ARTICLES

Traumatic Brain Injury in Children and Adolescents: Academic and Intellectual Outcomes Following Injury

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This study was conducted to examine the impact of childhood traumatic brain injury (TBI) on intellectual and academic outcomes postinjury. A comprehensive assessment of cognition, achievement, learning, and memory was administered to 27 children and adolescents 6 to 8 years post-TBI. Findings revealed that parent ratings of premorbid achievement were a significant predictor of achievement postinjury, reiterating the importance of obtaining information from parents regarding their child’s functioning. Furthermore, severity of injury had a significant impact on nonverbal IQ performance. Children and adolescents with more severe head injuries used less effective learning strategies to encode and recall information. Findings are addressed in terms of implications for educators and educational programming for working with school-age children following a TBI.

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It has been estimated that 1 million children sustain traumatic brain injury (TBI) each year in the United States (Lehr, 1990) and that patients under the age of 18 years constitute the majority of victims of TBI (Gopinath & Narayan, 1992). The National Head and Spinal Cord Injury Survey (NHSCIS; Kalsbeek, McLaurin, Harris, & Miller, 1980) determined an average head injury incidence of 150 per 100,000 in children between the ages of 1 day and 4 years, and the incidence increased to 550 per 100,000 between the ages of 15 and 24 years. TBI occurs more often and more severely in males than females with a ratio ranging from 2:1 to 4:1 (Begali, 1992; Lehr, 1990).

Permanent deficits resulting from a TBI have significant ramifications for the education of children with such injuries. A minimum of 1 of every 550 school-age children each year will experience a TBI that can result in a long-term disability (Savage & Walcott, 1994). According to the Individuals with Disabilities Education Act (IDEA), students with TBI may receive appropriate identification (as a specific educational disability category) and receive appropriate services in the schools (Begali, 1992) and continues under current iterations of the law. Hux, Marquardt, Skinner, and Bond (1999) found that nearly 29% of students with reported TBIs had received special education services. They also found that the younger the child was at the time of injury, the more likely he or she was to receive special education services, suggesting educators are better attuned to identifying and diagnosing academic, behavioral, and social challenges in younger children than in adolescents.

School-age children who have sustained a TBI will require extraordinary effort from individuals in their school, home, and community. Overall, children sustaining a TBI endure cognitive deficits that are positively correlated with the severity of the injury, thus increasing the need for special education services (Donders, 1994). It has been well documented that TBI in children is often associated with working memory impairment (Kinsella et al., 1995; McDowell, Whyte, & D’Esposito, 1997), motor problems (Chaplin, Deitz, & Jaffe, 1993), language problems (i.e., pragmatics, verbal fluency, word finding, concept formation, verbal comprehension), and general cognitive problems (Chadwick, Rutter, Thompson, & Shaffer, 1981), as well as behavioral (Johnson & Balleny, 1996), affective (Stratton & Gregory, 1994), and social interaction deficits, such as reduced social skills (Stratton & Gregory, 1994).

Given the nature and sequelae of TBI, it is important for school personnel to acknowledge students will likely have changes in how they learn, think, feel, and interact following TBI and should anticipate these changes while planning for continued progress in learning (D’Amato & Rothlisberg, 1996; Utah TBI Task Force, 1994). Furthermore, “to meet the needs of students with brain injuries, educational specialists…must adjust their usual procedures for identification and treatment to accommodate the changes associated with recovery” (D’Amato & Rothlisberg, 1996, p. 673). Thus, increased understanding of initial as well as long-term outcomes following head injury by educational specialists is necessary to inform best practices.

Given the need to accurately understand head injury in children and adolescents, the aim of this study was to examine the long-term intellectual and academic outcomes of a cohort of children and adolescents following TBI. The emphasis was on exploring the relations among predictive factors, such as premorbid ability, age, severity of injury,
socio-economic status, and functioning (i.e., academic, intellectual, verbal learning, and memory) in children and adolescents following TBI 6 to 8 years following head injury. Current literature (i.e., studies on learning, memory, cognitive functioning, and academic achievement) suggests that deficits persist long-term in children and adolescents who are severely injured, whereas children and adolescents with a mild to moderate TBI showed fewer deficits and greater recovery (e.g., Arroyos-Jurado, Paulsen, Merrell, Lindgren, & Max, 2000; Kinsella et al., 1995; McDowell, Whyte, & D’Esposito, 1997). Most longitudinal studies have examined changes over short intervals (i.e., up to 2 years). Few studies have evaluated outcomes up to 8 years postinjury.

