PERFORMANCE OF CHILDREN WITH AND WITHOUT TRAUMATIC BRAIN INJURY ON THE PROCESS SCORING SYSTEM FOR THE INTERMEDIATE CATEGORY TEST

DISSERTATION

Presented to the Graduate Council of the University of North Texas in Partial Fulfillment of the Requirements For the Degree of

DOCTOR OF PHILOSOPHY

By

Catherine Bass, B.A., M.S.

Denton, Texas

May, 1997
PERFORMANCE OF CHILDREN WITH AND WITHOUT TRAUMATIC BRAIN INJURY ON THE PROCESS SCORING SYSTEM FOR THE INTERMEDIATE CATEGORY TEST

DISSERTATION

Presented to the Graduate Council of the University of North Texas in Partial Fulfillment of the Requirements For the Degree of DOCTOR OF PHILOSOPHY

By

Catherine Bass, B.A., M.S.

Denton, Texas

May, 1997

The clinical utility of the Intermediate Category Test, a measure of executive functioning in children 9 to 14 years of age, is currently limited by the availability of only a Total Error score for normative interpretation. The Process Scoring System (PSS) was developed to provide a standardized method of assessing specific processing patterns and problem-solving errors. The purpose of this study was to determine the ability of the PSS scores to discriminate between children with and without suspected executive deficits, thereby providing evidence of criterion-related validity. Children with TBI were used in this study because of the high rate of executive dysfunction typically found in this group.

Twenty normally-achieving children without TBI and 20 children with TBI of varying severity, ages 9 to 14, participated in this study. ANCOVA (using socio-economic status as covariate) indicated a significant difference
in Total Error scores between the two groups, but no group differences in the discrete concept formation or problem-solving response type scores. However, preliminary analysis revealed that the TBI group scored within the average range overall, suggesting that this group was not representative of children with executive dysfunction. ANCOVA comparing uninjured children to a more severely injured subgroup of children with TBI (n = 14) indicated that more severely injured children make significantly more Perseverative Errors and random errors than uninjured children. Implications of these findings in terms of the clinical utility of the PSS were discussed.
I would like to express my appreciation to Dr. Sander Martin for his support and guidance in my graduate studies and to Dr. Cheryl Silver for her generous assistance in completing this project. I would like to thank my family and friends for their continued support and encouragement throughout my graduate studies. I am especially grateful to my husband, James Latta, for his emotional support and technical assistance in completing this project.
TABLE OF CONTENTS

ACKNOWLEDGMENTS .......................................................... iii

LIST OF TABLES ................................................................... v

CHAPTER

I. INTRODUCTION ............................................................... 1

   Executive Functioning in Children
   The Intermediate Category Test (CAT-I)
   The Limitations of the CAT-I
   Total Error Score
   The Process Scoring System
   Traumatic Brain Injury in Children
   Purpose

II. METHOD ................................................................. 44

   Participants
   Procedure

III. RESULTS ............................................................... 49

IV. DISCUSSION ........................................................... 53

APPENDICES ................................................................. 61

REFERENCES ................................................................. 81
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-1</td>
<td>Summary of Uninjured Group Demographic Information</td>
<td>73</td>
</tr>
<tr>
<td>E-2</td>
<td>Summary of Entire TBI Group Demographic Information</td>
<td>74</td>
</tr>
<tr>
<td>E-3</td>
<td>Summary of TBI Group Injury Information</td>
<td>75</td>
</tr>
<tr>
<td>E-4</td>
<td>Summary of Uninjured Group Descriptive Test Results</td>
<td>76</td>
</tr>
<tr>
<td>E-5</td>
<td>Summary of Entire TBI Group Descriptive Test Results</td>
<td>77</td>
</tr>
<tr>
<td>E-6</td>
<td>Summary of More Severely Injured TBI Subgroup Descriptive Test Results</td>
<td>78</td>
</tr>
<tr>
<td>E-7</td>
<td>Summary of ANCOVA Results on the PSS Scores - Uninjured Versus Entire TBI Group</td>
<td>79</td>
</tr>
<tr>
<td>E-8</td>
<td>Summary of ANCOVA Results on the PSS Scores - Uninjured Versus Severe TBI Subgroup</td>
<td>80</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

The Intermediate Category Test (CAT-I; Reitan & Davison, 1974) is a neuropsychological test for children 9 to 14 years of age used to measure components of executive functioning such as concept formation and problem-solving skills. For norm-based interpretation of the CAT-I, only the Total Error score is used, with clinicians relying on clinical observations for more detailed information about specific response patterns and problem-solving errors. The Process Scoring System (PSS; Silver & Pennett, 1993) was developed to provide a standardized method for assessing discrete CAT-I process variables and to operationalize types of errors made on the test. The purpose of this study was to examine the criterion-related validity of the PSS. This was done by assessing the ability of PSS subscores to discriminate between children with and without suspected executive function impairment. Since high rates of executive impairment have been identified in children with traumatic brain injury (TBI), this group was used in this study.
For introduction purposes, the following topics will be reviewed: (a) executive functioning in children, (b) the importance of measuring executive functioning, (c) the Intermediate Category Test, (d) the limitations of the CAT-I’s single, total error score, (e) the newly-developed CAT-I Process Scoring System, and (f) traumatic brain injury in children.

**Executive Functioning in Children**

Executive functions are a complex domain of cognitive skills which modulate one’s ability to successfully initiate and maintain independent, purposeful, self-serving behavior (Lezak, 1995). Capruso and Levin (1992) describe executive functions as “a type of supraordinate system that motivates self-initiated behavior, then governs the efficiency and appropriateness of task performance” (p. 886).

An important component of the executive system is its modulation of future- or goal-oriented behavior. One of the hallmarks of executive function is the ability to set appropriate goals, a complex process of realistically and rationally determining one’s needs and desires (Lezak, 1995). Related to this skill is the ability to develop effective plans and strategies in support of goals (Denckla, 1994; Lezak, 1995; Luria, 1966; Rourke, Fisk &
Strang, 1986; Snow, 1992; Welsh, Pennington, & Groisser, 1991). Effective planning involves determining the individual steps, materials, and other elements necessary for goal-achievement (Lezak, 1995).

Numerous researchers emphasize the role of independent self-regulation of behavior in executive function (Lezak, 1995; Williams & Mateer, 1992). Self-regulative behaviors include self-initiation of behavior (Capruso & Levin, 1992; Lezak, 1995; Snow, 1992), inhibition of irrelevant or competing stimuli, also called interference control (Denckla, 1994; Williams & Mateer, 1992) and inhibition of inappropriate responses, also called impulse control (Bigler, 1990; Chelune, Ferguson, Koon, & Dickey, 1986; Denckla, 1994; Gnys & Willis, 1991; Lezak, 1995; Luria, 1966; Welsh, Pennington, & Groisser, 1991; Weyant & Willis, 1994; Ylvisaker & Szekeres, 1989). Other important self-regulative behaviors are self-awareness and self-evaluation (Capruso & Levin, 1992; Ylvisaker & Szekeres, 1989), including the ability to recognize one’s own deficits (Lezak, 1995; Stuss & Benson, 1984) and the ability to recognize and benefit from feedback (Rourke, et al., 1986; Williams & Mateer, 1992).

Problem-solving skills are considered one of the hallmarks of executive functioning (Denckla, 1994; Welsh &
Pennington, 1988; Ylvisaker & Szekeres, 1989), and they are the focus of this study. Individual executive skills which facilitate effective problem-solving include flexibility of thought and behavior (Snow, 1992), organization of thought and behavior, including organized search (Denckla, 1994; Snow, 1992; Welsh et al., 1991; Weyant & Willis, 1994), concept formation skills (Denckla, 1994; Dennis, 1991; Farmer, Clippard, Luehr-Wiemann, Wright, & Owings, 1996), reasoning skills (Capruso & Levin, 1992; Farmer et al., 1996), abstraction skills (Bigler, 1990), and judgment (Bigler, 1990; Farmer et al., 1996; Michaud, Duhaime, & Batshaw, 1993).

Additional executive skills which support effective problem-solving include the ability to direct and sustain attention (Dennis, 1991; Lezak, 1995; Stuss & Benson, 1987; Williams & Mateer, 1992), maintain an appropriate cognitive set, (Lezak, 1995; Luria, 1973; Welsh & Pennington, 1988), shift from one set to another, or freedom from perseveration (Lezak, 1995, Luria, 1966; Williams & Mateer, 1992), generalize responses (Farmer et al., 1996), integrate isolated details to form a coherent whole (Stuss & Benson, 1984; Williams & Mateer, 1992), and maintain effort over time (Farmer et al., 1996; Williams & Mateer, 1992).
Finally, the executive system helps modulate arousal (Luria, 1973) and the ability to manage emotional responses in an effective, adaptive manner (Bigler, 1990). Clearly, the executive system is a dynamic and complex set of cognitive skills which is not yet clearly understood. The lack of clear understanding is partially due to the complexity of brain areas associated with executive functioning.

Localization of executive function. While anatomical correlates of executive function are not the focus of this study, a brief overview will be provided in light of its importance in executive function research. The region of the brain most often associated with executive functioning in adults is the prefrontal cortical region, believed to modulate behavior by its influence on selective attention, organization, and integration of information (Becker, Isaac, & Hynd, 1987; Welsh et al., 1991). The frontal regions are especially important because of their complex connections to almost all other regions of the central nervous system (Stuss & Benson, 1984).

Much of the research on frontal lobe functioning has been gathered from studies of adult patients who have sustained frontal lobe damage with resulting deficits in executive skills (Chelune et al., 1986; Glosser &
Goodglass, 1990; Luria, 1973; Stuss & Benson, 1984). Other researchers have found associations between executive functioning and the frontal regions of the brain (Dennis, 1991; Gnys & Willis, 1991; Welsh et al., 1991).

Neuropsychological tests designed to measure executive functioning, such as the Wisconsin Card Sorting Test (WCST; Berg, 1948), an adult test of conceptualization and problem-solving, have been found to be sensitive to frontal lobe lesions (Drewe, 1974; Milner, 1963; Robinson, Heaton, Lehman, & Stilson, 1980).

