.

The Mediation Model

Baron and Kenny (1986) describe a procedure by which variables can be tested as mediators between two other variables, if there are significant relationships between the three. Thus, a predictor variable is related to a dependent measure and the predicted variable is related to a mediating variable. If the relationship between the predictor and the dependent measure is significantly weakened when controlling for the mediator, then effective mediation is thought to occur. These authors conceptually describe, "For research oriented toward psychological levels of explanation (i.e., where the individual is the relevant unit of analysis), mediators represent properties of the person that transform the predictor or input variables in some way" (p. 1178). While this technique was originally devised for research in social psychology, its application to neuropsychological constructs seems of important benefit. According to Baron and Kenny (1986), a model can be tested for mediation if the independent variable and the mediator variables are significantly related to the dependent variable and the independent variable is significantly related to the mediator variable. A mediator is considered influential if it significantly weakens the relationship between the independent and dependent variables.

Objectives of the Current Study

Little, and somewhat inconclusive research has been conducted attempting to understand factors relevant to the academic achievement test performance of head-injured individuals. This seems particularly of concern since the most frequently head-injured group is school-aged individuals between the ages of fifteen and twenty-four.

The current study attempts to determine the relationship between neuropsychological data and academic achievement. More specifically, variables related to head injury, including cognitive test variables will be examined for their predictive power. The relationships established here may facilitate understanding of the basic cognitive skills related to the complex behaviors involved in reading, spelling and arithmetic performance in this population.

It is hypothesized that while severity of injury, time since injury, tests of crystallized abilities and tests of fluid abilities will be related to academic achievement following head injury, tests of crystallized and fluid abilities will, separately, serve as significant mediators in that prediction. Further, a crystallized-fluid difference score is also thought to be significant mediator between the severity of injury and academic achievement. Other interrelationships of variables will be explored.

CHAPTER II

METHODOLOGY

Subjects

The sample consisted of adolescents and young adults referred for neuropsychological assessment at various assessment and treatment facilities in the southeast that offer their participation in this research. Inclusion criteria includes history of closed-head trauma, including those individuals sustaining skull fracture, hematoma or other surgically treated problems secondary to the injury, age sixteen to twenty-three years. This age population is chosen as they are routinely administered the WAIS-R and are typically of high school and college age. Patients without academic achievement test results or IQ subtest scores were excluded. One subject was excluded due to missing the age variable. The sample consisted of sixty-one individuals. The demographics for this sample may be seen in Table 2.

Procedure

Tests of crystallized and fluid abilities were selected from previously published factor analytic studies (Corrigan & Hinkeldey, 1988; Earnst, Warner, Hochberg, and Townes, 1988; Newby, Hallenbeck and Emberson, 1983; and Swiercinsky and Howard, 1982), which demonstrate consistent separation of the subtests. The tests designated as measuring crystallized ability include WAIS-R Vocabulary, Comprehension, and Information subtests. The tests designated as fluid ability tests include WAIS-R Block Design, Picture Completion and Object

Table 2

Descriptive Statistics of Select Demographic Characteristics for the Sample (N=6)

Age		Sex		Education		Nature of Injury	
Mean	SD	% Males	% Females	Mean	SD	% MVA	% Other
19.84	2.29	56	44	12.03	2.02	59	41

Assembly subtests. Age corrected standard scores of the intelligence subtests were averaged based on the groupings as indicated above: Crystallized = (WAIS-R Information + Vocabulary + Comprehension)/3; Fluid = (WAIS-R Picture Completion + Block Design + Object Assembly)/3. Severity of injury was identified by post-traumatic amnesia (PTA) hours. Time since injury was identified by number of days from date of injury to date of testing. Crystallized abilities, fluid abilities, severity of injury, and time since injury served as independent measures in subsequent analyses.

The dependent variable is the average of the standard scores from the Arithmetic, Spelling, and Reading subtests of the Wide Range Achievement Test – Revised: (WRAT-R; Reading Standard Score + Spelling Standard Score + Arithmetic Standard Score)/3.

Statistical Analyses

To examine the interrelationships of selected variables, two-tailed Pearson correlations and regression analyses were conducted.

Mediation diagrams were graphed and criteria for mediation analyses were determined (Baron & Kenny, 1986). Multiple regression analyses were conducted to determine the affect of severity of injury on academic achievement after controlling for each of three variables in separate equations: crystallized ability, fluid ability, and crystallized-fluid difference in ability. In diagrams where mediation criteria were met, the significant differences of the mediated effect from the unmediated effect were determined by deriving z-scores (MacKinnon & Dwyer, 1993).

Description of Measures

Wechsler Adult Intelligence Scale – Revised (WAIS-R). This is a widely accepted measure of intelligence incorporating both "Performance" and "Verbal" scales into a "Full Scale IQ" index. Though this test is not the most recently published version of the Wechsler intelligence scales, it is commonly used currently by neuropsychologists because of the great extent of available normative data associated with this test in neurologically impaired populations. Performance subtests are identified as Picture Completion, Picture Arrangement, Block Design, Object Assembly and Digit Symbol. Verbal subtests are identified as Information, Digit Symbol, Vocabulary, Arithmetic, Comprehension, and Similarities (Wechsler, 1981).

Post-Traumatic Amnesia (PTA) Duration. Post-traumatic amnesia duration was obtained from patient interview. The period of unreliable day-to-day memory was considered to be the amnesia period. Thus, from the onset of coma to the point of continuous recollection of information following injury is PTA duration.

Time Since Injury. The date of injury was obtained from the patient, a family member or medical records. This date was then subtracted from the date of neuropsychological assessment to determine time since injury.

Wide Range Achievement Test – Revised (WRAT-R). The WRAT-R is a test designed to measure basic school subjects of reading, word recognition and pronunciation, written spelling, and arithmetic computation. (Jastak & Wilkinson, 1984).

The independent variable record form is provided in Appendix C.

The dependent variable record form is provided in Appendix D.

CHAPTER III

RESULTS

Descriptive statistics of the independent and dependent measures are provided in Table 3. The sample means are representative of very severe injury sustained and 1.8 years post injury. The difference of means between fluid abilities and crystallized abilities is found to only be approaching significance, with fluid abilities being superior (t [60] = 1.810, p = .075).

Pearson intercorrelations of select variables are provided in Table 4. These correlations reveal significant relationships among subtests within each ability area (crystallized and fluid), between ability areas, between both ability areas and all achievement areas, and between ability areas and post-traumatic amnesia. No significant correlations were found among the crystallized and fluid difference score, PTA and achievement ability areas.

No significant correlations were found between time since injury and fluid or crystallized abilities for the sample. Cases of the sample were selected for a) time since injury less than 90 days and b) time since injury less than 365 days. These intervals were selected due to the presumed high rate of recovery during those periods. Pearson intercorrelations were then examined for select variables and time since injury in these sample subsets (see Table 5). Significant relationships were found among time since injury and specific ability variables in these sub-samples.

The three mediation models are diagramed in Figures 3-5.