Researchers have argued that preinjury factors (e.g., intellectual and academic functioning) must be taken into account when evaluating outcomes following injury so as not to confound current performances with past capability. This study used a standardized instrument to assess preinjury academic functioning (i.e., Iowa Test of Basic Skills) that has not been used in any known study of TBI in school-age children. The use of premorbid standardized academic measures makes findings more relevant to outcomes in the school setting.

This study was conducted to determine the long-term impact of TBI on intellectual and academic outcomes and to determine which variables best predicted those outcomes 6 to 8 years following TBI. The following hypotheses were made:

1. Long-term academic functioning will be associated with severity of injury and lower socio-economic status as well as measures of premorbid ability.
2. Change in intellectual functioning following a TBI will be predicted best by measures of premorbid ability and achievement and incidence of psychiatric disorders.
3. Severity of injury, socio-economic status, premorbid ability, and achievement will be associated with specific aspects of learning and memory.

**METHOD**

**Participants**

Participants included consecutive admissions for TBI at a midwestern university hospital and other regional hospitals. Computerized axial tomography (CAT) scan on admission was used as a threshold criterion of TBI severity. Exclusion criteria included: (a) patients who had injuries so serious that they had not emerged from post-traumatic amnesia (PTA) 3 months following the injury; (b) penetrating TBI; (c) documented history of child abuse; (d) history of previous TBI involving hospitalization greater than one night; (e) history of mental retardation; (f) English as a second language; and (g) other acquired or congenital central nervous system disorder; preexisting acute or chronic serious illness.

Twenty-seven children and adolescents from an original cohort of 50 participants who suffered a TBI during the years of 1994 to 1997 participated in this study. Comprehensive academic, social, and neuropsychological assessments were conducted at “baseline” (as
soon as possible following the injury) and follow-up assessments at 3, 12, 24, and 72–96 months after the TBI. The participants were between 6 and 14 years of age at time of injury \((m = 10.4)\) and 63% were male. Mean age of participants at the time of this follow-up assessment was 16.4. Five children were in middle school (6th through 8th grade), 12 students in high school (9th through 12th grade), 2 at a state university, and 3 at a community college. One participant had received a GED after the 10th grade and another was a technical apprentice. Finally, three participants had dropped out of school during their 9th grade year. There were 7 children classified as having a severe injury, 8 children as having a moderate injury, and 12 children with mild injury. This breakdown of severity of injury corresponds to 47%, 89%, and 46% of the initial sample, respectively. All participants reported being of European American descent.

Measures

Several of the variables utilized in the current investigation were collected initially at the baseline assessment (i.e., immediately following injury) and were subsequently available for the current study (age at injury, severity of injury, socio-economic status, and number of psychiatric disorders). Parental consent was obtained so the investigators could request Iowa Test of Basic Skills (ITBS) scores (prior to injury) for the participants from the Iowa Testing Programs at the University of Iowa. Furthermore, parents of participants completed the Pediatric Behavior Scale (PBS; Lindgren & Koeppl, 1987), which included ratings of their child’s premorbid academic achievement. Lastly, participants were individually administered the Wechsler Intelligence Scale for Children–Third Edition (WISC–III; Wechsler, 1991; 5 verbal subtests and 5 performance subtests) during the baseline assessment to obtain verbal, performance, and full scale IQs. For the current investigation (i.e., 6 to 8 year follow-up assessment), the participants were administered the Weschler Abbreviated Scale of Intelligence (WASI; Psychological Corporation, 1999) and California Verbal Learning Test for Children (CVLT–C; Delis, Kramer, Kaplan, & Ober, 1994) as part of a comprehensive intellectual, academic, and neuropsychological evaluation.