The association between frontal lobes and executive functions has been further supported by technological methodologies such as positron emission tomography (PET) and cerebral blood flow studies (Lou, Henriksen, & Bruhn, 1984). In adults, Rezai, Andreason, Alliger, Cohen, Swayze, and O'Leary (1993) found that 3/4 of the commonly-used tests of executive skills produce left dorsolateral, prefrontal cerebral blood flow activity.

Cummings (1993) conducted a review of the frontal lobe literature to determine the role of frontal-subcortical circuits in various behavior disorders. He found five parallel but separate circuits connecting the frontal lobe with subcortical structures. Lesions in each of the five circuits were associated with a distinct behavioral
syndrome. His findings suggest that executive dysfunction is associated with lesions affecting the dorsolateral prefrontal circuit.

Stuss and Benson (1984), however, failed to find an exclusive relationship between the frontal lobes and executive functions in adults, likely because of the complex reciprocal pathways from the frontal lobes to numerous other areas of the brain (Chelune et al., 1986). While executive function localization is still under investigation, research findings in adults thus far appear to support the relationship between executive skills and the frontal lobes.

Executive function localization in children is even less clear, partially because of fewer studies examining this issue. In a preliminary study by Levin, Culhane, Mendelsohn, Lilly, Bruce, Fletcher, Chapman, Harward, and Eisenberg (1993), a significant relationship was found between the left frontal lobe and cognitive flexibility in children. However, further study is necessary to help clarify localization of executive function in children. While localization of executive function is an important area of study, Ewing-Cobbs and Fletcher (1990) note that neuropsychological assessment is most useful when focused on careful measurement of children's abilities rather than
on issues of localization. Thorough assessment of executive functioning can be difficult in adults, and is even further complicated in children because of complex developmental factors.

**Developmental factors in executive functioning.**

Executive functioning research in children is complicated by developmental factors. The age at which the frontal lobes are fully developed remains controversial (Becker et al., 1987). While in the past, psychologists commonly believed that executive functions were not yet operative until adolescence, more recent findings suggest that such skills are at least partly functional earlier in life (Welsh et al., 1991; Wilkening, 1989).

The findings of several researchers indicate that various components of executive function achieve adult levels from ages 10 to 12 years (Chelune & Baer, 1986; Kirk & Kelly, 1986). Chelune and Baer (1986) found that the WCST was able to discriminate differences in conceptualization and problem-solving skills in children with and without brain damage as young as age seven, suggesting that these skills are at least partially developed at this age. These authors found that children's scores on some WCST variables (Number of Categories Achieved, Number of Perseverative Errors, and Failure to Maintain Set) reached adult levels
by age ten. (Brief descriptions of the WCST testing procedures and scores are provided in the section entitled 'The Process Scoring System').

Studies by Becker et al. (1987) and Passler et al. (1985) adapted adult neuropsychological measures for use with children. They found that flexibility in strategic behavior can be identified in children as young as 6 years old, and that inhibition of irrelevant stimuli and perseverative responses reaches mastery by age 12.

Levin, Culhane, Hartmann, Evankovich, Mattson, Harward, Ringholz, Ewing-Cobbs, and Fletcher (1991) conducted a normative study of children and adolescents on measures believed to measure frontal lobe functioning. The results were consistent with previous studies, with the WCST indicating significant gains in concept formation, capacity to shift set, and suppression of inappropriate responding by age 12. The largest developmental shift in concept formation and problem-solving efficiency (Perseverative Errors), occurred between the 7-8 and 9-10 year old groups.

In general, the available research suggests that many skills associated with executive functioning develop rapidly after the age of 6 and generally reach adult levels by the age of 12 (Chelune et al., 1986). While
developmental factors complicate measurement of executive skills in children, Chelune and Thompson (1987) point out that such skills do not require complete mastery before they are amenable to examination by neuropsychologists.

**Importance of executive function assessment.** Timely and careful assessment of executive functioning in children is crucial because of the devastating impact of impairment in these skills on children's cognitive, academic, social, and emotional adjustment (Lezak & O'Brien, 1990). Planning, organization, self-regulation, and problem-solving skills are essential in most areas of human life. Rourke et al. (1986) noted that, "The capacities for generating plans of action, testing hypotheses, and benefitting from positive and negative informational feedback are extremely important for adaptive functioning, even at fairly early developmental levels" (p. 23).

For example, when a child encounters a problem in daily life, he or she must first recognize that a problem exists, attempt to understand the problem, evaluate possible solutions, take the initiative to develop a plan with specific strategies, put the plan in action, recognize and evaluate feedback, try another plan if necessary, and continue the process of problem-solving until an effective solution is successfully completed. For success in school,
social relationships, and even personal care and safety, this process must be repeated multiple times per day. The effectiveness with which it is carried out can have serious ramifications in children's lives and eventual level of independence. Symptoms of executive dysfunction such as reduced task initiation discussed by Capruso and Levin (1992), Lezak (1995), and Snow (1992), limit the achievements of children and may be misinterpreted as "laziness" or other personality factors. Poor or unreliable judgment noted by Bigler (1990) and Lezak (1995), particularly when combined with impulsivity or disinhibition also commonly found in executive dysfunction (Bigler, 1990; Lezak, 1995; Luria, 1966) may result in potentially dangerous behavior in addition to day-to-day decisions based on incomplete and erroneous information.

Specific cognitive errors associated with executive dysfunction can significantly impede problem-solving in a variety of settings. For example, perseveration, or repeating the same or similar response to different questions, tasks, or situations (Lezak, 1995; Luria, 1966; Williams & Mateer, 1992) may result in rigid, maladaptive cognitive and behavioral approaches to problem-solving, affecting educational progress as well as social adjustment. Additionally, personality and emotional
variables associated with executive dysfunction, including apathy, emotional lability, and impaired anger control, may limit social adjustment and preclude an effective social support system in coping with life stressors (Fennell & Mickle, 1992).

Careful assessment of these and other skills is especially important in educational remediation of executive dysfunction, especially in light of recent advances in cognitive rehabilitation among children with brain injury. According to Ylvisaker, Szekeres, and Hartwick (1992), cognitive rehabilitation for school-age children and adolescents includes manipulation of the educational environment and instructional programs to maximize performance given the child’s specific optimal learning conditions, practice in specific problem-solving processes, the teaching of compensatory strategies, and interventions designed to increase executive control over cognition and behavior. Effective assessment of executive skills, including problem-solving response style deficits, is essential for such targeted intervention.

Impaired executive function also has serious consequences in the overall rehabilitative process following brain insult. Ylvisaker and Szekeres (1989) note that not only do executive deficits directly affect the
chances of productive and independent living, they also limit rehabilitation options since active participation in rehabilitation requires some awareness of deficits, acceptance of goals, and the ability to learn compensatory behaviors and strategies. Careful measurement is necessary to determine the amount and type of feedback and structure needed in rehabilitation programs (Rourke et al., 1986).

The incidence of impaired executive function in children is high due to vascular anomalies, infections, traumatic brain injury (TBI), and other medical conditions (Rourke et al., 1986). Due to medical advances, more children survive injuries such as TBI than in the past and are faced with more serious disabilities which must be addressed in remediation efforts (Bigler, 1990).

The devastating nature of executive dysfunction in children necessitates timely and effective measurement of these skills in order to develop specific, effective treatment programs. One of the most common measures of executive functioning is the Category Test for Older Children.

The Intermediate Category Test

**History.** The CAT-I is an adaptation of the original Halstead Category Test developed in 1947 as a measure of abstraction and conceptualization skills in adults (CAT;
Halstead, 1947). Halstead derived the CAT from his work with sorting tasks, which he found differentiated adults with and without brain damage. The Category Test provided a standardized measure which required examinees to: "1) develop, as hypotheses, organizing principles or abstract concepts with regard to items and trials within a subtest; 2) evaluate these hypotheses in accordance with positive or negative reinforcement; and 3) adjust the hypotheses in an ongoing or dynamic way on the basis of the reinforcements received." (Bertram, Abeles, & Snyder, 1990, p. 245). In 1974, Reitan and Davison adapted the original test, shortening it from seven to six subtests, for inclusion in the Halstead-Reitan Neuropsychological Test Battery for Older Children (HRNB-C; Reitan & Davison, 1974).

**Description.** The original materials consist of a 10" by 8" screen on which 168 slides are presented consecutively to the examinee. Four levers numbered 1 to 4 are provided below the screen, and children are instructed to examine each slide and press the lever that corresponds to the answer they believe is correct. Immediate feedback is provided by a bell following correct responses and a buzzer following incorrect responses. Only one response is allowed per slide.
The CAT-I slides are divided into six groups, or subtests, each representing a specific principle or concept. Correct answers are obtained by deducing the subtest's principle by trial and error hypothesis testing and continuing to respond according to this principle throughout the subtest.

The principles or concepts are relatively simple in Subtests I and II and become increasingly more complex in later subtests. Subtest I involves matching Arabic numerals to Roman numerals and Subtest II requires counting the number of geometric shapes presented. Subtest III involves the concept of uniqueness, with the correct response being the number which corresponds to the figure which is most different from the others. Subtests IV and V involve the concept of fractional parts of a whole, with correct responses obtained by determining the proportion of the stimulus that is made up of solid versus dotted lines. Subtest VI presents various slides already seen and requires recall for previous items rather than adherence to a unitary concept. A sample of stimulus items is provided in Appendix A. In scoring and interpreting the CAT-I, examiners most often derive a single score, the Total Error score, which reflects the total number of incorrect responses across subtests.
Psychometric properties of The CAT-I. Few reliability studies have been conducted on the children's version of the CAT, and reliability must in part be inferred from adult findings. In a study of adults, Shaw (1966) found a split-half reliability of .98. Matarazzo, Matarazzo, Wiens, Gallo, and Klonoff (1976) found test-retest coefficients of .72 for chronic schizophrenics, .82 for patients with a history of carotid endarterectomy, .96 for patients with diffuse cerebrovascular disease, and .60 for a comparison group of males with no known impairment.