All three models demonstrate that severity of injury (as measured by PTA)

Table 3

Descriptive Statistics of Independent and Dependent Variables (N = 61)

Variable	Mean	SD	Minimum Obtained	Maximum Obtained	Maximum Possible
PTA Duration (hrs.)	254.52	424.09	.00	1824.00	-
Time Since Injury (days)	631.39	762.35	29.00	5236.00	-
Crystallized Ability (INF, VOC, COM)	7.92	2.60	3.00	17.33	19.00
Fluid Ability (PC, BD, OA)	8.33	2.56	2.67	13.67	19.00
Average WRAT-R	88.75	16.57	57.33	134.67	155.00

Table 4

Pearson Intercorrelations of Select Variables (N = 61)

Variable	PTA	TSI	INF	VOC	COM
PTA	-	.040	-.321*	-.361**	-.308*
TSI	.040	-	-.077	.064	.079
INF	-.321*	-.077	-	.816**	.826**
VOC	-.361**	.064	.816**	-	.821**
COM	-.308*	.079	.826**	.821**	-
PC	-.314*	.019	.469**	.505**	.518**
BD	-.384**	.148	.658**	.662**	.705**
OA	-.309*	-.061	.674**	.657**	.701**
CRYST. (INF, VOC, COM)	-.351**	.022	-	-	-
FLUID (PC, BD, OA)	-.394**	.022	.705**	.715**	.753**
DIFFERENCE SCORE (CRYST - FLUID)	.055	.000	-	-	-

*p < .05
**p < .01

Table 4

(continued)

Variable	PC	BD	OA
PTA	-.314*	-.384**	-.309*
TSI	-.019	.148	-.061
INF	.469**	.658**	.674**
VOC	.505**	.662**	.657**
COM	.518**	.705**	.701**
PC	-	.525**	.479**
BD	.525**	-	.735**
OA	.479**	.735**	-
CRYST. (INF, VOC, COM)	.530**	.719**	.722**

*$p < .05$
**$p < .01$

Table 4

(continued)

Variable	PTA	TSI	INF	VOC	COM
WRAT-R READING	-.193	-.142	.588**	.638**	.600**
WRAT-R SPELLING	-.248	-.113	.647**	.745**	.652**
WRAT-R ARITH.	-.315*	-.040	.549**	.562**	.536**
WRAT-R AVG.	-.297*	-.117	.701**	.761**	.702**

*p < .05
**p < .01

Table 4

(continued)

Variable	PC	BD	OA
WRAT-R READING	.495**	.521**	.493**
WRAT-R SPELLING	.500**	.574**	.501**
WRAT-R ARITH.	.343**	.509**	.462**
WRAT-R AVG.	.527**	.630**	.575**

*p < .05
**p < .01

Table 4

(continued)

Variable	CRYST. (INF, VOC, COM)	FLUID (PC, BD, OA)	WRAT-R READING	WRAT-R SPELLING	WRAT-R ARITH.
WRAT-R READING	.648**	.593**	-	.767**	.427**
WRAT-R SPELLING	.724**	.618**	.767**	-	.526**
WRAT-R ARITH.	.584**	.513**	.427**	.526*	-
WRAT-R AVG.	.768**	.679**	-	-	-
CRYST. (INF, VOC, COM)	-	.772**	.648**	.724**	.584**
FLUID (PC, BD, OA)	.772**	-	.593**	.618**	.513**
DIFFERENCE SCORE (CRYST. – FLUID)	-	-	.096	.174	.119

*p < .05
**p < .01

Table 5

Pearson Intercorrelations of Select Variables and Time Since Injury Sub-Samples

Variable	TSI < 90 Days (N = 8)	TSI < 365 Days (N = 28)
PTA	.239	-.026
CRYST. (INF, VOC, COM)	-.903**	-.384*
FLUID (PC, BD, OA)	-.930**	-.099
DIFFERENCE SCORE (CRYST. - FLUID)	.513	-.442*
WRAT-R AVG.	-.605	-.353

*p < .05
**p < .01

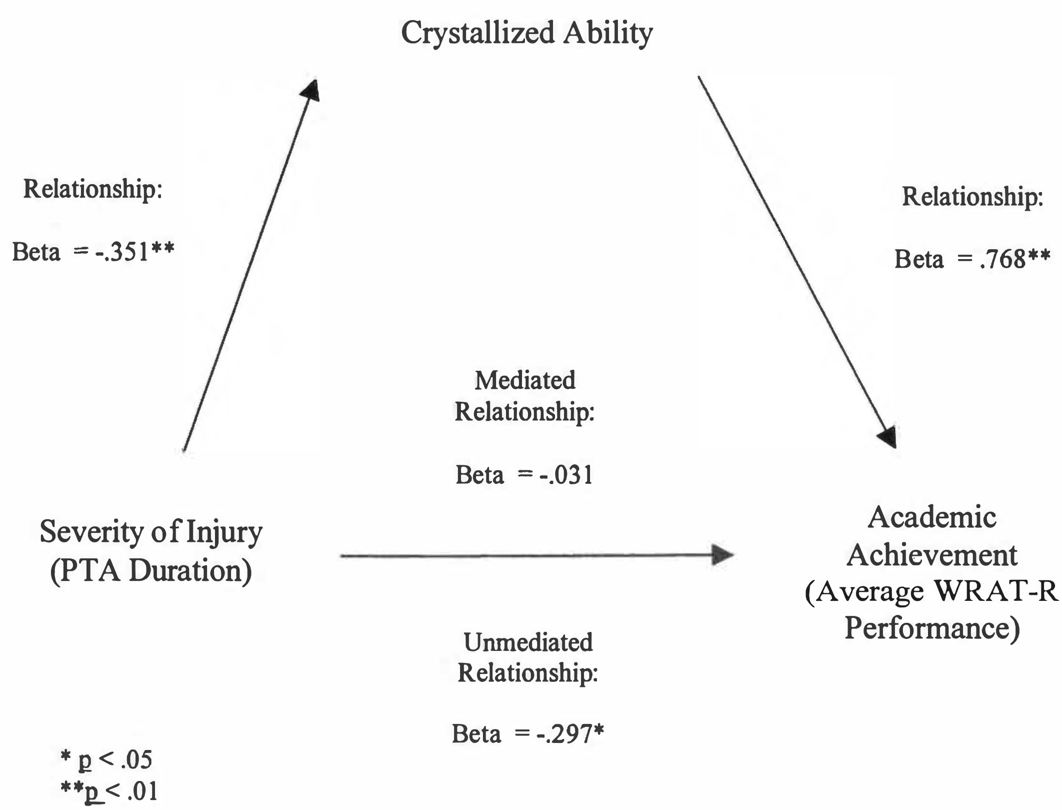

Figure 3. Diagram of the crystallized variable mediation model.

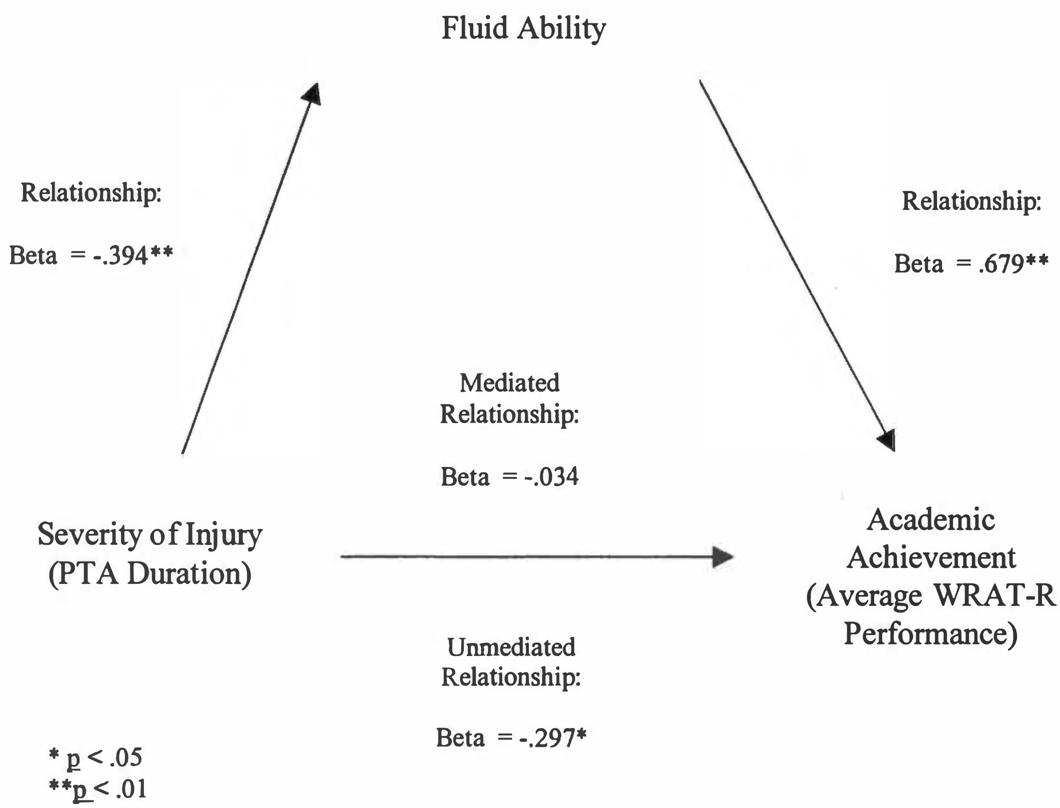

Figure 4. Diagram of the fluid variable mediation model.