Neurological Measure

The psychiatric measures were obtained at follow-up via clinical interviews and evaluation. Severity of brain injury was measured using the lowest score from the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974). The GCS measures motor response (obeying, localizing, withdraws, flexing, extending, none), eye opening (spontaneous, to speech, to pain, none), and verbal responsiveness (oriented, confused, inappropriate words, incomprehensible sounds, none) with scores ranging from 3 (unresponsive) to 15 (normal). Segatore and Way (1992) provide support for the reliability and validity of the GCS.

Categories of TBI severity were classified as follows: Severe injury was defined by a lowest postresuscitation GCS score \(\leq 8\), moderate injury by a lowest postresuscitation GCS score of 9–12 or a score of 13–15 with an intracranial lesion or with a depressed skull fracture seen on the initial CAT scan. Mild injury is defined by a lowest postresuscitation GCS score of 13 to 15, irrespective of any associated linear skull fracture.
Premorbid Functioning Measures

Premorbid academic functioning was assessed by using the preinjury national percentile rank for vocabulary on the ITBS (Hoover, Hieronymus, Frisbie, & Dunbar, 1993). The ITBS provides a comprehensive assessment of student progress in the basic skills and is used with students from kindergarten to 9th grade. The ITBS is made up of a core battery consisting of listening (levels 5–8 only), word analysis (levels 5–8 only), vocabulary, reading, language, and mathematics. The complete battery adds social studies, science, and sources of information starting at level 7. The ITBS has been found to be a highly reliable test, and studies lend overwhelming support for the ITBS as a valid measure of basic academic skills (Hoover et al., 1993).

At baseline assessment, the parents of the injured participants completed the PBS, which serves as a measure of premorbid academic status of 6 to 16 year olds and preschoolers aged 3 to 5 years. The PBS consists of 165 items assessing problems in 24 behavioral dimensions in six general areas (i.e., conduct, attention deficits, depression–anxiety, deviation, health, and cognition). The PBS also has items obtaining the following information: socioeconomic status, medications taken regularly, and educational functioning of the child. The latter consists of ratings of the child’s preinjury intelligence and academic achievement on a scale from far below average to far above average. The parent’s rating of premorbid academic achievement was used in this study. The PBS has adequate validity and reliability (Lindgren & Koeppel, 1987).

Intellectual and Academic Measures

The ITBS national percentile ranks for the core total (reading total, language total, and math total) and composite (core total, social studies, science, maps/diagrams, reference materials, and sources of information) were also used in data analyses as measures of academic outcome at 6 to 8 years postinjury.

The WISC–III was administered at the baseline assessment (i.e., immediately following injury) as a measure of intellectual functioning. The WASI was administered at the 6 to 8 year follow-up to assess current levels of intellectual functioning. The WISC–III is designed to assess the general intellectual ability of children and adolescents aged 6 to 16 years 11 months. The WASI is designed for quickly and accurately estimating the intellectual functioning of individuals aged 6 to 89 and consists of two verbal subtests (vocabulary and similarities) and two performance/nonverbal subtests (block design and matrix reasoning). A change score from immediate postinjury verbal and performance IQ to the 6 to 8 year verbal and performance IQ was calculated and used in subsequent analyses.

The CVLT–C was administered to assess the functions involved in learning and recalling verbal information. The CVLT–C is designed for individuals from 5 to 16 years of age. Administration of the CVLT–C yields information or scores for the following parameters: total recall and recognition on all trials; semantic clustering; serial-position effects; learning rate across trials; consistency of item recall across trials; interference effects; immediate- and delayed-recall; discriminability and response bias; perseverations and intrusions in recall; and false positives in recognition. The CVLT–C has adequate validity and reliability (Delis et al., 1994).
RESULTS