Charter, Adkins, Alekoumbides and Seacat (1987) obtained a corrected split-half reliability coefficient of .95 for the adult version of the CAT in a study of 311 adults. Similarly, in a study of 285 adult patients, Moses (1985) found a coefficient alpha of .96.

In one of the few studies examining reliability of the CAT-I, Sarazin and Spreen (1986) obtained test-retest reliabilities on an abbreviated version of the test in a sample of children with learning disabilities. The mean age at first and second testing was 10 and 25 years, respectively. The sample included children in three groups, those with documented neurological dysfunction, minimal brain dysfunction, and learning disabilities in the absence of neurological impairment. Measures included an
abbreviated version of the CAT-I and other intellectual and neuropsychological measures. The abbreviated CAT-I test-retest coefficients for the children with brain damage, minimal brain dysfunction, and learning disabilities were .60, .50, and .83, respectively. These findings are limited by the use the abbreviated version.

Numerous researchers have established the validity of the CAT Total Error score in discriminating between adults with and without brain damage (Filskov & Goldstein, 1974; Hevern, 1980; Reitan, 1955). While the ability of the CAT to localize frontal damage is disputed by some researchers (Bornstein, 1986, Pendleton and Heaton, 1982; Reitan & Wolfson, 1995), others have found the CAT to be a valid measure of frontal-lobe-mediated abilities such as abstraction, logical analysis, and analysis of complex problems (Nici & Reitan, 1986). The test's validity in identifying executive skills deficits such as impaired problem-solving is well-established.

In establishing the validity of CAT-I, Reed, Reitan, and Klove (1965) compared children with brain damage to unimpaired children from 10 to 14 years of age on numerous intellectual and neuropsychological measures including the CAT-I Total Error score. The children with brain damage
obtained significantly higher CAT-I Total Error scores than their unimpaired peers.

Selz (1977) examined the neuropsychological differences between children 9 to 14 years of age with learning disabilities, brain damage, and no known impairment. Analysis revealed significantly higher CAT-I Total Error scores among children with brain damage.

Reitan and Wolfson (1988) compared children aged 9 to 14 with and without brain damage on neuropsychological functioning in each of four categories: (a) motor functions, (b) sensory-perceptual functions, (c) visual-spatial skills, (d) attention, concentration, and memory, and (e) abstraction, reasoning, and logical analysis. Analysis revealed that children with brain damage earned significantly lower scores than children without brain damage in all categories. Significantly, aside from motor function deficits, children with brain damage performed most poorly in the area of abstraction, reasoning, and logical analysis as determined by significantly lower CAT-I scores.

These results are comparable to those found by Boll (1974), who compared children ages 9 to 14 years with and without brain damage on: (a) perceptual skills, (b) conceptual abilities, or executive function (measured by
the Category Test), and (c) primary motor skills. Boll found that conceptual skills were by far the most sensitive to brain damage, followed by perceptual skills and finally motor skills.

In general, the CAT-I is considered to have adequate psychometric properties based on use of the Total Error score. Exclusive use of this score, however, may result in the loss of valuable information about children’s problem-solving available from their CAT-I performance.

Limitations of a Single Total Error Score

While the CAT-I has proven useful in identifying problem-solving and other executive skills deficits in children, the use of a single total error score provides little information about the specific types of problem-solving errors contributing to overall deficits. The test reveals whether, but not how, problem-solving skills are impaired. Several researchers have advocated a more process-oriented approach to testing which goes beyond the simple identification of impairment based on a single score.

As early as 1942, Goldstein (1942) asserted that overall quantitative scores have little significance in studying particular deficits related to brain damage. He emphasized examination of the methods used by patients in
their approach to problem-solving. Similarly, Luria (1967) considered a patient's "performance style" to be more useful than quantitative scores in neuropsychological assessment.

Kaplan's "process-oriented" approach to assessment supports this emphasis on considering the method of problem-solving over final numerical scores (Milberg, Hebben, & Kaplan, 1986). The "Boston Process Approach" to neuropsychological assessment that these authors describe stresses understanding of the qualitative nature of one's performance on clinical instruments. For each assessment instrument used, subscores are developed which measure specific underlying cognitive components of performance, allowing for an overall quantitative assessment of performance along with a rich, dynamic description of the information processing style used.

Ewing-Cobbs, Fletcher, and Levin (1986) also found that most research identifies general areas of impairment, such as deficits in list learning, as opposed to potential mechanisms underlying the impairment, such as inadequate interference control. Like the authors above, these researchers found assessment of underlying processes to be more useful in developing interventions for specific
deficits at different stages of recovery following brain insult.

Reitan asserted that the use of numerical scores is only one of four types or levels of inference useful in interpreting neuropsychological tests (Reitan, 1967; Reitan & Davison, 1974; Reitan & Heineman, 1968). The four types he outlined were: (a) level of performance, (b) pattern of performance, (c) right and left brain differences, and (d) pathognomonic signs. Level of performance (comparing a score with a normative standard) is considered the easiest method because it is relatively understandable and lends itself to the use of conventional statistics. However, the author states that such analysis may be misleading and less useful than examination of an individual's pattern of performance which identifies the cognitive processes used.

The approach to assessment advocated by these researchers emphasizes evaluation of cognitive processes, response patterns, and underlying mechanisms. In terms of the CAT, assessment of these sometimes subtle variables relies entirely on clinical observations in the absence of operationalized process-oriented scores. Several researchers have addressed the need for expanded, quantifiable scoring for various versions of the CAT.
In the adult research, Bond and Buchtel (1984) consider use of the CAT Total Error score inadequate for analyzing the specific cognitive processes underlying performance. They advocate a "think aloud" or "process tracing" approach to CAT interpretation. Believing that children may fail for different reasons on the test, the authors asked examinees to "think aloud" about their reasons for making response choices. The authors assert that CAT utility will increase if different kinds of brain impairment are found to be associated with characteristic reasons for failure. A limitation of this type of CAT-I interpretation is that describing one's reasoning on each slide changes the properties of the test and may influence subsequent responses.

Rattan, Dean, and Fischer (1986) examined the contribution of CAT response time to performance on the entire HRNB. The authors administered the battery to adult volunteers without known cognitive impairment. Average response times for each slide were computed for all correct responses (CRT), for all incorrect responses (IRT), and for total responses (TRT). Results indicated that approximately 15% of the variability in CAT error scores was explained by response time measures (TRT and IRT). Factor analysis revealed that the three response time scores comprised a
factor that accounted for 21% of all explained variability in HRNB performance, while the CAT Total Error score, along with three other measures, loaded on a factor which accounted for only 6% of the variability. The authors concluded that CAT response time is an important factor in HRNB performance, and may be more meaningful than total error scores in interpreting HRNB results.

A more common approach to expanding CAT scoring has been to examine the individual subtests scores separately. Perrine (1993) conducted a study of conceptual processing differences between individual CAT-I subtests and WCST subscores.

In Perrine's study, the CAT and WCST were administered to a sample of adults along with several other concept formation measures assessing attribute identification and rule learning. Correlational and multivariate stepwise multiple regression analyses suggested that individual CAT subtests are associated with different aspects of concept formation. For example, WCST Nonperseverative Errors and Unique Errors were significantly related only to CAT Subtest IV. WCST conceptual level responses were highly associated with CAT subtest VII, both of which the author believes to measure difficulty maintaining set. The WCST Perseverative Error score, measuring the failure to abandon
a previously correct principle when it no longer applies, was highly correlated with CAT Subtests IV, V, VI, and VII. The author discusses possible explanations for these high correlations, including the large number of differing stimuli in Subtest VI and the frequently changing stimulus patterns in Subtest VII.

The author concluded that the scores of each subtest were useful in identifying specific aspects of conceptual processing, and could be more helpful than simply using cutoff scores to identify overall problems. The suggested that “further research involving a more detailed analysis of the information processing components of concept formation could help refine knowledge of the component aspects of such abilities, with less reliance on global terms such as 'abstraction' in interpreting tests as complex as the (CAT) and WCST.” (p. 471-472).

Others have examined individual CAT-I subtest performance in children. Anderson, Butkus, Vellet, Kaul, Voelker, and DeLuca (1989) conducted a study of the relationships among CAT-I subtest scores, intellectual functioning, and psychosocial adjustment in psychiatric patients ages 9 to 14 years. Percent Error scores for CAT-I Subtests III, IV, and V were computed by dividing the number of errors in each subtest by the total number of
errors across the three subtests. Subtests I and II were excluded as the concepts were considered too elementary, and Subtest VI was excluded due to its heterogeneous content.

Results indicated no significant correlations among CAT-I subtest performance, intellectual functioning, and psychosocial adjustment scores, and no differences between children who scored high versus low on CAT-I subtest error scores. A cluster analysis of CAT-I scores yielded five subtypes, each with differing Percent Error score patterns for Subtests III, IV, and V. No significant differences among subtypes were found on the majority of IQ and psychosocial variables. Despite a lack of significant findings, the authors concluded that the identification of five subtypes, each with several subjects, supported the use of subtest analysis in obtaining additional information from the CAT.

Kelly, Kundert, and Dean (1992) examined the factor structure of the six CAT-I subtests in children 9 to 14 years of age who were referred for neuropsychological evaluation due to suspected learning disabilities. The children were randomly assigned to one of two equal-sized groups. For each group, a three-factor solution emerged with variable loadings of similar pattern, magnitude, and
direction. Factor 1 (Visual Perception/Spatial Orientation) included Subtests IV and V, Factor 2 (Visual Abstract Reasoning/Memory) included Subtests III and VI, and Factor 3 (Number Counting/Attention) included Subtests I and II. The authors conclude that the CAT-I measures more than one underlying construct in this sample of children with learning difficulties, and that use of the total error score alone may restrict interpretation of the multiple abilities measured.

Fischer and Dean (1990) examined the factor structure of the adult CAT in a sample of children with learning disabilities aged 9 to 14 years. The authors used the seven subtests of the CAT along with multiple other neuropsychological measures in factor analyses of the total sample, by gender, and for each of six age groups. Results yielded three factors for the CAT subtests across age and gender.