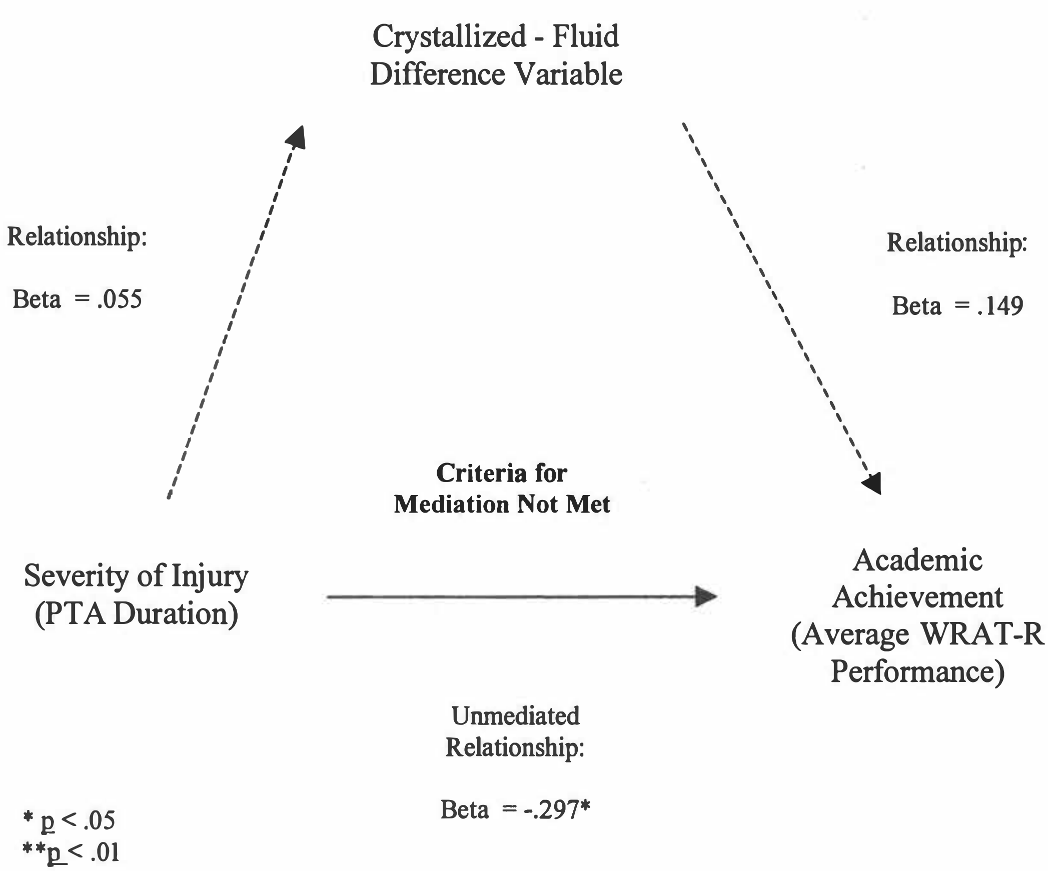

Figure 5. Diagram of the false crystallized-fluid difference variable mediation model.

was a significant predictor of academic achievement (average of WRAT-R tests), ([beta] = -.297; SE = .005, p < .05).

The first model further shows that PTA and crystallized ability are significantly related ([beta] = -.351; SE = .001, p < .01), and that crystallized ability and academic achievement are significantly related ([beta] = .768; SE = .531, p < .0001). Thus, the criteria for a mediation effect have been met. To determine the mediation effect of crystallized ability, the relationship of PTA on academic achievement, controlling for crystallized ability, was obtained and found to weaken, ([beta] = -.031; SE = .004, p>.1). The formula for testing the difference of these beta weights (MacKinnon & Dwyer, 1993) was calculated resulting in a z-score of 8.368, significantly greater than 1.96, p < .001. This indicates that crystallized ability is a significant mediator between severity of injury and academic abilities.

The second model further shows that PTA and fluid ability are significantly related ([beta] = -.394; SE = .001, p < .01), and that fluid ability and academic achievement are significantly related ([beta] = .679; SE = .618, p < .001). Thus, the criteria for a mediation effect have been met. To determine the mediation effect of fluid ability as a mediator, the relationship of PTA on academic achievement, controlling for fluid ability, was obtained and also found to weaken ([beta] = -.034; SE = .004, p > .1). The difference of beta weights was calculated resulting in a z-score of 7.685, significantly greater than 1.96, p < .001. This indicates that fluid ability is a significant mediator between severity of injury and academic abilities.

The final model further shows that PTA and the difference score between crystallized and fluid abilities are not significantly related ([beta] = .055; SE = .001, p

$> .05$), and that the difference of abilities score and academic achievement are not significantly related ([beta] = .149; SE = 1.223, $p > .05$). Thus, the criteria for a mediation effect have *not* been met. No further analysis with this model could be conducted and mediation with this variable cannot be determined.

CHAPTER IV

DISCUSSION

This research demonstrates the importance of fluid and crystallized abilities to mediate the effects of the severity of injury on academic performance in head-injured adolescents. Further, these adolescents showed an actual, though not significant, difference in their ability scores, with *fluid* being higher. This is seen as consistent with literature that emphasizes the importance of considering the developmental progress of an individual when predicting the effects of injury on ability. Clinical observation and empirical findings with adults reveal a marked particular decrease in their ability with novel, speeded and visual-spatial tasks following head injury. This may also be true with adolescents or children. However, the pre-morbid skill levels of these individuals may markedly influence their intellectual test results. Another possible explanation for the inferiority of crystallized ability following closed-head injury may relate to a pre-morbidly biased sample. Perhaps there are other variables, pre-morbid and/or injury characteristics, which are important in understanding the seemingly inconsistent changes in varying types of abilities such as crystallized and fluid abilities. It may be incorrect to state that, generally, head injury results in a meaningful, predictive crystallized (or verbal)-fluid (or non-verbal) differential. Strength and weakness patterns may depend on variables not yet identified as relevant. Additional research could focus on the pre-morbid characteristics that may influence post-morbid intellectual ability change.

Verbally mediated assessment is used to evaluate verbal information in both tests of crystallized ability and academic achievement. Simple correlations demonstrate the strong correlations of crystallized ability with WRAT-R Reading, Spelling and average achievement scores. Fluid ability, in contrast, is strongly correlated only with Spelling and average achievement scores. Future research should involve separate analysis of cognitive skills involved in arithmetic or types of arithmetic.

As support for previous findings, such as those of Butterbaugh, et al. (1996) and Chadwick, et al. (1981), the PIQ-VIQ differential seems to be relatively insignificant with milder injuries, and with more severe injuries after adequate time in recovery. Other factors, such as time lateralization of damage, age of the patient, skill level acquired at the time of injury, seem to impact how intelligence scores are revealed.

One explanation of the similarity of the crystallized and fluid ability variables in predicting achievement my lie in the measurement characteristics of the instrument used. IQ tests may not adequately capture the essence of the fluid ability construct, and may loose interpretive value from the method of averaging across unique subtests. The construct of fluid ability may be more strongly represented by other neuropsychological tests. Tests such as the Trail Making Test, the Category Test, and the Tactual Performance Test consistently relate to subtests from the WAIS-R, creating a factor identified by several researchers as fluid ability (Earnst, Warner, Hochberg, & Townes, 1988; Newby, Hallenbeck, & Emberson, 1983; Swiercinsky & Howard, 1982). However, these tests may not be as strongly correlated with crystallized ability, as fluid ability is in this sample and, therefore, may allow for greater augmentation of the explained variance in the dependent measure.