Preliminary Analyses

Logistic regression analysis was conducted to ascertain whether there was a significant relation between performance at 2 years following injury and participation at the 6 to 8 year follow-up. A dichotomous variable was computed that represented participation and nonparticipation at 6 to 8 years postinjury. This “drop-out” variable served as the dependent measure. The independent variables were represented by academic and intellectual functioning predictors from 2 years postinjury. An achievement variable was computed using the mean score of the reading, arithmetic, and spelling subtest scaled scores from the Wide Range Achievement Test–Third Edition (WRAT–3). A learning and memory variable was computed using the mean score of the design memory, verbal learning, story memory, and finger windows scaled scores from the Wide Range Assessment of Memory and Learning Test (WRAML). The Full-Scale Intellectual Quotient (FSIQ) from the WISC–III represented the final predictor. These three variables (mean achievement, mean memory, and FSIQ) were entered into a logistic regression analysis. The outcomes of these analyses resulted in none of these predictor variables reaching statistical significance suggesting that achievement and intellectual functioning at 2 years postinjury is not related to dropout status at 6 to 8 years postinjury (see Table 1).

Overall, 23 participants from the original cohort of 50 participants at baseline did not participate in the 6 to 8 year assessment (14 with mild injuries, 1 with a moderate injury, and 8 with severe injuries) due to being unwilling or unavailable to participate as well as previous attrition from the study.

Bivariate Correlations

Correlations between the dependent and independent variables were computed for each of the hypotheses. Significant correlations were found between premorbid functioning (ITBS percentile rank for vocabulary) and academic outcome (post-ITBS core and composite total scores), \( r = .49; p = .047 \) and \( r = .60; p = .01 \), respectively. Ratings by parents of premorbid achievement were correlated significantly with academic outcome, \( r = .77; p = .01 \) and \( r = .73; p = .001 \), respectively. Severity of injury was correlated significantly with the change score from immediate postinjury performance IQ to the 6 to 8 year performance IQ (\( r = -.54; p = .006 \)), CVLT List A Trials 1–5 total score

<table>
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<th>Variable</th>
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<th>( SE ) B</th>
<th>( \beta )</th>
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<td>FSIQ</td>
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Note. FSIQ = full scale intelligence quotient.
(r = −.42; p = .028), CVLT semantic cluster ratio (r = −.47; p = .013), and CVLT serial cluster ratio (r = .51; p = .007). Age at injury was correlated significantly with CVLT List A Trials 1–5 total score (r = −.42; p = .028), CVLT semantic cluster ratio (r = −.47; p = .013), CVLT serial cluster ratio (r = .51; p = .007), and the difference score between CVLT short-delay and long-delay cued recall (r = −.41; p = .035).

Hypothesis 1

The independent variables (i.e., age at injury, severity of injury, parent education level, premorbid ability, and parental ratings of premorbid overall school achievement) were entered into a linear regression analysis to predict achievement 6 to 8 years following injury. Separate analyses were run for each of the two outcome variables, ITBS core total, and ITBS composite total, respectively. The pre- and postinjury ITBS percentile rank scores were transformed into standardized scores (i.e., z scores) to put them on a more nearly normal distribution before entering them into the model. Both regression models were significant; however, only the model for ITBS composite total is presented here given that this composite includes the same subtests as the core total in addition to social studies, science, and sources of information.

The regression model for the ITBS composite total was significant $F(5, 11) = 6.17$, $p = .006$, accounting for 74% of the variance in achievement and showed that parental ratings of premorbid overall school achievement were a predictor of achievement. That is, when all variables were entered into the regression model at one time, the model reached statistical significance and showed parental ratings to be a significant predictor of achievement on the ITBS 6 to 8 years postinjury. The results for this model are presented in Table 2. Review of residual plots did not show any significant outliers for this model.

Hypothesis 2

The independent variables (i.e., age at injury, severity of injury, parent education level, premorbid ability, parental ratings of premorbid overall school achievement, and number of psychiatric diagnoses) were entered into linear regression analyses to predict change in intellectual functioning from baseline to 6 to 8 years following a TBI. Separate analyses

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<th>SE B</th>
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<tr>
<td>Premorbid achievement</td>
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<td>.222</td>
<td>.625*</td>
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</tbody>
</table>

*p < .05.