The authors found that Subtests I and II loaded with other measures on 'attention and incidental memory'. Subtests III and IV and Subtests V, VI, and VII loaded on two factors independent of the other neuropsychological measures, making identification of the underlying constructs difficult. The authors note that subtests in two of these factors have loadings of similar magnitude but
opposite directions, which indicates a complex relationship between subtests. Comparison of these factor loadings with those found by Kelly et al. (1992) is difficult because the studies used different versions of the CAT. However, the authors of both of these studies conclude that the use of a single CAT error score is questionable because the subtests likely reflect different underlying skills. A consensus emerged among these authors that the use of a single CAT error score unnecessarily limits the amount and type of information the test can provide. The Process Scoring System was developed to address this limitation in the CAT-I.

The Process Scoring System

Development of the PSS. Silver and Pennett (1993) developed the CAT-I Process Scoring System to provide a coherent, standardized scoring system which allows for assessment of specific problem-solving response types involved in executive dysfunction. As a model for the PSS, the authors used the scoring guidelines of the WCST.

The WCST scoring system was used as a model for the PSS because of its apparent similarity to the CAT-I and its utility in measuring specific conceptual and problem-solving response types. As stated previously, the WCST was developed by Berg (1948) to measure abstraction abilities
in adults using a card sorting task requiring flexibility of thinking in problem solving.

The WCST consists of four stimulus cards along with 128 response cards. Each card contains figures of varying colors, geometrical shapes, and number of figures presented. The four stimulus cards are placed in front of the examinee in a pre-determined, left to right order. The examinee is asked to match each of the response cards to the stimulus card he or she believes it matches. Correct responses are obtained by adhering to a "correct" principle or concept (color, form, or number). The examinee is told only whether responses are right or wrong; the operative concept is never divulged. When the examinee has made ten consecutive correct responses, the sorting concept is changed without notice. The examinee uses the resulting feedback to develop and test hypotheses about the new sorting principle. Several such shifts in set occur throughout the test, and the test is ended after five shifts are successfully completed or all of the of 128 cards have been used.

The CAT-I and WCST are similar in that they each require selective responding to a single aspect of a stimulus, the ability to benefit from positive and negative feedback, and the ability to effectively shift response
sets (Pendleton & Heaton, 1982). Additionally, they each involve multiple successive trials with immediate feedback, formation of hypotheses about the concept which results in correct responses, and the ability to inhibit responding. Both tests use visual stimuli and neither requires a verbal response. The tests differ in the actual stimuli used, the type of motor response required, the criterion for changing categories or principles, the criterion for discontinuation, and, according to Bond and Buchtel (1984) and Pendleton & Heaton (1982), the greater complexity of the stimuli in the CAT-I versus the WCST.

WCST subscores are obtained by summing similar types of responses across all items administered. The most commonly used response types include: (a) Total Number of Errors, (b) Total Number of Correct Responses, (c) Number of Categories Completed, (d) Perseverative Responses, (e) Perseverative Errors, and (f) Nonperseverative Errors (Heaton, Chelune, Talley, Kay, & Curtiss, 1993). Also provided are two scores measuring conceptual skills (Trials to Complete the First Category and Failure to Maintain Set). WCST subscores may be reviewed in more detail in the WCST Manual (Heaton, 1993).

Several of the WCST subscores have been found to discriminate effectively between adults with frontal and
nonfrontal brain lesions (Heaton, 1993). Milner (1963) found that patients with dorsolateral frontal lesions scored significantly worse on WCST Perseverative Errors and Total Errors, but not on Nonperseverative Errors or Categories Completed. Drewe (1974) found that patients with frontal lesions scored significantly worse on Perseverative Errors, Categories Completed, and Correct Responses than patients with nonfrontal lesions.

Chelune and Thompson (1987) found that children referred for evaluation of suspected neuropsychological problems scored significantly lower than unimpaired controls on Percentage of Correct Responses and Categories Achieved, and higher on Perseverative Responses, Perseverative Errors, and Percentage Perseverative Errors.

Levin et al., (1993) found that children 6 to 10 years of age with severe head injury used significantly fewer categories in sorting WCST cards than less severely injured and uninjured children. No significant differences were found among groups on Percent Perseverative Errors, and no significant WCST differences were found in an older group (11 to 16 years) with head injury. Despite conflicting findings, the WCST research overall suggests that individual scores effectively discriminate between adults and children with and without brain impairment. The test
continues to be considered an effective measure of problem-solving skills and is widely used by neuropsychologists.

The necessity for a new scoring system for the CAT-I may be questioned given that the WCST already provides for measures of problem-solving response types and conceptualization skills. Although the tests have numerous similarities, they are not interchangeable.

Empirical findings suggest differences in the constructs measured by the two tests (Franzen, Smith, Paul, & MacInness, 1993). In studies comparing performance on the commonly-used scores of both tests, moderate correlations have been found. In a study of adults with and without brain damage, Pendleton and Heaton (1982) found that the correlation coefficients of the WCST perseverative responses and CAT total error score were .56 for those with brain damage and .55 for those without. King and Snow (1981) compared scores on WCST number of categories achieved and CAT total errors, finding correlation coefficients of -.53 for adults with brain injury and -.43 for uninjured adults. These and other adult studies (Donders & Kirsch, 1991; Perrine, 1993) suggest substantial differences between the WCST and the CAT when using the CAT error score currently in use.
The studies above share a common limitation which makes comparison of the two tests difficult. Each compares only the CAT Total Error score or total errors on each subtest to multiple discrete types of responses on the WCST. The development of the PSS provides for parallel scores on the two tests, making comparisons more meaningful. More importantly, adaptation of the WCST scoring system for the CAT-I is expected to enrich the amount and types of information available for remediation of children's executive skills deficits.

Description of the PSS. In deriving PSS scores, Silver and Pennett used only Subtests II through V, as Subtest I is considered too simple to yield meaningful information and Subtest VI is a measure of memory rather than concept formation. The PSS yields two Concept Formation subscores and six Problem Solving Response Type subscores. The PSS concept formation subscores are as follows:

1) Categories Completed (CC): This subscore reflects the number of subtests in which a child is able to learn the relevant concept and use it to obtain ten consecutive correct responses, regardless of the number of stimulus presentations needed to meet this criterion.
2) Trials to Learn Concepts (TL): This subscore reflects the total number of stimulus presentations (thus feedback) necessary to learn the concept in each subtest and use it to obtain correct responses.

The PSS Problem Solving Response Type Subscores are as follows:

1) Total Errors (TE): This subscore reflects the total number of errors made in Subtests II through V.

2) Perseverative Responses (PR): This subscore includes the total number of perseverative responses made, whether correct or incorrect. Perseveration is defined as: 1) responses consistent with a correct concept from the previous subtest, 2) responses within a subtest in which an incorrect response is repeated for an identical stimulus, and 3) identical responses at least three times in a row when at least one of the first two responses is correct.

3) Perseverative Errors (PE): This is the total number of incorrect perseverative responses.

4) Generalization Errors (GE): This occurs when an examinee fails to adapt a correct principle to changing types of stimuli. This variable is not available on the WCST because of the structure of the test.
5) Failure to Maintain Set (FM): This occurs when a correct principle is used consistently, followed by an error on a similar item.

6) Other Errors (OE): All errors not included in the three types of scores above.

As with all newly developed tests and scoring systems, psychometric properties must be established before the procedure is determined to be appropriate for clinical use. In a study of children with learning disabilities, ages 10 to 13, Silver, Pennett, and Koneru (1994) found adequate interscorer reliability, with agreement of 88% to 100% on PSS subscores. In the same study, the authors examined the relationships between PSS scores and their corresponding WCST scores. Significant relationships were found between the CAT-I and WCST Perseverative Responses ($r=.52$) and Perseverative Errors ($r=.50$). No significant relationships were found between the corresponding variables of Categories Completed, Trials to Learn Concepts, Nonperseverative Errors, or Failure to Maintain Set. Restricted ranges in the Categories Completed and Failure to Maintain Set variables resulted in reduced power and thus reduced likelihood of finding significant relationships in these two scores. A significant relationship was not expected for the WCST Nonperseverative
Errors score because the tests provide for different types of errors (e.g., CAT-I provides for generalization errors while the WCST does not).

To further examine the clinical utility of the PSS variables, the authors examined the PSS performance of children whose CAT-I Total Error score indicated intact problem-solving. Process variables indicated different response patterns among these children and detected relative problem-solving difficulties in several children. The study above is considered a preliminary examination of PSS properties, and further investigation is necessary to determine what the PSS scores measure and how effectively they do so.

All validation procedures concern the relationship between test performance and independently observable behavior (Anastasi, 1982). The type of validation currently being investigated is that of criterion-related validity, or the ability of scores to discriminate between groups of children with and without expected problem-solving deficits.

To demonstrate the ability of the PSS to discriminate between such groups, a sample must be identified with an expected high incidence of problem-solving deficits. According to a large body of neuropsychological research,
one such group is that of children with traumatic brain injury (TBI).

**Traumatic Brain Injury**

Children with traumatic brain injury (TBI) will be included in this study because of the high incidence and devastating nature of executive dysfunction in this population. TBI is defined by Michaud et al. (1993) as "physical damage to, or functional impairment of, the cranial contents from acute mechanical energy exchange (exclusive of birth trauma)" (p. 553).

The brain-skull contact involved in TBI most often results in frontal and temporal brain lesions (Bigler, 1990; Capruso & Levin, 1992). As noted in a previous section, the frontal lobe is most commonly associated with executive function in adults and, although further investigation is needed, a similar association in children was found by Levin and his colleagues (Levin et al., 1993) in preliminary research.

Levin, Amparo, Eisenberg, Williams, High, McArdle, and Weiner (1987) identified the most common areas of lesion in 76 patients with TBI ages 6 to 16 years using Magnetic Resonance Imaging (MRI). Forty percent of the patients had sustained lesions exclusively or primarily in the frontal region. An additional 15% of patients with primarily
extrafrontal damage suffered some damage to frontal regions as well. These results were consistent with previous research regarding the vulnerability of the frontal area to damage following closed head injury.