Further, fluid abilities may become impaired following head injury but may not adequately be reflected in achievement test scores. Ewing-Cobbs, Fletcher, and Levin (1986) describe these achievement test limitations with this population:

> Academic achievement test scores may overestimate the child's ability to function in the classroom. Difficulties with attention, memory, motor speed, and behavioral control will diminish the child's capacity to perform. Moreover, basic academic functions, such as reading and spelling, are often not immediately affected by closed head injury. Skills that are overlearned and automatized may show little disruption after injury. However,...reading problems may become apparent two years after the injury, reflecting the cumulative influences of the child's subtle learning difficulties. (p. 62)

The time since injury measure, surprisingly, did not correlate with other variables in the overall sample. However, when the cases of the sample were selected for time since injury less than 90 days, this variable was significantly correlated with both fluid and crystallized ability variables. When cases were selected with time since injury less than 365 days, this variable was significantly correlated with the crystallized ability variable. These time intervals suggest the periods of most rapid and dramatic recovery in typical cases, as suggested by Long and Webb (1983). Because recovery is thought to begin to plateau after approximately one year, the relatively large number of cases here that are in that plateau period my have prevented observed relationships with other variables.

The complexity of the literature, including mixed findings and the multitude of variables that may influence intelligence test results, seems to offer support of the importance of *assessment*, in contrast to test administration, in making diagnostic and prognostic decisions regarding a patient. Neuropsychological assessment, comprehensive and integrative of many test instruments and techniques, is particularly useful in separating out specific skills (with little averaging across subtests) as well as examining the emotional, personality and environmental influences on the individual. One cannot underestimate the importance of the developmental level of the patient, pre-morbid skill levels, time since injury and severity of injury. Perhaps the next step in research of the head-injured adolescent should include a more multi-variable approach to prediction of academic success. In a hypothetical example, specific variables, such as pre-morbid status, fine motor speed or anomia, early in recovery, could be predictors of specific areas of academic skills, such as writing by copy or story recall. This approach may shift the focus from intelligence, as measured by intelligence tests, to fundamental neuro-behavioral functioning related to specific tissue damage and ultimately to later school performance.

References

American Psychological Association (2002). **Retrieved September 21, 2002, fromhttp://proxy.lib.edu:2065/webspirs/changeGuideTopic.ws?topic=1.**

Applebaum, A. S., & Tuma, J. M. (1982). The relationship of the WISC-R to academic achievement in a clinical population. *Journal of Clinical Psychology, 38,* 401-405.

Bachrach, H., & Mintz, J. (1974). The Wechsler Memory Scale as a tool for the detection of mild cerebral dysfunction. *Journal of Clinical Psychology, 30,* 58-60.

Barnes, M. A., Dennis, M., & Wilkenson, M. (1999). Reading after closed head injury in childhood: Effects on accuracy, fluency, and comprehension. *Developmental Neuropsychology, 15,* 1-24.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51,* 1173-1182.

Bassett, S. S., & Slater, E. J. (1990). Neuropsychological function in adolescents sustaining mild closed head injury. *Journal of Pediatric Psychology, 15,* 225-236.

Bawden, H. N., Knights, R. M., & Winogron, H. W. (1985). Speeded performance following head injury in children. *Journal of Clinical and Experimental Neuropsychology, 7,* 39-54.

Berg, R. A. (1986). Neuropsychological effects of closed head injury in children. In J. E. Obrzut & G. W. Hynd (Eds.), *Child Neuropsychology, Volume 2: Clinical* *practice* (pp. 113-135). Orlando: Academic Press.

Beers, S.R. (1992). Cognitive effects of mild head injury in children and adolescents. *Neuropsychology Review, 3,* 281-320.

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

Berger-Gross, P., & Shackelford, M. (1985). Closed-head injury in children: Neuropsychological and scholastic outcomes. *Perceptual and Motor Skills, 61,* 254.

Binder, L. M., Rohling, M. L., & Larrabee, G. J. (1997). A review of mild head trauma. Part I: Meta-analytic review of neuropsychological studies. *Journal of Clinical and Experimental Neuropsychology, 19,* 421-431.

Blosser, J. L., DePompei, R. (1989). The head-injured student returns to school: Recognizing and treating deficits. *Topics in Language Disorders, 9,* 67-77.

Brooks, D. N. (1976). Wechsler Memory Scale performance and its relationship to brain damage after severe closed head injury. *Journal of Neurology, Neurosurgery, and Psychiatry, 39*, 593-601.

Butterbaugh, G., Roochvarg, L, Slater-Rusonis, E.,Miranda, D, & Heald, F. (1993). Academic abilities in adolescents with traumatic brain injuries: An 18-month follow-up study. *Journal of Clinical and Experimental Neuropsychology, 15,* 84-85.

Chadwick, O., Rutter, M., Brown, G., Shaffer, D., & Traub, M. (1981). A prospective study of children with head injuries: II. Cognitive sequelae. *Psychological*

Medicine, 11, 49-61.

Chadwick, O., Rutter, M., Shaffer, D., & Shrout, P. (1981). A prospective study of children with head injuries: IV. Specific cognitive deficits. *Journal of Clinical Neuropsychology, 3*, 101-120.

Chelune, G. J., & Moehle, K. A. (1986). Neuropsychological assessment and everyday functioning. In D. Wedding, A. M. Horton, Jr., & J Webster (Eds.), *The Neuropsychology handbook: Behavioral and clinical perspectives* (pp. 489-525). New York: Springer.

Corrigan, J. D. & Hinkeldey, N. S. (1988). Patterns of performance within the Halstead-Reitan Neuropsychological Test Battery. *The International Journal of Clinical Neuropsychology, 10,* 25-33.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). New York: Academic Press.

Crawford, J. R., Johnson, D. A., Mychalkiw, B., & Moore, J. W. (1997). WAIS-R performance following closed-head injury: A comparison of the clinical utility of summary IQs, factor scores, and subtest scatter indices. *The Clinical Neuropsychologist, 11,* 345-355.

Cullum, C. M., Steinman, E. R., & Bigler, E. D. (1983). Relationship between fluid and crystallized cognitive functions using Category Test and WAIS scores. *The International Journal of Clinical Neuropsychology, 6,* 172-174.

D'Amato, R. C., Gray, J. W., & Dean, R. S. (1988). A comparison between intelligence and neuropsychological functioning. *Journal of School Psychology, 26*, 283-292.

Dalby, P. R. & Obrzut, J. E. (1991). Epidemiologic characteristics and sequelae of closed head-injured children and adolescents: A review. *Developmental Neuropsychology, 7,* 35-68.

Dhaliwal, A. S. & Sharma, J. P. (1976). Relationship between intelligence and academic achievement. *Journal of Psychological Researches*, *20*, 28-32.

Dikmen, S. S., Machamer, J. E., Winn, H. R., & Temkin, N. R. (1995). Neuropsychological outcome at 1-year post head injury. *Neuropsychology, 9,* 80-90.

Dorman, C. & Laatsch, L. (1983). Prediction of spelling and reading performance in cerebral palsied adolescents using neuropsychological tests. *The International Journal of Clinical Neuropsychology*, *6*, 142-144.

Ernst, J., Warner, M. H., Hochberg, M., & Townes, B. D. (1988). Factor analysis of the Halstead-Reitan Neuropsychological Battery including the WAIS and replications using the WAIS-R. *International Journal of Clinical Neuropsychology, 10,* 103-105.

Ewing-Cobbs, L., & Fletcher, J. M. (1987). Neuropsychological assessment of head injury in children. *Journal of Learning Disabilities*, *20*, 526-535.

Ewing-Cobbs, L., Fletcher, J. M., & Levin, H. S. (1986). Neurobehavioral sequelae following head injury in children: Educational implications. *Journal of Head Trauma Rehabilitation, 1,* 57-65.

Ewing-Cobs, L. Levin, H. S., Eisenberg, H. M. & Fletcher, J. M. (1987). Language functions following closed-head injury in children and adolescents. *Journal of Clinical and Experimental Neuropsychology, 9,* 575-592.

Filley, C. M., Cranberg, L. D., Alexander, M. P., & Hart, E. J. (1987). Neurobehavioral outcome after closed head injury in childhood and adolescence. *Archives of Neurology, 44,* 194-198.

Franzen, M. & Berg, R. (1989). Screening Children for Brain Impairment. New York: Springer.

Fuld, P. A., & Fisher, P. (1977). Recovery of intellectual ability after closed head-injury. *Developmental Medicine and Child Neurology, 19,* 495-502.