TABLE 2

Summary of Linear Regression Analysis for Variables Predicting Achievement 6 to 8 Years Postinjury (Composite Total)
were run for each of the outcomes, the change score from immediate postinjury verbal and performance IQ to the 6 to 8 year verbal and performance IQs, respectively. The first model failed to reach significance, suggesting that verbal IQ following TBI cannot be predicted using these variables. The second model accounted for 44% \((p < .02)\) of the variance in intellectual change and showed that severity of injury was a predictor of change in performance IQ. That is, when all variables were entered into the regression model at one time, the model reached statistical significance and showed severity of injury to be a significant predictor of performance IQ change 6 to 8 years postinjury. Furthermore, the results indicate the mildly and moderately injured groups did not show much change in performance IQ from immediately following injury to 6 to 8 years following injury, suggesting that their intellectual functioning remained at similar levels or possibly increased. On the other hand, the severe group showed much change in performance IQ from immediately following injury to 6 to 8 years following injury suggesting that their intellectual functioning as measured by a standardized measure decreased or got worse over time. The results are presented in Table 3.

### Hypothesis 3

The independent variables (i.e., age at injury, severity of injury, parent education level, premorbid ability, and parental ratings of premorbid overall school achievement) were entered into a linear regression analysis to predict learning and memory 6 to 8 years following injury. There were 7 outcomes representing different aspects of learning and memory: difference between short- and long-delay free recall; difference between short- and long-delay cued recall; learning slope (increment in words recalled/trial); semantic cluster ratio (learning strategy); serial cluster ratio (learning strategy); recall (mean performance of short- and long-delay free and cued recall); and trial learning. Separate linear regression models were conducted using each of these outcomes; however, only the models representing learning strategies (i.e., semantic and serial cluster ratios) reached significance. The model with semantic cluster ratio as an outcome was significant; however, post-hoc investigation of the residual plot showed one case to be a potential outlier for this model. When this case was removed from the regression model,
it no longer reached statistical significance; however, the results still indicate a trend suggesting that severity of injury is predictive of semantic learning.

The model with serial cluster ratio as an outcome was significant $F(5, 19) = 3.2$, $p = .029$, accounting for 46% of the variance in learning and showed that severity of injury was a predictor of learning. That is, when all variables were entered into the regression model at one time, the model reached statistical significance and showed severity of injury to be a significant predictor of serial learning 6 to 8 years postinjury. The results are presented in Table 4. Review of residual plots for this model did not show any significant outliers.

### DISCUSSION AND CONCLUSIONS

#### Study Findings and Implications

The primary goal of this study was to investigate the long-term intellectual and academic outcomes of a cohort of children and adolescents following TBI. More specifically, the emphasis was on exploring the relations among predictive factors such as premorbid ability/status, age, severity of injury, socio-economic status, and performance/functioning (i.e., intellectual, verbal learning, and memory) in children and adolescents with mild to severe TBI 6 to 8 years following head injury. By addressing these outcomes, educators and psychologists in school settings may be better informed regarding best practices in educational programming for students with a TBI. It is critical for educational specialists to be knowledgeable about the impact of TBI, that is, about preinjury (e.g., premorbid function) and postinjury (e.g., sequelae and long-term outcome) factors associated with outcome and recovery of TBI.

**Achievement.** Findings from this study indicate that parental ratings of premorbid school achievement can help predict academic performance 6 to 8 years following a TBI. These findings suggested that parents are good sources of information regarding their child’s perceived achievement prior to injury. Their ratings were shown to be predictive of how well their child would be functioning academically 6 to 8 years
postinjury. More specifically, the higher the child’s rated ability is before injury, the higher his or her achievement is 6 to 8 years postinjury. Furthermore, children and adolescents’ achievement improved, as they got older.