Neuropsychological deficits following pediatric TBI can be pervasive and devastating. Numerous researchers have found that the extent of dysfunction is significantly related to severity of injury (Ewing-Cobbs et al., 1986; Levin & Eisenberg, 1979). Injury severity is often determined by patients' score on the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974), which measures the stimulus required to induce eye opening, the best motor response, and the best verbal response (Bigler, 1990). Scores of 13-15 indicate mild injury, scores of 9-12 indicate moderate injury, and scores of 3-8 indicate severe injury. Duration of coma and post-traumatic amnesia (PTA) are also used to determine severity of injury.

Jaffe, Fay, Polissar, Martin, Shurtleff, Rivara, and Winn (1992) investigated neuropsychological outcome (at an average of three weeks post-resolution of PTA) among children ages 6 to 15 years with closed head injuries of varying levels of severity. Results indicated few lasting deficits in children with mild injury. Children with moderate to severe injury evidenced deficits compared to
uninjured controls in intellectual functioning, adaptive problem-solving, memory, academic performance, motor skills, and psychomotor skills. The authors found that, while moderately to severely injured children retained relatively intact intellectual and problem-solving skills (the latter measured by the CAT), they were unable to use these skills as quickly and efficiently as their uninjured peers.

Although some studies have found relatively few lasting neuropsychological deficits in children with mild TBI (Jaffe et al., 1992), others note that even mild head injury has resulted in significant and lasting problems (Rourke, et al., 1986). Children with no loss of consciousness or relatively brief coma have demonstrated measurable, although sometimes subtle, neuropsychological impairment not easily detectible without careful neuropsychological assessment (Levin & Eisenberg, 1979; Klonoff, Clark, & Klonoff, 1993). Even with careful clinical evaluation, the highly structured nature of the typical neuropsychological assessment is often less useful than observations in naturalistic settings in detecting the deficits in organization, planning, and follow-through seen in many patients with TBI (Ylvisaker & Szekeres, 1989).
Chadwick, Rutter, Shaffer, and Shrout (1981) conducted a longitudinal study of cognitive outcome following pediatric head injury. The authors compared the neuropsychological functioning of children ages 5 to 14 with severe head injury to a matched group (age, sex, parental occupation) of children with accidental orthopedic trauma without head injury. The children were tested shortly after resolution of post-traumatic amnesia, at 4 months, at 1 year, and at 2 1/4 years. On initial evaluation, the children with TBI scored significantly lower than the control group on intellectual measures and virtually all neuropsychological measures. By 4 month follow-up, the head injury group evidenced significant differences on only six of the measures. By final follow-up at 2 1/4 years post-injury, significant impairment was found in three tests which reflected lasting deficits in response speed, visuomotor skills and visuospatial skills.

In a study of children and adolescents who sustained closed head injury, Levin and Eisenberg (1979) conducted neuropsychological assessments six months post-injury. As in other studies, the extent of neuropsychological deficit found was directly related to injury severity. Pervasive neuropsychological deficits were found in the six months following CHI. Memory deficits predominated and 1/4 to 1/3
of the children evidenced deficits in each of the other areas tested (language, memory, visuospatial skills, somatosensory skills, and motor skills).

Michaud et al. (1993) reviewed common sequelae of pediatric TBI. The authors described common neuropsychological findings in children with severe TBI, including deficits in attention, memory, information processing, motor speed, problem-solving skills, abstraction skills, organizational skills, and judgment.

Nici and Reitan (1987) concluded from their extensive study of children with TBI that executive skills such as abstract thinking, logical analysis, flexibility of thought, speed in comprehending and analyzing complex situations are significantly impaired following TBI, and these higher-order deficits are often neglected when determining areas for targeted remediation, and brain-retraining efforts, should be focused on these deficits. While not all children with traumatic brain damage suffer severe executive dysfunction, the available research indicates that "conceptual, abstraction, and reasoning deficits are extremely prominent in brain-damaged children as compared with normal children, and (other abilities) are not as consistently impaired" (Reitan and Wolfson, 1992, p. 282).
Although standardized test scores indicate that many of these executive deficits remit over time, Boll (1983) found that, even with mild head injury, subtle and seemingly transient problems with attention, behavior, and information processing may result in enduring difficulties in terms of children’s achievement and self-confidence (Boll, 1983). The predominance of executive dysfunction and its debilitating effects, at least in the earlier stages of TBI recovery, justify the inclusion of this group in this study examining differences in conceptualization skills and problem-solving response types in children with and without expected executive deficits.

Purpose

The purpose of this study was to determine whether the PSS can effectively discriminate between children with and without TBI. Results indicating that children with TBI make greater CAT-I Total Errors (both the traditional and the PSS measure) than children without injury would be further evidence that TBI does result in overall executive dysfunction in children 9 to 14 years of age.

Results indicating differences in specific types of errors made by children with and without TBI would imply that these groups differ from each other in the cognitive
processes used and the type of errors made in problem-solving, and that PSS variables effectively discriminate between the two groups. This would be preliminary evidence of the criterion-related validity of the Process Scoring System in discriminating between children with and without expected executive dysfunction. Should the two groups be similar, as expected, in the number of "Other Errors" made, this would imply that non-specific, random errors are equally likely in both groups.

Should further study support the ability of the PSS to distinguish problem-solving differences between children with and without executive dysfunction, the PSS may eventually be an effective means of gaining specific, process-related information about children's problem-solving and contribute to more individualized and meaningful remediation of executive dysfunction.

Hypotheses

Based on the literature reviewed above, the research hypotheses of the current study were as follows:

Hypothesis 1. Children with TBI will perform significantly poorer (score higher) than children with no neurological impairment on the commonly-used CAT-I Total Error Score (using all subtests).
Hypothesis 2. Children with TBI will perform significantly poorer (score higher) than children with no neurological impairment on the following Process Scoring System variables: Trials to Learn Concepts, Total Errors (4 subtests), Perseverative Responses, Perseverative Errors, Generalization Errors, and Failure to Maintain Set.

Hypothesis 3. Children with TBI will perform significantly poorer (score lower) than children with no neurological impairment on Categories Achieved.

Hypothesis 4. Children with TBI will not score significantly differently from children with no neurological impairment on the PSS variable Other Errors.
CHAPTER II

METHOD

Participants

Twenty-four children without suspected neurological deficits were tested for inclusion in the control group of this study. Of these, two were excluded for estimated IQ scores based on the Wechsler Intelligence Scale for Children-Third Edition (WISC-III; Wechsler, 1991) greater than two standard deviations above the mean, one was excluded for lack of socio-economic status (SES) data, and one was excluded for indication of past learning problems on a Parent Questionnaire.

Twenty children were included in the final control sample. Eight of the children were female (40%) and twelve were male (60%). The average age was 12.5 years and ranged from 9.9 to 14.7 years. The average grade level was 6 and ranged from 3 to 8. The average SES level for this group was 54.8, with a range of 36 to 66 (Hollingshead, 1975). Eighteen of the children were students in a large urban school district and two of the children were students in a suburban school district. A summary of demographic

44
information for children without suspected neuropsychological impairment is provided in Table 1, Appendix E.

The clinical files of 21 children with TBI were reviewed for inclusion in this study, with one excluded for lack of SES data. Twenty children with TBI were included in the final sample. Eleven of the children were female (55%) and nine were male (45%). The average age was 11.7 years and ranged from 9.5 to 14.6 years. The average grade level was 5.75 and ranged from 4 to 9. The average SES level for this group was 44.5, with a range of 27 to 66. A summary of demographic information for children with TBI is provided in Table 2, Appendix E.

The average length of coma of children in this group was 10.12 days and ranged from no coma to 49 days. Five children experienced no or brief loss of consciousness, and were considered to have mild TBI. Three children sustained damage primarily frontal lobe damage, and three sustained frontal damage along with damage in other areas. The remainder of the children sustained damage in combinations of other brain areas. Localization of damage in this study was obtained by the examining neuropsychologist based on medical records reporting X-ray, CT scan, or MRI results, on parent report, on location of external injuries, or on
neuropsychological test results. The average age at injury was 8.3 years and ranged from 2 to 13.9 years. The average number of years since injury was 3.5 years and ranged from .1 to 8.8 years. Eight of the children sustained injury as pedestrians hit by vehicles, seven were passengers in motor vehicle accidents, three sustained falls, and two sustained blows to the head by objects (a metal spike and a swing set pole). A summary of injury information for children with TBI is provided in Table 3, Appendix E.

**Procedure**

Normally-achieving children in a large urban school district (n = 18) and a suburban school district (n = 2) served as participants in the control group of this study. Information for 18 of these children was collected from the research files of an area neuropsychologist who collected the data as part of ongoing research in a large urban public school system. In collecting data for these children, area schools were selected which represented a geographic and socio-economic cross-section of the district. Grades one to seven were targeted. Following approval by the school principal, individual teachers were contacted and asked to select students who were achieving at an average level and who were not suspected of having learning or emotional difficulties. A letter was sent to
parents of these children describing the study (Appendix B), and an informed consent form was obtained from consenting parents (Appendix C).

A brief questionnaire was completed by each consenting parent to ensure that participants had no history of head injury involving loss of consciousness, severe learning or neurological problems, or relevant medical conditions (Appendix D). Children meeting all criteria were individually administered the Vocabulary and Block Design subtests of the Wechsler Intelligence Scale for Children-Third Edition (WISC-III; Wechsler, 1991) by a trained examiner to ensure at least average intellectual functioning. These subtests were administered as they are the verbal and performance subtests most highly correlated with overall intelligence (Sattler, 1988). Estimated WISC-III Full Scale Deviation Quotients were obtained for each child (Sattler, 1992), and children with quotients greater than two standard deviations above or below the mean were excluded in order to obtain a sample with approximately average intelligence. The CAT-I was individually administered in the children's home school under standardized testing conditions. Children from the suburban district were tested in a quiet room in their home, under
otherwise standard testing conditions. Process Scoring System scores were computed.