Glass, G. V., McGaw, B., Smith, M. L. (1981). *Meta-Analysis In Social Research.* Beverly Hills, CA: Sage Publications.

Greenwald, D. F., Harder, D. W., & Fisher, L. (1982). WISC scatter and behavioral competence in high-risk children. *Journal of Clinical Psychology, 38,* 397-401.

Gulbrandsen, G. B. (1984). Neuropsychological sequelae of light head injuries in older children 6 months after trauma. *Journal of Clinical Neuropsychology, 6,* 257-268.

Haas, J. F., Cope, D. N., & Hall, K. (1987). Premorbid prevalence of poor academic performance in severe head injury. *Journal of Neurology, Neurosurgery, and Psychiatry, 50,* 52-56.

Hale, R. L., & Foltz, S. G. (1982). Prediction of academic achievement in handicapped adolescents using a modified form of the Luria-Nebraska Pathognomonic Scale and WISC-R Full Scale IQ. *Clinical Neuropsychology, 4,* 99-102.

Halstead, W. C. (1947). *Brain and Intelligence*. Chicago: University of Chicago Press.

Hawkins, K. A., Plehn, K., & Borgaro, S. (2002). Verbal IQ-performance IQ differentials in traumatic brain injury samples. *Archives of Clinical Neuropsychology, 17,* 49-56.

Heaton, R. K., & Pendleton, M. G. (1981). Use of neuropsychological tests to predict adult patients' everyday functioning. *Journal of Consulting and Clinical Psychology*, *49*, 807-821.

Horn, J. L., & Cattell, R. B. (1966). Age Differences in fluid and crystallized intelligence. *Acta Psychologica*, p. 628.

Horn, J. L., & Cattell, R. B. (1966b). Age differences in primary mental abilities. *Journal of Gerontology*, *21*, 210-220.

Jastak, J. F. & Jastak, S. R. (1965). *The Wide Range Achievement Test Manual of Instruction.* Wilmington, D. E: Guidance Associates.

Jastak, J. F. & Jastak, S. R. (1978). *The Wide Range Achievement Test Manual of Instructions*. Wilmington, D. E: Guidance Associates.

Jastak, J. F. & Wilkinson, G. S. (1984). *The Wide Range Achievement Test-Revised Administration Manual*. Wilmington, D. E: Guidance Associates.

Kear-Colwell, J. J. (1973). The structure of the Wechsler Memory Scale and its relationship to 'brain damage.' *British Journal of Social and Clinical Psychology*, *12*, 384-392.

Kear-Colwell, J. J., & Heller, M. (1980). The Wechsler Memory Scale and closed head injury. *Journal of Clinical Psychology*, *36*, 782-787.

Knights, R. M., & Ogilvie, R. M. (1967, June). *A comparison of test results from normal and brain damaged children.* Paper presented at the Canadian Psychological Association Meeting, Ottawa., KS.

Kolb, B., & Whishaw. I. Q. (1985). *Fundamentals of Human Neuropsychology* (2nd ed.). New York: W. H. Freeman.

Konold, T. R., Kush, J. C., & Canivez, G. L. (1997). Factor replication of the WISC-III in three independent samples of children receiving special education. *Journal of Psychoeducational Assessment, 15,* 123-137.

Kraiuhin, C., Shores, E. A., & Roberts, C. (1996). Sensitivity of the WAIS-R Verbal-Performance IQ difference and intersubtest scatter to traumatic brain injury. *Brain Injury, 10,* 677-685.

Kraus, J. F. (1980). A comparison of recent studies on the extent of the head and spinal cord injury problem in the United States. *Journal of Neurosurgery, 53,* S35-S43.

Kundu, R. (1975). In investigation into the relationship between abstract intelligence and attainments in different subjects of higher secondary course. *Journal of Psychological Researches, 19*, 71-75.

Lambert, N. M. (1972). Intellectual and nonintellectual predictors of high school status. *The Journal of Special Education, 6*, 247-259.

Levin, H. S., Eisenberg, H. M., Wigg, N. R., & Kobayashi, K. (1982). Memory and intellectual ability after head injury in children and adolescents. *Neurosurgery, 11*, 668-673.

Light, R., Asarnow, R., Satz, P., Zaucha, K., McCleary, C., & Lewis, R. (1998). Mild

Closed-head injury in children and adolescents: Behavior problems and academic outcomes. *Journal of Consulting and Clinical Psychology, 66,* 1023-1029.

Long, C. J. (1985). Neuropsychology in private practice: Its changing focus. *Psychotherapy in Private Practice*, *3*, 45-55.

Long, C. J., & Webb, W. L. (1983). Psychological sequelae of head trauma. In R. C. W. Hall (Ed.), Psychiatric Medicine (pp. 35-77). New York: SP Medical & Scientific Books.

MacKinnon, D. P., & Dwyer, J. H. (1993). Estimating mediated effects in prevention studies. *Evaluation Review, 17,* 144-158.

Matthews, C. G., Shaw, D. J., & Klove, H. (1966). Psychological test performance in neurologic and "pseudo-neurologic" subjects. *Cortex*, *2*, 244-253.

Moore, A. D., Stambrook, M, Gill, D. D., Hawryluk, G. A., Peters, L. C., & Harrison, M. M. (1993). Factor Structure of the Wechsler Adult Intelligence Scale-Revised in a traumatic brain injury sample. *Canadian Journal of Behavioral Science, 25,* 605-614.

Newby, R. F., Hallenbeck, C. E., & Embretson (1983). Confirmatory factor analysis of four general neuropsychological models with a modified Halstead-Reitan Battery. *Journal of Clinical Neuropsychology*, *5*, 115-133.

Orwin, R. G. (1983). A fail-safe *N* for effect size in meta-analysis. *Journal of Educational Statistics, 8,* 157-159.

Paniak, C. E., Silver, K., Finlayson, M. A. J., & Tuff, L. P. (1992). How useful is the WAIS-R in closed head injury assessment? *Journal of Clinical Psychology, 48,* 219-225.

Parker, R. S., & Rosenblum, A. (1996). IQ loss and emotional dysfunctions after mild head injury incurred in a motor vehicle accident. *Journal of Clinical Psychology, 52,* 32-43.

Pentecoste, J. C., & Lowe, W. F. (1977). The Quick Test as a predictive instrument for college success. *Psychological Reports*, *41*, 759-762.

Perrott, S. B., Taylor, H.G., & Montes, J. L. (1991). Neuropsychological sequelae, familial stress, and environmental adaptation following pediatric head injury. *Developmental Neuropsychology, 7,* 69-86.

Rapoport, M., McCauley, S., Levin, H., Song, J., & Feinstein, A. (2002). The role of injury severity in neurobehavioral outcome 3 months after traumatic brain injury. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology, 15,* 123-132.

Reitan, R. M. (1958). The validity of the Trail Making Test as an indicator of organic brain damage. *Perceptual Motor Skills*, *8*, 271-276.

Reitan, R. M. (1985). Relationships between measures of brain functions and general intelligence. *Journal of Clinical Psychology*, *41*, 245-253.

Reschly, D. J., & Reschly, j. E. (1979). Brief reports on the WISC-R: I. Validity of WISC-R factor scores in predicting achievement and attention for four sociocultural groups. *Journal of School Psychology*, *17*, 355-361.

Rimel, R. W., & Jane, J. A. (1983). Characteristic of the head-injured patient. In M.

Rosenthal, E. R. Griffith, M. R. Bond, & J. D. Miller (Eds.), *Rehabilitation of the head injured adult* (pp. 9-21).

Rourke, B. P., & Orr, R. (1977). Prediction of the reading and spelling performances of normal and retarded readers: A four-year follow-up. *Journal of Abnormal Child Psychology*, *5*, 9-20.

Rourke, B. P., & Finalyson, M. A. J. (1978). Neuropsychological significance of variations in patterns of academic performance: Verbal and visual-spatial abilities. *Journal of Abnormal Child Psychology*, *6*, 121-133.

Ruesch, J. (1944). Intellectual impairment in head injuries. *American Journal of Psychiatry*, *11*, 480-496.