Findings regarding the importance of parental ratings provide a distinctive contribution to the present literature. Most TBI studies tend to focus on child variables to predict outcomes or else focus on family variables (e.g., global functioning; e.g., Rivara et al., 1994). When studies incorporated parent ratings of premorbid school performance or personal achievement, this information was generally gleaned from scales assessing behavior, not achievement (e.g., Light et al., 1998; Yeates & Taylor, 1997). Other studies have parents compare the educational, professional, and standard of living of their children with brain injury to their siblings (Koskiniemi, Kyykka, Nybo, & Jarho, 1995). In other cases, parent ratings are utilized postinjury to assess behavior and competence (e.g., Taylor et al., 1999). Parental ratings of achievement are probably not utilized as frequently because information regarding the child’s premorbid performance can be assessed via grade point averages, mean school grades, mean achievement test scores, and teacher ratings (e.g., Light et al., 1998; Slater & Kohr, 1989); however, the findings in this study emphasize the importance of gathering information regarding premorbid achievement from parents to predict long-term outcomes.

An interesting finding in this study was that premorbid ability was not a statistically significant additional predictor of achievement at 6 to 8 years postinjury when parental premorbid ratings were also taken into account. That is, it is no longer clear that premorbid ability provides additional predictive information. A previous study by the investigator and colleagues showed premorbid ability to be a significant predictor of achievement (i.e., reading and spelling) 2 years postinjury (Arroyos-Jurado et al., 2000); however, parental ratings of premorbid school achievement were not included as a predictor of achievement. Therefore, follow-up analysis of the 2 year data was conducted with parental ratings included as a predictor to determine if it is a significant predictor of 2 year outcomes as well. The results indicated that when parental ratings of premorbid achievement were entered into the regression model, parental ratings replaced premorbid ability as a significant predictor of spelling achievement at 2 years, $F(4, 29) = 5.11, p = .003$. Premorbid ability continued to be a significant predictor of reading achievement at 2 years whether or not parental ratings were entered into the model, $F(4, 29) = 5.71, p = .002$). These results again lend credence to the importance of parental ratings.

Another interesting finding was that the variable used as the premorbid estimate of ability (i.e., national percentile rank for vocabulary from the ITBS) was not significantly correlated with the outcome variables (i.e., ITBS core and composite totals) nor was a significant predictor of these outcomes. That is, performance on the ITBS prior to injury was not predictive of performance on the same measure over the long-term (approximately 6 to 8 years later). These findings suggest standardized tests may not be the most useful tool in predicting long-term outcomes for children with TBI. It is also important to consider other sources of information (i.e., parents) to help predict long-term functioning rather than relying solely on standardized achievement testing.

**Ability.** Current findings indicate that severity of injury is the best predictor of intellectual change 6 to 8 years following a TBI. More specifically, severity of TBI had
the greatest negative impact on future performance on nonverbal tests. The results suggest that severe TBI was associated with lowered performance (i.e., nonverbal) IQ at 6 to 8 years postinjury. Verbal IQ was not associated with any of the predictors and could not be predicted using the present variables. This finding corroborates the current literature in this area that shows a consistent deficit in performance IQ over verbal IQ (e.g., Chadwick et al., 1981; Donders, 1993; Filley, Cranberg, Alexander, & Hart, 1987; Jaffe et al., 1992, 1993; Massagli et al., 1996) and that this deficit persists over time (e.g., Chadwick et al., 1981). Performance IQ (PIQ), given its reliance on motor speed and manipulation and demand on active problem solving, is more sensitive to brain damage (Capruso & Levin, 1992). Verbal IQ, on the other hand, requires more semantic knowledge (i.e., rote and overlearned), which is relatively resistant to brain damage (Capruso & Levin, 1992); however, this latter argument can be disputed given the present findings regarding verbal learning that indicate verbal skills are affected by head injury (see next section for overview). Many studies have shown that although PIQ improves over time, it still remains at lower levels compared to the PIQ levels of mildly injured or noninjured cohorts. For example, Chadwick and colleagues (1981) found that deficits in PIQ persisted over the 2½ years test interval; that is, there was a comparable deficit in PIQ as at 1 year follow-up. Donders (1993) also showed that the average PIQ of the group with more severe injuries was lower than was the case for participants with mild to moderate injuries and controls. In a more recent study, Anderson, Catroppa, Rosenfeld, Haritou, and Morse (2000) showed recovery of PIQ (i.e., improved scores at 1 year) over time, but participants with severe injuries continued to perform lowest compared to peers with less injuries at 1 year follow-up; however, there have been very few studies (e.g., Chadwick et al.) conducted that have assessed the long-term recovery of PIQ beyond 2 years postinjury; thus, this study provides a valuable contribution to the literature and demonstrates that PIQ deficits persist 6 to 8 years postinjury.