Data for subjects with TBI were obtained from clinical files of children who have undergone neuropsychological evaluation following traumatic brain injury. CAT-I protocols, demographic information, injury-related information, and measures of intellectual functioning were obtained from the files, with all identifying information deleted. Children with severe medical illnesses or pre-injury learning, behavioral, psychiatric, or neurological problems were excluded. CAT-I responses were re-scored according to the Process Scoring System.

A modification of the Hollingshead Four Factor Index of Social Status (Hollingshead, 1975) was used to obtain SES levels for each child. Because only two factors (head of household's years of education and occupation) were available for most of the children, these values were weighted and summed according to the Four Factor procedure to obtain SES levels. For four of the children with TBI, only the clinician's estimate of SES was available, and corresponding Hollingshead scores were computed.
CHAPTER III

RESULTS

In a preliminary analysis, t-tests were used to determine whether significant differences in age and socio-economic status (SES) existed between the two groups. A significant group difference was found in SES ($t = -2.85, df = 38, p < .007$), but not in age ($t = -1.78, df = 38, p > .08$). Therefore, only SES was used as a covariate in subsequent analyses.

The mean Total Error scores (6 subtests) for the uninjured and the TBI groups are provided in Tables 4 and 5, respectively. The mean Total Error score for the uninjured children was 26.35 ($SD = 10.88$). This score approached one standard deviation below (better than) the normative mean for this age group ($M = 38.9, SD = 14.5$; Knights & Norwood, 1980). The mean Total Error score for the children with TBI was 43.00 ($SD = 22.06$), which is well within normal limits for this age group ($M = 38.9, SD = 14.5$; Knights & Norwood, 1980).

The research hypotheses employed separate one-way analyses of covariance for the commonly-used CAT-I Total Error score and the PSS subscores. The independent variable
for each analysis was group membership (children with TBI versus children without TBI), the dependent variable was the individual PSS subscore, and the covariate was SES. A summary of ANCOVA results comparing uninjured children to the entire group of children with TBI is provided in Table 6.

The first research hypothesis stated that children with TBI would score higher (poorer) than children without TBI on the commonly used Total Error score using all subtests (TE6). The analysis of covariance revealed a significant main effect for group membership on this variable, $F(1, 37) = 4.64, p < .038$, supporting the first hypothesis.

The second hypothesis stated that children with TBI would score higher (poorer) on the PSS Trials to Learn Concepts variable, on the problem-solving response type variables (Perseverative Responses (PR), Perseverative Errors (PE), Generalization Errors (GE), and Failure to Maintain Set (FM)), and on the Total Error score using four subtests (TE4). The mean scores on each variable by group membership are provided in Table 4, Appendix E. A significant main effect was found for Total Errors only, $F(1, 37) = 4.11, p < .05$. Children with TBI ($M = 39.05$) had significantly higher error scores than children without TBI.
significantly poorer than children without TBI on the concept formation variable Trials to Learn Concepts or on any of the problem-solving response type subscores.

The third hypothesis stated that children with TBI would score lower (poorer) on the PSS concept formation variable Categories Completed. No significant difference was found between groups, \( F(1, 37) = .32, p > .57 \), and this hypothesis was not supported.

The fourth hypothesis stated that no significant difference would be found between groups on the PSS Other Errors score. The ANCOVA supported this hypothesis, \( F(1, 37) = 3.71, p > .06 \).

**Exploratory Analyses**

Several researchers have found that neuropsychological impairment following head injury is significantly related to severity of injury (Ewing-Cobbs et al., 1986; Jaffe et al., 1992; Levin & Eisenberg, 1979). The present study included five children with mild head injury (experiencing no or minimal loss of consciousness). To determine whether inclusion of these children affected the results of this study, separate analyses were performed using only children with moderate to severe injury.

The mean PSS scores for this more severely injured subgroup (\( n = 14 \)) are provided in Table 7, and a summary of
the univariate F-tests using the more severely injured group in PSS variables is provided in Table 8. The more severely injured group scored higher than uninjured children on PSS Total Errors, $F(1, 31) = 9.06, p < .005$ at a level of probability substantially lower than that using the entire group (p < .05). Unlike the entire TBI group, the more severely injured group made significantly more Perseverative Errors, $F(1, 31) = 8.23, p < .007$, and Other Errors, $F(1, 31) = 7.61, p < .01$, than did the uninjured group.
CHAPTER IV

DISCUSSION

The purpose of this study was to examine whether the PSS subscores effectively differentiate between children with and without suspected executive dysfunction. The finding of a significant group difference in Total Error scores is consistent with previous findings in adults and children (Reed, Reitan, & Klove, 1965; Reitan & Wolfson, 1988; Selz, 1977). Further evaluation of the PSS subscores is complicated by the finding that the TBI group in this study did not differ from the normative mean in overall problem-solving ability and that the normally-achieving group scored substantially higher than the normative mean. The significant difference in Total Error scores may reflect the unusually high abilities of the comparison group. The finding of no specific deficits in this group of children with TBI may be due to their not being representative of children with executive dysfunction. This may be explained by the inclusion of children with mild TBI, some having experienced no loss of consciousness.

The exploratory analysis using only children with more severe TBI was conducted to examine the effect of the
inclusion of mildly injured children. The resulting probability level for the Total Error score analysis decreased substantially ($p < .05$ to $p < .005$), indicating a stronger effect in the more severely injured group. More importantly, unlike the more heterogeneous group, the more severely injured group made significantly more Perseverative Errors ($p < .007$) and more Other Errors ($p < .01$) than did the uninjured group.

The higher Perseverative Errors scores among children with more severe TBI suggests that this group has a greater tendency than uninjured children to become "stuck" in an unsuccessful response type. Uninjured children scored from 2 to 13, with lower scores indicating better performance. The entire TBI group scored from 2 to 20, and the more severely injured TBI subgroup scored from 4 to 20. None of the uninjured group scored above 13, while 25% of the entire TBI group and 36% of the more severely injured TBI subgroup did so. None of the severe TBI subgroup made fewer than 4 Perseverative Errors, while 15% of the entire TBI group and 20% of the uninjured group did so.

The Perseverative Errors finding is consistent with numerous studies of brain injury using the Perseverative scores of the WCST (Chelune & Thompson, 1987; Drewe, 1974). These findings, along with the high correlation found between these scores in children with learning disabilities
(Silver, Pennett, & Koneru, 1994), suggest that the Perseverative Error scores of the WCST and CAT-I may indeed measure the same construct.

The higher Other Errors score in this group may reflect the random responses and lack of strategy (even ineffective strategy) often found in children with executive dysfunction (Denckla, 1994; Lezak, 1995; Luria, 1966; Rourke, Fisk & Strang, 1986; Snow, 1992; Welsh, Pennington, & Groisser, 1991). None of the children with TBI made fewer than 9 of these random errors, while 25% of the uninjured children made fewer than 9 such errors. None of the uninjured children made more than 38 Other Errors, while 20% of the entire TBI group and 28% of the TBI subgroup made more than 38 such errors.

No significant group differences were found in the remaining PSS variables. However, qualitative analysis reveals a pattern of decreased performance in children with TBI in most of these variables. For example, Categories Completed scores indicate that, overall, children with TBI were able to correctly identify and apply the concepts in as many subtests as uninjured children. However, the restricted range of responses may have decreased the likelihood of finding significant differences. Scores of 0 to 4 are possible on the Categories Completed variable, with 4 being the best performance. No child in the
with 4 being the best performance. No child in the uninjured group scored below 2 Categories, while one child in each of the injury groups completed only one category. Fifty-five percent of the uninjured children made a perfect score, while only 40% of the entire TBI group and 36% of the more severely injured TBI subgroup did so.

Scores on the Trials to Learn Concepts variable indicated that, overall, children with TBI needed no more attempts (and therefore feedback) to learn concepts than uninjured children. Scores on this variable can range from 20 to 160, with lower scores indicating better performance. Scores in the uninjured group ranged from 24 to 93, with 60% of children scoring below 60. Scores in the entire TBI group ranged from 28 to 116, with 50% of children scoring below 60. Scores in the subgroup of more severely injured children ranged from 30 to 116, with only 29% of children scoring below 60.

Scores on the Failure to Maintain Set variable indicate that children with TBI are not more likely to lose track of a successful problem-solving concept than are uninjured children. Scores of 0 to 18 are possible on the Failure to Maintain Set variable, with lower scores indicating better performance. The percentage of children
with no FM errors was 60%, 25%, and 35% for the uninjured, TBI, and severe TBI subgroup, respectively.

Generalization Errors indicate that children with TBI are not more likely than uninjured children to become confused when stimulus properties change. The range of scores possible on the Generalization Errors variable is 0 to 20, with lower scores indicating better performance. Interestingly, the only score of 0 was obtained by a child in the more severely injured TBI subgroup. The worst score, 5 Generalization Errors, was as obtained by a child in the entire TBI group. The percentage of children scoring in the highest range obtained in this study (4-5 errors) was 20%, 10%, and 7% for children in the uninjured, total TBI, and severe TBI subgroup, respectively. Contrary to expectations, uninjured children in this study appeared to make more Generalization Errors than children with TBI.

Despite a lack of significant group differences in many of these variables, a pattern of decreased performance in children with TBI is evident (in all variables except that of Generalization Errors, in which performance appears to be slightly better in children with TBI in this study). These patterns in the expected direction indicate that differences may exist which did not reach statistical
significance in this study but that might be important to investigate further.

Several researchers have suggested that even with mild TBI, subtle executive dysfunction exists and often goes undiagnosed due to the inadequacy of available measures (Boll, 1983; Ylvisaker & Szekeres, 1989). Based on the current sample, the PSS was unable to identify discrete executive problems in a group including mildly injured children, and may be more useful in the assessment of more severely injured children.