Russell, W. R. (1932). Cerebral involvement in head injury. *Brain*, *35*, 549-603.

Sattler, J. M. (1992). *Assessment of Children* (Revised and updated 3rd edition). San Diego: Jerome M. Sattler.

Satz, P. (2001). Mild head injury in children and adolescents. *Current Directions in Psychological Science, 10,* 106-109.

Satz, P., Zaucha, K., McCleary, C., Light, R., Asarnow, R., & Becker, D. (1997). Mild head injury in children and adolescents: A review of studies (1970-1995). *Psychological Bulletin, 122,* 107-131.

Seidenberg, M., Giordani, B., Berent, S., & Boll, T. J. (1983). IQ level and performance on the Halstead-Reitan neuropsychological test battery for older children. *Journal of Consulting and Clinical Psychology*, *51*, 406-413.

Selz, M., & Reitan, R. M. (1979). Neuropsychological test performance of normal, learning-disabled, and brain-damaged older children. *The Journal of Nervous and Mental Disease, 167,* 298-302.

Slater, E. J., & Kohr, M. A. (1989). Academic and intellectual functioning of adolescents with closed head injury. *Journal of Adolescent Research, 4,* 371-384.

Smith, T. C. & Smith, B. L. 91988). The Visual Aural Digit Span Test and Bender Gestalt Test as predictors of Wide Range Achievement Test-Revised scores. *Psychology in the Schools*, *25*, 264-269.

Steinmeyer, C. H. (1986). A meta-analysis of Halstead-Reitan test performances of non-brain damaged subjects. *Archives of Clinical Neuropsychology, 1,* 301-307.

Stevens, R., & Pihl, R. O. (1982). The identification of the student at-risk for failure. *Journal of Clinical Psychology*, *38*, 540-545.

Stevenson, H. W., & Newman, R. S. (1986). Long-term prediction of achievement and attitudes in mathematics and reading. *Child Development*, *57*, 646-659.

Stover, S. L., & Zeiger, H. E. (1976). Head injury in children and teenagers: Functional recovery correlated with the Duration of Coma. *Archives of Physical Medicine and Rehabilitation, 57,* 201-205.

Strom, D. A., Gray, J. W., Dean, R. S., & Fisher, W. E. (1987). The incremental validity of the Halstead-Reitan Neuropsychological Battery in predicting achievement for learning-disabled children. *Journal of Psychoeducational Assessment*, *2*, 157-165.

Swiercinsky, D. P. & Howard, M. E. (1982). Programmatic series of factor analysis for evaluating the structure of neuropsychological test batteries. *Clinical Neuropsychology, 4*, 147-152.

Telzrow, C. F. (1987). Management of academic and educational problems in head injury. *Journal of Learning Disabilities, 20*, 536-545.

Tooth, G. (1947). On the use of mental tests for the measurement of disability after head injury. *Journal of Neurology, Neurosurgery and Psychiatry, 10*, 1-11.

Troutman, J. G. (1978). Cognitive predictors of final grades in finite mathematics. *Education and Psychological Measurement, 38*, 401-401.

Verger, K., Junque, Levin, H. S., Jurado, M. A., Perez-Gomez, M., Bartres-Faz, D, Barrios, M., Alvarez, A., Bartumeus, F., Mercader, J. M. (2001). Correlation of atrophy measures on MRI with neuropsychological sequelae in children and adolescents with traumatic brain injury. *Brain Injury, 15,* 211-221.

Vignolo, G. E. (1980). Closed head injuries of school-age children: Neuropsychological sequelae in early adulthood. *The Italian Journal of Neurological Sciences, 2,* 65-73.

Warner, M. H., Ernst, J., Townes, B. D., Peel, J., & Preston, M. (1987). Relationships between IQ and neuropsychological measures in neuropsychiatry populations: Within-Laboratory and cross-cultural replications using WAIS and WAIS-R. *Journal of Clinical and Experimental Neuropsychology, 9,* 545-562.

Wechsler, D. (1945). A standardized memory scale for clinical use. *Journal of Psychology, 19*, 87-95.

Wechsler, D. (1955). *Manual for the Wechsler Adult Intelligence Scale*. San Antonio: The Psychological Corporation.

Wechsler, D. (1981). *Wechsler Adult Intelligence Scale-Revised Manual*. Cleveland, OH: The Psychological Corporation.

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children, Third Edition Manual*. San Antonio, TX: The Psychological Corporation.

Winogron, H. W., Knights, R. M. & Bawden, H. N. (1984). Neuropsychological deficits following head injury in children. *Journal of Clinical Neuropsychology, 6,* 269-286.

Wright, D. (1987). Intelligence and achievement: A factor analytic and canonical correlational study. *Journal of Psychoeducational Assessment*, *3*, 236-247.

Zakzanis, K. K. (2001). Statistics to tell the truth, the whole truth, and nothing but the truth: formulae, illustrative numerical examples, and heuristic interpretation of effect size analysis for neuropsychological researchers. *Archives of Clinical Neuropsychology, 16,* 653-667.

Appendices

Appendix A

Intellectual Sequelae of Traumatic Brain Injury in Adolescents: A Quantitative Review

Method

A search of the literature began with PsychInfo (American Psychological Association, 2002) database, via electronic access. Search words within this database included "intelligence," "head injury," "crystallized intelligence," "adolescents," "head injured adolescents," "neuropsychology," "IQ," "Wechsler," and "trauma," in various combinations. Article titles were then examined for relevance to the current study and selected. Approximately fifty articles were located and examined; from these, inclusion and exclusion criteria were implemented for this study. Articles were included if they: (1) involved pre-adolescents, adolescents and/or young adults (ages 11–23), at the time of assessment, who were clearly identifiable and separate from a larger sample including older adults and/or children; (2) involved adolescents and/or young adults who had some kind of closed-head trauma (of various etiologies and may involve skull fracture); (3) revealed data regarding Verbal IQ and Performance IQ means and standard deviations (or data from which these statistics could be derived); and (4) were available in English. Books obtained by this author thought to explore the issues of this study were reviewed and their reference sections examined for possible studies of inclusion. Searching also included examining the reference sections of articles that met inclusion criteria and/or review articles. Article searching was terminated when located articles were consistently duplications of articles already obtained. Studies were eliminated for a variety of reasons, including, but not limited to: medians reported instead of means, only Full Scale IQ reported, the sample involved a range of ages that included children and/or older adults, the sample only utilized an adult or child (below age 11) population, no statistical information was provided, the study examined intelligence using an esoteric or measure that is not commonly used. Seven studies remained following the application of inclusion and exclusion criteria. When the study involved more than one head-injured group (ex. mild and severe impairment) the more severely impaired group was chosen for this review. If more than one assessment was conducted, the initial assessment results were chosen. Table A1 gives some information regarding the nature of these studies, including title, author(s), sample characteristics and outcome of the variables of interest to this study.

Table A1

Select Characteristics of the Studies Included in this Quantitative Review

Title	Authors	Date of Publication	Age (yrs) of Sample (*M*)	Size of Sample	Severity of Injury	Time Since Injury	VIQ	PIQ
Performance vs. Verbal IQs in head injured adolescents and young adults: A three center study	Mutchnick	(in preparation)	19.44	79	342.37 PTA hrs.	2029 day	90.09	87.49
Correlation of atrophy measures on MRI with neuropsychological sequelae in children and adolescents with traumatic brain injury	Verger, et al	2001	18.11	19	5.89 GCS	9.42 years	89.68	99.10
Neuropsychological differences between college students with learning disabilities and those with mild head injury	Beers, et al	1994	20.5	25	"mild"	< 14 yrs	100.7	97.9
Neuropsychological function in adolescents sustaining mild closed head injury	Bassett & Slater	1990	15.9	10	4-8 GCS	unknown	91. 7	87.5

Table A1

(continued)

Title	Authors	Date of Publication	Age of Sample (*M*)	Size of Sample	Severity of Injury	Time Since Injury	VIQ	PIQ
Neuropsychological sequelae of light head injuries in older children 6 months after trauma	Gulbrandsen	1984	11*	56	< 15 min LOC	6 months	101.4	109.9
Closed head injuries of school-age children: Neuropsychological sequelae in early adulthood **	Vignolo	1980	20.28	18	various coma levels	9.78 years	99.8	101.44
Neuropsychological test performance of normal, learning-disabled, and brain-damaged older children	Seltz & Reitan	1979	11.15	25	mixed/mixed etiology	unknown	85.76	89.24

*this age estimation was based on a normally distributed range of 9 to 14
**modified: only subjects below age 24 were included in this study/all other analyses (taken from raw data)

The studies were summarized by the effect size of the Verbal vs. Performance IQs, utilizing Cohen's *d*, as suggested by Zakzanis (2001) for neuropsychological research:

$$\text{Cohen's } d = \frac{[M_1 - M_2]}{SD_{\text{pooled}}}$$

M_1 is the mean of Verbal Intelligence from each study, M_2 is the mean of Performance intelligence from each study, and *SD* pooled is the pooled standard deviation of these means. Pooled standard deviation can be obtained as shown:

$$SD_{\text{pooled}} = \frac{SD_1 + SD_2}{2}$$

SD_1 is the standard deviation from M_1 and SD_2 is the standard deviation from M_2.