**Learning and memory.** Current findings indicate that severity of injury is the best predictor of learning and memory 6 to 8 years following a TBI. Components of learning predicted by TBI severity involve strategies of learning. The results demonstrate that children and adolescents with more severe head injuries tend to use a serial clustering (i.e., recalling words by their place on a list) strategy more often than mildly to moderately injured peers. This strategy tends to be a less efficient means of storing and recalling information than semantic clustering, which involves chunking words by categories. Although not statistically significant, analyses of semantic clustering strategies also suggest a trend that children and adolescents with more severe head injuries tend to use less of a semantic clustering strategy than mildly to moderately injured peers as well. Furthermore, correlation analyses suggest that learning strategies (semantic and serial clustering) are also associated with age at injury. Older children and adolescents tend to use less semantic clustering and use more serial clustering strategies as well.

These findings corroborate recent reports from another longitudinal study (3–5 year injury-test interval) by Levin and colleagues (2000), who also found age and severity of injury to be related to semantic clustering strategies on the CVLT–C. Interestingly, the current findings also contradict a previous investigation showing no differences in learning characteristics (i.e., semantic and serial clustering from the CVLT–C) between
control and TBI groups (Yeates, Blumenstein, Patterson, & Delis, 1995). Another study (Roman et al., 1998) showed an increase in semantic clustering over time with a trend for decreased use of serial clustering over time in another cohort of children and adolescents sustaining a TBI; however, these studies did not look at the impact of head injury on learning and memory outcomes over the long term (assessments were conducted immediately to 3 months postinjury). Thus, the present findings along with data from Levin and colleagues (2000) suggest TBI does have a significant impact on learning and memory years after the initial injury and point toward the importance of assessment of these deficits across time (i.e., past the initial recovery phase).

Correlation analysis from this study suggests that older children and adolescents tend to recall fewer words than younger children when given cues to recall information. Furthermore, children and adolescents older at the time of injury and with more severe injuries tend to recall less information given several trials of learning than younger, less injured children. Overall, these findings are consistent with the literature on learning and memory outcomes in children and adolescents with TBI. The literature has shown children and adolescents with severe head injuries to have more difficulty with verbal learning and memory (Donders, 1993; Farmer et al., 1999; Hoffman, Donders, & Thompson, 2000; Jaffe et al., 1992; Levin et al., 1993; Levin et al., 2000; Massagli et al., 1996; Stefano et al., 2000; Yeates et al., 1995). More specifically, these children and adolescents exhibit more difficulties with encoding (e.g., Farmer et al., 1999; Hoffman et al., 2000; Stefano et al., 2000), immediate recall (e.g., Farmer et al., 1999; Hoffman et al., 2000; Jaffe et al., 1992; Levin et al., 2000; Stefano et al., 2000), delayed recall (e.g., Donders, 1993; Hoffman et al., 2000; Jaffe et al., 1992, 1993; Levin et al., 1993; Levin et al., 2000; Stefano et al., 2000), and recognition of verbal (e.g., Hoffman et al., 2000; Jaffe et al., 1992) and visual (Hoffman et al., 2000) information. In addition, they have more difficulties with learning, storage, and retrieval over the long term (e.g., Yeates et al., 1995). They also demonstrate deficits in learning across trials (e.g., Levin et al., 1993; Yeates et al., 1995). The value of this investigation is that these deficits were shown to persist over a long period of time, lending support to the importance of remediation of these deficits early in recovery so as to prevent these deficits from persisting.