This study has several limitations which may have affected the results. The average Total Error score of the children with TBI (even the more severely injured group) fell within normal limits for their age group, indicating that this sample may not be one with high levels of executive dysfunction. The uninjured children, however, scored substantially better than the mean for their age group on Total Errors and on estimated IQ, and may have represented a group of high rather than average achievers. The significant Total Error score difference may result from this discrepancy rather than from deficits in the TBI group. Additional limitations were the relatively low number of participants and the lack of matching groups in terms of age and SES.
The relatively low number of children with specific frontal lobe damage (n = 6, 30%), may have reduced the likelihood of significant subscore findings. Another possibly confounding factor was the lack of effort made to exclude uninjured children whose CAT-I Total Error score might have fallen within the "impaired" range. Such children may have had unrecognized executive deficits and introduced error into the current results.

The results of this investigation of the criterion-related validity of the CAT-I Process Scoring System are inconclusive. Some evidence emerged that two discrete PSS variables (Perseverative Errors and Other Errors) effectively discriminate between more severely injured children and their uninjured peers. However, the limitations of this study discussed above may have affected the findings and decreased the chances of obtaining significant results.

Future research using children with documented, rather than suspected, executive dysfunction would help clarify differences between impaired and unimpaired groups. In addition, using larger sample sizes with a greater percentage of children with identified frontal damage, eliminating uninjured children scoring in the "impaired" range on the CAT-I Total Error score, and matching children
by age and SES might prove useful. Such research will be necessary in order to determine the usefulness of the PSS in identifying specific executive deficits and in contributing to individualized and meaningful rehabilitative and educational efforts.
APPENDIX A

SAMPLE CAT-I STIMULUS ITEMS
APPENDIX B

LETTER TO PARENTS
January 17, 1997

Dear Parent(s) or Guardian(s):

Your child's school has been selected to participate in a project designed to help us understand how children solve problems in their daily lives. This project is being coordinated by the University of Texas Southwestern Medical Center at Dallas and has been reviewed and approved by the Dallas Independent School District.

Your child was identified by his/her teacher as doing well in school. If you decide to participate in our project, you will help us to learn about the development of good problem-solving, which will also help us to learn about children who may not be good problem solvers (such as children who have learning disabilities or attention deficit disorder).

You can help us in the following ways:

1) Simply take a few minutes to fill out the two short questionnaires we included in this packet. A postage-paid envelope is provided for the return of the questionnaires. Your information will be kept confidential.

2) If you are willing to allow your child to participate in Part 2 of our project, sign the pink consent form and return it in the same envelope.

For Part 2, we will be selecting a group of children based on age to participate in several problem-solving tasks. These tasks are like games, they will take about an hour to complete, and most children think they are fun to do. If you are willing to allow your child to participate, we ask that you sign the consent form provided and return it along with the questionnaires. If your child is selected to participate, you will be contacted by phone by our staff within the next month to tell you more about our study. You will have the opportunity to ask any questions you may have. After the study is completed we will send you information about your child's scores and the results of our study, if you wish.

Even if you do not want your child to participate, you can help by returning the two questionnaires. Thank you for taking the time and effort to help us with this important project. If any further information is needed, please feel free to contact us at (214) 648-1740.

Sincerely,

Laura Goulden
Doctoral Candidate in Clinical Psychology

Cheryl Silver, Ph.D.
Assistant Professor
APPENDIX C

INFORMED CONSENT FORM
THE UNIVERSITY OF TEXAS SOUTHWESTERN MEDICAL CENTER AT DALLAS
SUBJECT CONSENT TO PARTICIPATE IN RESEARCH

TITLE OF STUDY:
Children's Problem-Solving and Adaptive Thinking: An Ecological Study

SPONSOR:
UT Southwestern

INVESTIGATORS: OFFICE PHONE #: NIGHT/WEEND #
Cheryl H. Silver, Ph.D. 648-1740 648-1740

You are being asked to participate in a research study. Persons who participate in research are entitled to certain rights. These rights include but are not limited to the subject's right to:

1. Be informed of the nature and purpose of the research;
2. Be given an explanation of the procedures to be followed in the research, and any drug or device to be utilized;
3. Be given a description of any attendant discomforts and risks to be reasonably expected;
4. Be given a disclosure of any benefits to the subject to be reasonably expected, if applicable;
5. Be given a disclosure of any appropriate alternatives, drugs, or devices that might be advantageous to the subject, their relative risks and benefits;
6. Be informed of the alternatives of medical treatment, if any, available to the subject during or after the experiment if complications arise;
7. Be given an opportunity to ask any questions concerning the research and the procedures involved;
8. Be instructed that consent to participate in the research may be withdrawn at any time, and the subject may discontinue participation without prejudice;
9. Be given a copy of the signed and dated consent form;
10. And be given the opportunity to decide to consent or not to consent to participate in research without the intervention of any element of force, fraud, deceit, duress, coercion, or undue influence on the subject's decision.

Page 1 of 3 Pages
TITLE OF STUDY:
Children's Problem-Solving and Adaptive Thinking: An Ecological Study

You have the right to privacy. All information that is obtained in connection with this study that can be identified with you will remain confidential within the limits of State Law. Information gained from this study that can be identified with you will be released only to the investigators, and if appropriate, to your physician and the sponsors of the study. For studies regulated by the Food and Drug Administration (FDA), there is a possibility that the FDA may inspect your records. The results of this study may be published in scientific journals without identifying you by name.

In addition, the records of your participation in this study may be reviewed by members and staff of the Institutional Review Board, and you may be contacted by a representative of the Board for information about your experience with this study. If you wish, you may refuse to answer any questions the Board may ask of you. We also would like for you to understand that your record may be selected at random (as by drawing straws) for examination by the Board to insure that this research project is being conducted properly.

Every effort will be made to prevent any injury that could result from this research. Compensation for physical injuries incurred as a result of participating in the research is not available. The investigators are prepared to advise you about medical treatment in case of adverse effects which you should report to them promptly. Phone numbers where the investigators may be reached are listed in the heading of this form.

If you have any questions about the research or about your rights as a subject, we want you to ask us. If you have questions later, or if you wish to report a research-related injury (in addition to notifying the investigator), you may call the Chairman of the Institutional Review Board during office hours at 214/648-2258.

Participation in this research study is entirely voluntary. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without affecting your status (as a patient, student, employee, etc.), or the medical care that you will receive. Under certain circumstances the study may be discontinued by the sponsor or the investigator.

Any significant new findings developed during the course of the research which may relate to your willingness to continue participation in this study will be provided to you.

YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP

(02/93)
Children’s Problem-Solving

PURPOSE: This study will look at children’s ability to solve problems, both in daily life and on tests. Children from ages 5 to 14 years are the focus of this study. The first part of the study asks you to fill out a questionnaire. If your child is chosen for the second part, he or she will be asked to take one or more problem-solving tests that will take no more than 90 minutes to complete.

WHAT YOU/YOUR CHILD WILL BE ASKED TO DO: You are being asked to fill out a short questionnaire about how your child acts in daily life. Based on your child’s age, he or she may be chosen to take one or more problem-solving tests. These tests are like games; for example, one test involves matching shapes and another involves stacking colored balls. Most children think that these tests are fun to do.

POSSIBLE RISKS/DISCOMFORTS: No risks to your child are expected.

POSSIBLE BENEFITS: This study will help us to learn about how children of different ages solve problems. By filling out the questionnaires and allowing your child to take the tests, you will be adding to our knowledge. After the study is completed, we will tell you about your child’s scores on the questionnaires and tests, and we will tell you the results of our study, if you wish.

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE IN THIS STUDY. YOU SHOULD NOT SIGN UNTIL YOU UNDERSTAND ALL THE INFORMATION PRESENTED IN THE PREVIOUS PAGES AND UNTIL ALL YOUR QUESTIONS ABOUT THE RESEARCH HAVE BEEN ANSWERED TO YOUR SATISFACTION. YOUR SIGNATURE INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE AND TO ALLOW YOUR CHILD TO PARTICIPATE, HAVING READ (OR BEEN READ) THE INFORMATION PROVIDED ABOVE.

<table>
<thead>
<tr>
<th>Name of child</th>
<th>Age</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Signature of Legally Responsible Representative

<table>
<thead>
<tr>
<th>Relationship to Child</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

Signature of Person Obtaining Consent

<table>
<thead>
<tr>
<th>Signature of Investigator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
PARENT-CARETAKER QUESTIONNAIRE

The following information will be helpful in determining if your child is eligible for this particular study of children's problem solving skills. This information will remain strictly confidential; if your child is selected to participate in this study, this information will be coded and entered into a database with all identifying data removed.

Name of child: ___________________________ Sex ______ Name of School: ___________________________

Date of birth: __________ Age: ______ Grade: ______

Name of parent/s completing this form: __________________________________________________________

Parent's mailing address: _________________________________________________________________

Parent's phone number: (H) ______________________ (W) ______________________

Is your child enrolled in any resource programming or special ed. classes? ______
If yes, please describe _________________________________________________________________

Has your child ever been diagnosed with...

a learning disability? ______
If yes, please describe _________________________________________________________________

a attention deficit/hyperactivity disorder? ______

a developmental disorder (such as autism, Tourette's, or mental retardation)? ______

Has your child ever been diagnosed or treated for:

a seizure disorder? ______

Has your child ever suffered a hit to the head (from a car accident, fall, or fight) that resulted in a loss of consciousness or "blacking out"? ______
If you answered "Yes" to the last question, for how long was your child unconscious, and what was the nature of the injury: ________________________________

Is your child currently being treated for any major medical disorder? Y N

If you answered "Yes" to the last question, please describe the nature of the illness: ________________________________

Is your child currently taking any prescription medications? Y N
If so, please list: ________________________________

Is your child currently taking any over-the-counter (non-prescription medications)? Y N
If so, please list: ________________________________

The following questions are necessary in order to determine demographic information:

Who is currently living in the home: ________________________________

Years of school mother has completed: ________________________________

Mother's occupation: ________________________________

Years of school father has completed: ________________________________

Father's occupation: ________________________________

Ethnicity/race of child: ________________________________

Thank you for taking the time to fill this out, please return this in the self-addressed, stamped envelope that has been provided.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>Percent</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.08</td>
<td></td>
<td>12.45</td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td>1.17</td>
<td></td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td>SES</td>
<td>11.02</td>
<td></td>
<td>54.75</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>8</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>17</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>African-American</td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian-American</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>2</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2