Though there is caution recommended when trying to derive general descriptors across varied research, Cohen (1988) indicated that an effect size (Cohen's *d*) of 0.2 suggests a small effect, 0.5 suggests a medium effect, and 0.8 suggests a large effect.

The mean effect size across all utilized studies was obtained. Finally, the "fail-safe *N* formula (Orwin, 1983; Zakzanis, 2001)" was applied to the data to determine the number of hypothetical studies that would be needed to overturn the obtained mean effect size to a small or meaningless effect size. This formula is composed as follows:

$$\frac{N_{fs} = N(d - d_c)}{d_c}$$

N_{fs} is the number of hypothetical studies that could be added to the meta-analysis to overturn the results in the meta-analysis to a pre-determined small effect criterion, *N* is the number of studies in the meta-analysis, d is the average effect size, and d_c is the suggested small effect criteria (0.2).

Results

The effect size from each study is represented in Table A2.

The average of the effect sizes is – 0.11. This suggests a generally insignificant effect of there being significant difference between Verbal and Performance IQs following head trauma in adolescents and young adults.

The fail-safe *N* is not used here to determine how many studies would be needed to overturn the hypothesized significant effect, since there was a non-significant finding. Thus, the fail-safe N will be utilized to determine the number of studies needed to make the effect of Performance being lower than Verbal IQ (as hypothesized) significant. In this analysis, the criterion value, d_c is + 1.00. The fail-safe *N*, N_{fs}, therefore, is calculated to equal 6.23. This suggests that approximately 6 additional studies would be needed to demonstrate a significant difference between Verbal and Performance IQs (Performance being lower than Verbal). One can note that this number of studies is almost equal to the number presently included after an exhaustive literature search.

Table A2

Effect Sizes of the Studies Included in this Quantitative Review

Author (s)	Cohen's *d*
Mutchnick	.18
Verger, et al	-.53*
Beers, et al	.27
Bassett & Slater	.28
Gulbrandsen	-.70*
Vignolo	-.08*
Selz & Reitan	-.17*

*negative effect sizes indicate performance scores greater than verbal scores

Appendix B

Review of Neuropsychological Data and Head Injury in Adolescents and Young Adults

Cognitive Sequelae of Closed-Head Injury

Beers, Goldstein, and Katz (1994) found that mildly head-injured college students demonstrated deficits in visual-spatial skills, attention, memory and novel problem solving. This differed from students diagnosed with heterogeneous subtypes of learning disabilities, and no head injury, who performed more poorly on linguistically oriented tests. Somewhat in contrast, Bassett and Slater (1990), found that adolescents, assessed immediately following a mild head injury, were impaired in verbally based measures of learning, abstraction and reasoning, though were unimpaired on tasks of attention, motor speed and visual memory.

One can see that the literature regarding the specific patterns of deficit and strength following closed-head injury in adolescents is not clear. There seem to be differences in studies with regard to the role of time since injury and severity of injury as important intervening variables. Further, the types of deficits found vary from sample to sample, and is not conclusive.

Memory Loss Following Closed-Head Injury

Perhaps the most universal symptom following head trauma is the impairment of memory. Bachrach and Mintz (1974) employed discriminant analysis with four subtests form the Wechsler Memory Scale (Information, Story Recall, Visual Reproduction, and Paired Associates) and were able to differentiate neurologically confirmed brain impaired from non-confirmed patients, seventeen years old and older. The Visual Reproduction subtest alone significantly differentiated the groups to a degree scarcely different than when using all of the subtests combined. When comparing severely head-injured individuals, with post-traumatic amnesia (PTA) of at least two days, to orthopedic patients, head-injured subjects performed significantly worse on six of the eight Wechsler Memory Scale subtests (Information and Orientation were added, Mental Control was divided into "errors" and "time" and Digit Span was divided into "forwards" and "backwards"). The two subtests that did not differentiate the groups were Mental Control errors and Digit Span forward (Brooks, 1976).

Dividing head-injured individuals by age, using thirty-five years as the point of division, the younger head-injured group performed significantly worse than the older group on a factor characterized by significant loadings of Orientation and Information subtests of the Wechsler Memory Scale (Kear-Colwell & Heller, 1980). Factor analytic procedures, by those authors, further showed that Wechsler Memory Scale measures all loaded onto the same factors as Verbal, Performance and Full Scale IQ measures. However, the authors pointed out, "memory as measured by the WMS is intimately related to intelligence but there is still some variance independent of intellectual ability" (Kear-Colwell, 1973, p. 387).

Adolescents with severe head injury exhibited memory deficits both initially (mean time = .3 months), post injury, and at follow-up (mean time = eleven months) using a selective reminding test (verbal memory) and a visual recognition test. No adolescent in this study achieved Verbal or Performance IQ scores below eighty (Levin, Eisenberg, Wigg, & Kobayashi, 1982).

It can be seen from the research cited here that head injury impairs memory including that which relates to previously learned and novel material. In addition, young subjects, perhaps due to the nature of their injury, may reveal more weakness in basic memory ability than older subjects; memory disability that may not be adequately reflected by intellectual measurement. This suggests that overall intellectual performance may not be as sensitive as memory performance following head injury. Overall intellectual performance may rely more on pre-morbid status, and less on novel learning, than does memory performance.

Intelligence and Neuropsychological Test Performance

Research involving simple correlational analysis indicates that intellectual and other neuropsychological tests' performances are very strongly related. FSIQ of the WAIS and WAIS-R were significantly related to many of the Halstead-Reitan Neuropsychological Test Battery (HNRB) tests in a sample of individuals referred for neuropsychological evaluation (Werner, Ernst, Townes, Peel, & Preston, 1987). The tests of the HNRB most strongly related to intelligence were those tests that rely on conceptual problem solving, mental efficiency, auditory perception and other language related skills. These tests include the Category Test, the Tactual Performance Test, the Trail Making Test, the Speech Sounds Perception Test, the Seashore Rhythm Test, and the linguistic portions of the Aphasia Screening Test. This finding is supported by other research. Seidenberg, Giordani, Berent and Boll (1983) demonstrated that simple motor and perceptual tests, such as Finger Tapping, Grip Strength, and Greek Cross drawing showed no differences between intellectual groupings.

Research demonstrates that intelligence, as measured by intelligence tests, relates significantly to performance on neuropsychological tests. However, although there is overlap in skills measured by the WISC-R and the HRNB, each offers unique information about an individual. It has been demonstrated that only approximately ten percent of the variance explained by the WISC-R and that explained by the Halstead-Reitan battery is shared (D'Amato, Gray & Dean, 1988).

Factor analyses have demonstrated the relationship between intellectual subtests and tests from modified Halstead-Reitan batteries. Generally, these studies reveal that many neuropsychological measures load onto factors unique to those represented by intelligence subtests. However, many neuropsychological tests, from the Halstead-Reitan battery, load onto factors with certain WAIS or WAIS-R intelligence measures. Factors that may be represented as fluid abilities and crystallized abilities, because they are composed of the intellectual measures typically identified as such, also contain certain Halstead-Reitan variables (Corrigan & Hinkeldey, 1988; Earnst, Warner, Hochberg, & Townes, 1988; Newby, Hallenbeck & Emberson, 1983; Swiercinsky & Howard, 1982).