Implications. Current findings have significant implications for educators. It is critical to collect information regarding preinjury variables from multiple sources. Relying solely on standardized measures potentially could decrease the prediction of long-term outcomes. These findings suggest that parents are good sources of information regarding how their child was performing prior to injury; however, we should not limit our assessment to tests and parents. Although teacher ratings were not included in this study, their ratings of student performance also will be a valuable source of information regarding performance pre- and postinjury (Kinsella et al., 1995). Validity of information and predictive utility will increase when multiple raters are utilized. Best practices mandate that assessment use multiple methods, sources, and settings (Merrell, 1999). Although generally a multimethod, multisource, and multisetting model is utilized for assessment of social–emotional difficulties, it is easily applicable to assessment of academic challenges as well. Early identification of important injury-related variables and information (including parental concerns), appropriate assessment (including using a multidisciplinary approach), and effective
intervention are supported as being useful guidelines in promoting school success for students with TBI (Farmer & Peterson, 1995).

These findings point to the necessity of teaching structured learning strategies as an essential component of intervention. Strategies for improving performance should be taught to students with TBI. Students with head injuries need to learn how to encode information more effectively to be able to recall and utilize that information when the tasks at hand demand it. Educators can play an integral role in designing educational programs or informing individualized education programs that include teaching these essential learning strategies. To successfully teach learning strategies to students with head injuries, it will be important to draw on their strengths. Harris (1996) argued that individuals with severe head injuries, compared with normal students and students with mild injuries, have poorer long-term memory storage for initial information and insufficient verbal rehearsal necessary for adequate storage but may have a stronger working memory. He further stated that active use of verbal rehearsal may be a skill that is difficult to reacquire following injury and that those who are severely injured and those who are mild-to-moderately injured tend to use a similar pattern of rehearsal (i.e., single-item rehearsal to a significantly greater extent than multi-item and organization). Not only do educators need to draw on student’s strengths, they also need to come up with novel approaches to teaching learning strategies.

The present findings also have important implications for parents. These findings can be used to encourage parents to become more involved in the assessment of their child with a head injury because their input could potentially be a significant predictor of future performance. Via this assessment process, parents can become better informed regarding how to help their child in school and at home. They will become more adept at predicting outcomes and planning for their child’s future.

**Limitations of the study.** One limitation is the relatively small sample size; however, the sample size is comparable to other studies in this area (Berger-Cross & Shackelford, 1985; Cattelani, Lombardi, & Mazzuchi, 1998; Harris, 1996; Kinsella et al., 1995, 1997; Massaglia et al., 1996). The study also included a good premorbid estimate of ability that is not found in many other studies. The small sample size, however, makes it difficult to generalize the findings. This study is an important initial step toward informing the literature on long-term outcomes in TBI; follow up to this study is equally important.

The second limitation is the unequal distribution of subgroups, although this is a clinical sample that is fairly representative of the general population. Equal percentages of mild and severely injured participants were recruited for this study with almost all of the moderately injured participants taking part in the investigation.

Another limitation of this study is that a different assessment battery than the one given previously at 2 years postinjury was utilized at the 6 to 8 year follow-up; however, more up-to-date (e.g., instruments with newer norms), reliable, and valid instruments were utilized in this study.

**Recommendations for future research.** Future work should focus on validating the findings regarding achievement being associated with parental ratings of premorbid
achievement. The importance of parent ratings has significant implications for parent training that can help children with TBI reenter their schools. Furthermore, information gleaned from parental ratings will aid educators in helping those parents and students plan better for the future. Future work should focus also on other measures that have not been well assessed. These include measures of parent ratings, intervention research, and program development.

Future research is needed to determine which aspect of nonverbal IQ is most affected by TBI. Speed and efficiency of process are likely determinants of outcome; however, it is unknown whether specific perceptual processing is affected. Further research should focus on the specific subtests and processes that comprise performance IQ and the impact that severity of injury has on functioning.

The focus of research should be in the development of practical, day-to-day interventions that can be utilized by educators in schools to help children with TBI be successful. Educational programs focusing on structured learning should be implemented and evaluated with students who have sustained a TBI. This investigation clearly shows that children and adolescents with severe TBI are not adept at using effective learning strategies. Students need more instruction on how to learn, store, and recall information; otherwise, these students are doomed to academic frustration and failure. Educators, including school psychologists, should be central in developing, implementing, and evaluating these programs for students.

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