Summary of Entire TBI Group Demographic Information

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>Percent</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td>11.71</td>
<td>1.53</td>
</tr>
<tr>
<td>Grade</td>
<td></td>
<td></td>
<td>5.75</td>
<td>1.55</td>
</tr>
<tr>
<td>SES</td>
<td></td>
<td></td>
<td>44.5</td>
<td>11.74</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>9</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>11</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>17</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>African-American</td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian American</td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3

Summary of Entire TBI Group Injury Information

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>Percent</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at Injury</td>
<td>8</td>
<td>40</td>
<td>8.20</td>
<td>3.03</td>
</tr>
<tr>
<td>Years Since Injury</td>
<td></td>
<td></td>
<td>3.48</td>
<td>2.94</td>
</tr>
<tr>
<td>Length of Coma (days)</td>
<td></td>
<td></td>
<td>10.12</td>
<td>10.80</td>
</tr>
</tbody>
</table>

Cause of Injury

<table>
<thead>
<tr>
<th>Cause of Injury</th>
<th>Frequency</th>
<th>Percent</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian Struck by Vehicle</td>
<td>8</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Passenger in Motor Vehicle Accident</td>
<td>7</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Falls</td>
<td>3</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Blow to Head with Object</td>
<td>2</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
Table 4

Summary of Uninjured Group Descriptive Test Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>WISC-III Estimated IQ</td>
<td>109.85</td>
<td>8.12</td>
<td>94-120</td>
</tr>
<tr>
<td>CAT-I Total Errors (6 subtests)</td>
<td>26.35</td>
<td>10.88</td>
<td>8-54</td>
</tr>
<tr>
<td>PSS Concept Formation Scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Categories Completed</td>
<td>3.45</td>
<td>.69</td>
<td>2-4</td>
</tr>
<tr>
<td>Trials to Learn Concepts</td>
<td>53.20</td>
<td>17.85</td>
<td>24-93</td>
</tr>
<tr>
<td>PSS Problem-Solving Response Types</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Errors</td>
<td>25.35</td>
<td>10.88</td>
<td>8-49</td>
</tr>
<tr>
<td>Perseverative Responses</td>
<td>7.35</td>
<td>3.79</td>
<td>2-17</td>
</tr>
<tr>
<td>Perseverative Errors</td>
<td>5.55</td>
<td>2.56</td>
<td>2-13</td>
</tr>
<tr>
<td>Generalization Errors</td>
<td>2.20</td>
<td>1.15</td>
<td>1-4</td>
</tr>
<tr>
<td>Failure to Maintain Set</td>
<td>.65</td>
<td>1.04</td>
<td>0-4</td>
</tr>
<tr>
<td>Other Errors</td>
<td>17.15</td>
<td>10.48</td>
<td>1-38</td>
</tr>
</tbody>
</table>
Table 5

Summary of Entire TBI Group Descriptive Test Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>WISC-III Estimated IQ</td>
<td>93.50</td>
<td>21.48</td>
<td>54-129</td>
</tr>
<tr>
<td>CAT-I Total Errors (6 subtests)</td>
<td>43.00</td>
<td>22.06</td>
<td>15-93</td>
</tr>
<tr>
<td>PSS Concept Formation Scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Categories Completed</td>
<td>3.1</td>
<td>.91</td>
<td>1-4</td>
</tr>
<tr>
<td>Trials to Learn Concepts</td>
<td>63.00</td>
<td>22.59</td>
<td>28-116</td>
</tr>
<tr>
<td>PSS Problem-Solving Response Types</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Errors</td>
<td>39.05</td>
<td>19.04</td>
<td>13-79</td>
</tr>
<tr>
<td>Perseverative Responses</td>
<td>10.70</td>
<td>6.63</td>
<td>15-93</td>
</tr>
<tr>
<td>Perseverative Errors</td>
<td>8.45</td>
<td>5.11</td>
<td>2-20</td>
</tr>
<tr>
<td>Generalization Errors</td>
<td>2.05</td>
<td>1.19</td>
<td>0-5</td>
</tr>
<tr>
<td>Failure to Maintain Set</td>
<td>1.05</td>
<td>.89</td>
<td>1-3</td>
</tr>
<tr>
<td>Other Errors</td>
<td>27.95</td>
<td>15.16</td>
<td>9-63</td>
</tr>
</tbody>
</table>
Table 6

Summary of ANCOVA Results on the PSS Scores - Uninjured Versus Entire TBI Group

<table>
<thead>
<tr>
<th>Variable</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TE6</td>
<td>1438.06</td>
<td>1</td>
<td>1438.06</td>
<td>4.64</td>
<td>.038</td>
</tr>
<tr>
<td>TE4</td>
<td>975.02</td>
<td>1</td>
<td>975.02</td>
<td>4.11</td>
<td>.050</td>
</tr>
<tr>
<td>CC</td>
<td>.20</td>
<td>1</td>
<td>.20</td>
<td>.32</td>
<td>.574</td>
</tr>
<tr>
<td>TL</td>
<td>375.91</td>
<td>1</td>
<td>375.91</td>
<td>.91</td>
<td>.347</td>
</tr>
<tr>
<td>PR</td>
<td>51.94</td>
<td>1</td>
<td>51.94</td>
<td>1.79</td>
<td>.190</td>
</tr>
<tr>
<td>PE</td>
<td>51.54</td>
<td>1</td>
<td>51.54</td>
<td>3.10</td>
<td>.086</td>
</tr>
<tr>
<td>GE</td>
<td>1.00</td>
<td>1</td>
<td>1.00</td>
<td>.74</td>
<td>.396</td>
</tr>
<tr>
<td>FM</td>
<td>.30</td>
<td>1</td>
<td>.30</td>
<td>.33</td>
<td>.567</td>
</tr>
<tr>
<td>OE</td>
<td>626.71</td>
<td>1</td>
<td>626.71</td>
<td>3.71</td>
<td>.062</td>
</tr>
</tbody>
</table>

Note. TE6 = Total Errors (6 subtests); TE4 = Total Errors (4 subtests); CC = Categories Completed; TL = Trials to Learn Concepts; PR = Perseverative Responses; PE = Perseverative Errors; GE = Generalization Errors; FM = Failure to Maintain Set; OE = Other Errors

Table 7
### Summary of More Severely Injured TBI Subgroup Descriptive Test Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>WISC-III Estimated IQ</td>
<td>88.93</td>
<td>18.41</td>
<td>54-112</td>
</tr>
<tr>
<td>CAT-I Total Errors (6 subtests)</td>
<td>49.21</td>
<td>22.39</td>
<td>16-93</td>
</tr>
<tr>
<td>PSS Concept Formation Scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Categories Completed</td>
<td>3.00</td>
<td>.96</td>
<td>1-4</td>
</tr>
<tr>
<td>Trials to Learn Concepts</td>
<td>69.93</td>
<td>22.75</td>
<td>30-116</td>
</tr>
<tr>
<td>PSS Problem-Solving Response Types</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Errors</td>
<td>44.5</td>
<td>19.27</td>
<td>16-79</td>
</tr>
<tr>
<td>Perseverative Responses</td>
<td>12.5</td>
<td>6.62</td>
<td>4-24</td>
</tr>
<tr>
<td>Perseverative Errors</td>
<td>9.93</td>
<td>5.14</td>
<td>4-20</td>
</tr>
<tr>
<td>Generalization Errors</td>
<td>1.93</td>
<td>1.07</td>
<td>0-4</td>
</tr>
<tr>
<td>Failure to Maintain Set</td>
<td>.86</td>
<td>.86</td>
<td>0-3</td>
</tr>
<tr>
<td>Other Errors</td>
<td>32.36</td>
<td>15.55</td>
<td>10-63</td>
</tr>
</tbody>
</table>
Table 8

Summary of ANCOVA Results on the PSS Scores - Uninjured Versus Severe TBI Subgroup

<table>
<thead>
<tr>
<th>Variable</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TE6</td>
<td>2863.94</td>
<td>1</td>
<td>2863.94</td>
<td>9.66</td>
<td>.004</td>
</tr>
<tr>
<td>TE4</td>
<td>2050.72</td>
<td>1</td>
<td>2050.72</td>
<td>9.06</td>
<td>.005</td>
</tr>
<tr>
<td>CC</td>
<td>.85</td>
<td>1</td>
<td>.85</td>
<td>1.28</td>
<td>.267</td>
</tr>
<tr>
<td>TL</td>
<td>1503.59</td>
<td>1</td>
<td>1503.59</td>
<td>3.67</td>
<td>.065</td>
</tr>
<tr>
<td>PR</td>
<td>143.09</td>
<td>1</td>
<td>143.09</td>
<td>5.31</td>
<td>.025</td>
</tr>
<tr>
<td>PE</td>
<td>124.16</td>
<td>1</td>
<td>124.16</td>
<td>8.23</td>
<td>.007</td>
</tr>
<tr>
<td>GE</td>
<td>.66</td>
<td>1</td>
<td>.66</td>
<td>.51</td>
<td>.479</td>
</tr>
<tr>
<td>FM</td>
<td>2.00</td>
<td>1</td>
<td>2.00</td>
<td>.02</td>
<td>.887</td>
</tr>
<tr>
<td>OE</td>
<td>1273.31</td>
<td>1</td>
<td>1273.31</td>
<td>7.61</td>
<td>.010</td>
</tr>
</tbody>
</table>

Note. TE6 = Total Errors (6 subtests); TE4 = Total Errors (4 subtests); CC = Categories Completed; TL = Trials to Learn Concepts; PR = Perseverative Responses; PE = Perseverative Errors; GE = Generalization Errors; FM = Failure to Maintain Set; OE = Other Errors
REFERENCES


Chelune, G. J., Ferguson, W., Koon, R., & Dickey, T. O. (1986). Frontal lobe disinhibition in Attention Deficit
Disorder. Child Psychiatry and Human Development, 16(4), 221-234.


Neuropsychological Battery tests. The International Journal of Clinical Neuropsychology, 7(3), 164-166.


frontal lobes revisited (pp. 141-158). New York: IRBN Press.