Neuropsychological Test Performance and Achievement

Neuropsychological data has traditionally been used to determine the presence of brain damage, the location of lesions, and the functional consequences of neurological insult. More recently, however, attention by researchers has been directed to the relationship between neuropsychological test performance and complex behaviors of daily living, specifically in the areas of self-care, independent living skills, employment status, and academic performance (Chelune & Moehle, 1986; Heaton & Pendleton, 1987). Heaton and Pendleton pointed out that in most studies of prediction, only intelligence tests or neuropsychological screening tests were used. These do not adequately assess the complex patterns of strengths and deficits that are associated with brain disorders and are not likely to adequately reflect the potential of other neuropsychological methods in the prediction of everyday behavior. They continue, that comprehensive neuropsychological assessment is required for assessing the academic potential in individuals with brain lesions. If an individual reveals significant impairment, academic failure would be likely even if he/she demonstrates adequate intelligence. Deficits that may be associated with brain damage, involving conceptual ability, attention, memory, and specific academic abilities may lead to observed differences between general intelligence and academic performance.

The Trail Making Test, a test of the HRNB, is thought to be particularly sensitive to neurological dysfunction, which is thought to relate to the complex, integrative and timed nature of the test. The Trail Making Test was performed significantly slower and with more errors by brain-damaged children (age nine to fourteen years) when compared to normal children (Knights & Ogilvie, 1967). The two groups were matched on the Peabody Picture Vocabulary Test IQ (mean IQ = 109.1 for each group). Brain dysfunction was evident from case history or neurological exam and included conditions such as prematurity, anoxia, toxemia, birth injury, post-natal disorders, open and closed-head trauma, vascular disorders and neoplasms. The Trail Making Test also discriminates brain damaged from normal adults (Reitan, 1958), suggesting perceptual-motor and problem solving dysfunctions associated with brain damage that is not necessarily age specific.

The Impairment Index (Halstead, 1947) was designed as a psychobiological approach to making gross distinctions between individuals with different levels of brain function. Key predictor test scores obtained from an individual are compared to normative cut-off scores and assigned a "one" if over the cut-off or a "zero" if not. A proportion of these assigned scores is then compared with a standard; .5 and above is indicative of possible brain impairment. The Impairment Index, utilizing test scores from select tests of the HRNB, has been described as a better indicator of brain impairment than are intelligence scores (Reitan, 1985). Further, it has been shown to differentiate neurologic from "pseudo-neurologic" subjects better than any other variable from a modified Halstead-Reitan battery (Matthews, Shaw & Klove, 1966). The Impairment Index has remained the most frequently used and one of the most sensitive indicators of brain dysfunction, including dysfunction resulting from closed-head injury.

Strom, Gray, Dean, and Fischer (1987) conducted a study to determine the incremental validity of the Halstead-Reitan Neuropsychological Battery for older children, beyond the WISC-R, in predicting scores on the Wide Range Achievement Test (WRAT). Children referred for psychological testing as a result of classroom learning problems were examined in the study. The results indicated that fifteen percent of the WRAT Reading subtest variance was explained by the WISC-R subtests. The HRNB measures added twenty-eight percent ($p < .01$) explanation to the variance. Similarly, the HRNB measures added significant explanation to the variance of the WRAT Arithmetic and Spelling subtests, which was already explained by measures of the WISC-R. The subtests of the HRNB employed in the analyses, generating eleven scores, were the Category Test, the Tactual Performance Test, the Seashore Rhythm Test, the Speech Sounds Perception Test, the Trail Making Test and the Finger Tapping Test.

In an investigation of prediction of academic achievement in mentally retarded and learning-disabled children, the WISC-R Full Scale IQ and the Pathognomonic Scale from the Luria-Nebraska neuropsychological battery were employed as independent variables. The Pathognomonic Scale is used as a general indicator of neurological integrity and involves items of motor, tactile, visual, receptive speech, expressive speech, writing, reading, numerical, memory (retention and retrieval), and intellectual (understanding pictures, discursive reasoning, and arithmetic) abilities. Stepwise regression techniques to predict performance on the WRAT revealed that the Pathognomonic Scale was a significant predictor of academic achievement and the intellectual measure was not (Hale & Foltz, 1982). Employing the Metropolitan Achievement Test (MAT) and the WRAT measures as dependent variables, Rourke and Orr (1977) demonstrated that the Underlining Test was predictive of eventual (four years later) reading and spelling performances of both normal and "retarded" readers. Further, the Underlining Test was shown to be more predictive than the MAT, WRAT, WISC and Peabody Picture Vocabulary (PPVT) variables in the retarded reading group. Subjects were classified as retarded readers because they had a percentile score of twenty or below on the Reading subtest of the MAT and thirty-five or below on either the Word Knowledge or the Word Discrimination subtests. The Underlining Test is a measure of speed and accuracy of visual discrimination for various kinds of verbal and nonverbal visual stimuli presented singly and in combination. Dorman and Laatsch (1983) examined adolescents with cerebral palsy and demonstrated that a pre-determined factor of the Luria-Nebraska battery, called "rhythm" followed by a verbal conceptual factor of the WISC-R and Luria-Nebraska are most highly correlated with the Reading and Spelling subtests of the WRAT when compared to other factors of the Luria-Nebraska and Digit Span of the WISC-R. The rhythm factor is composed of items relating to auditory processing such as those items that involve counting the number of rapidly presented auditory stimuli. The verbal conceptual factor is composed of Similarities, Comprehension, and Vocabulary subtests of the WISC-T, and the expressive speech portion of the Luria-Nebraska. In children with low academic achievement, the Visual Aural Digit Span Test and the Bender-Gestalt Test were significant predictors of WRAT-R scores (Smith & Smith, 1988).

Research reveals that measuring constructs of brain functioning, other than "intelligence," may be more predictive of future academic achievement than intelligence tests or even current measures of achievement. Though intelligence tests, other neuropsychological tests, and achievement tests are intercorrelated, the variance of achievement explained by neuropsychological tests might be unique to that explained by intelligence tests.

Appendix C

Independent Measure Record Form

Neuropsychological Data and Academic Performance

Please note: boxes indicate variables used in data coding and analyses.

Date:______________ Laboratory: [ ]

ID# [ ]

(Name: ____)

Age: [ ] Sex: [ ] Race: [ ] Grade: [ ]

Employment: ____

Dominance: [ ]

Nature of Injury: ______________________________________ [ ]

Complications associated with injury (hematoma, surgery, etc.): ____________________ [ ]

Hx: Neuro: ____________ LD: ______________________ [ ]

Other: ____

PTA: Days: ______________; Hrs [ ] Coma d [ ]

TSI: Date of Assessment: _______ _______ _______

Date of Injury: _______ _______ _______

Y M D

Months: _______________ Days: [ ]

WAIS-R: VIQ [ ] [ ] [ ]

	RAW SCORE	SCALED SCORE	ACSS
INF:	______	[ ]	[ ]
VOC:	______	[ ]	[ ]
COM:	______	[ ]	[ ]
PC:	______	[ ]	[ ]
BLKD:	______	[ ]	[ ]
OA:	______	[ ]	[ ]

COMMENTS:

Appendix D

Dependent Measure Record Form

Neuropsychological Data and Academic Performance

Please note: boxes indicate variables used in data coding and analyses.

ID# [ ]

WRAT -R:

Date of Administration: ______________________

	Raw Score	Standard Score	Percentile	Grade Equivalent	
READING:	________	[ ]	________	[ ]	[ ]
SPELLING:	________	[ ]	________	[ ]	[ ]
ARITHMETIC:	________	[ ]	________	[ ]	[ ]

VITA

Murry George Mutchnick was born in Mobile, Alabama, on October 30, 1963. He was raised in Mobile and attended high school at Murphy High School, as did his parents, his siblings and his nephews. Murry received his B.A. from the University of Alabama and his M.S. from the University of Memphis. He has worked for a number of years as a Licensed Psychological Examiner in a variety of settings including inpatient, outpatient, private practice, rehabilitation, correctional and educational.

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