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Predictors and indicators of academic outcome in children 2 years following traumatic brain injury

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Abstract

Within the context of a longitudinal study investigating outcome for children following traumatic brain injury, this paper reports on the utility of neuropsychological testing in predicting academic outcome in children 2 years following traumatic brain injury (TBI). Twenty-nine school-age children who were admitted to hospital after TBI were assessed with a battery of neuropsychological and academic measures at 3 and 24 months postinjury. The neuropsychological battery included measures of memory, learning, and speed of information processing. Academic outcome was assessed in terms of post-TBI change in school placement. According to logistic regression analysis, change in placement from regular to special education at 2 years post-TBI was predicted by injury severity and by neuropsychological performance at 3 months post-TBI. Findings suggest that neuropsychological testing is useful in identifying children with special educational needs subsequent to TBI. (*JINS*, 1997, *3*, 608–616.)

Keywords: Traumatic brain injury, Pediatrics, Neuropsychological assessment, Academic outcome

INTRODUCTION

Outcome from significant pediatric traumatic brain injury (TBI) has been considered in various dimensions but failure to thrive academically can be argued to be one of the most serious consequences following injury (Levin et al., 1987; Knights et al., 1991; Jaffe et al., 1993; Goldstein & Levin, 1985). Adequate academic performance is crucial to the successful reintegration of the child with head injury, and the social consequences of academic failure can contribute directly to long-term handicap and ultimately limited quality of life (Ewing-Cobbs et al., 1986; Telzrow, 1987; Perrot et al., 1991).

Several previous research studies have been able to document limitations in academic performance following moderate to severe TBI in childhood (Chadwick et al., 1981; Fletcher et al., 1990; Donders, 1994; Rivara et al., 1994). However, researchers have also recognized a difficulty in adequately identifying academic outcome due to (1) a lack of sensitivity in traditional tests of academic achievement (Perrot et al., 1991; Donders, 1994); (2) the fact that teacher ratings of school performance can be compromised due to a reluctance by teachers to identify low educational achievement following TBI (Fletcher & Ewing-Cobbs, 1991); and (3) the fact that teacher ratings can also suffer from a poor return rate (Kinsella et al., 1995). An alternative approach is to document change in the educational process following injury, such as placements in special education programs, additional tutoring, or grade repetition. Nevertheless, these academic markers also require caution in interpretation as they may reflect not only the severity of the child's learning problems but also community attitudes, parent coping strategies, and material resources (Rutter et al., 1980).

Although neuropsychological impairments, most typically memory and learning deficits, are common documented consequences following TBI (Levin et al., 1990; Dalby & Obrzut, 1991; Donders, 1993; Jaffe et al., 1993; Kaufmann et al., 1993; Goldstein & Levin, 1995; Yeates et al., 1995), the contribution of these postinjury features to prediction of long-term academic outcome is relatively unknown. Donders (1994) found that immediate academic out-

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come (school placement at 6 to 12 months postinjury) could be predicted by the Verbal IQ from the Wechsler Intelligence Scale for Children–Revised (WISC–R). However, process-specific neuropsychological tests of memory and learning abilities were not assessed, and other researchers (eg., Fletcher et al., 1985) have argued that TBI-related deficits in these specific aspects of neuropsychological status may be critical in underlying long-term problems in acquiring new knowledge and skills.

In a follow-up pediatric TBI study conducted by our research team (Kinsella et al., 1995) preliminary findings at 1 year postinjury found that change in school placement from regular to special education was predicted by injury severity and by neuropsychological performance at 3 months post-TBI, even though at this early stage of academic reintegration the early neuropsychological performance did not contribute beyond that achieved by injury severity. It was hypothesized that by later follow-up, the strength of the predictive value of early neuropsychological assessment, as indexed by memory and learning performance, would become apparent. This reflects the view that previously acquired skills would be expected to have decreasing relevance for school performance over time, and yet postinjury deficits in memory and learning will create an increasing academic disability in learning.

When considering prediction of outcome, recent work in TBI (Crepeau & Scherzer, 1993) has begun to distinguish between predictors and indicators. Apart from injury characteristics, predictors are drawn from the composite of pretrauma characteristics of the child, and early recovery data that may relate to future academic performance. The establishment of reliable predictors identifies rehabilitation needs, and those children most likely to achieve academic success. In contrast, indicators are those measures of cognitive, behavioral or social functioning that are obtained concurrently with outcome, and can be used to determine current academic needs. These variables focus attention on developing online goals related to classroom activities and school requirements.

The aim of this study is to extend our previous findings (Kinsella et al., 1995) and report on the relationship between neuropsychological status and academic achievement in children 2 years following TBI. The study considers issues of (1) early prediction; and, (2) concurrent indicators of academic outcome. Academic outcome was assessed by postinjury requirement of special education. Measures used to predict this academic outcome were selected from injury severity and early recovery data, the central ones being neuropsychological performance at 3 months postinjury, represented by measures of memory, learning, and speed of information processing. Additional predictors derived from measures of early academic achievement (standardized scores of reading, spelling, and arithmetic), were enlisted to gauge the coherence between these traditional academic markers and academic outcome as determined by special education provision postinjury. In relation to prediction, it was hypothesized that (1) early measures of memory, learning and speed of information processing (neuropsychological status) would add to injury severity in predicting changes in emergent provision of special education support; and (2) early markers of academic achievement would also add to injury severity in predicting changes in provision of special education support.

Similar measures taken at 2 years postinjury were evaluated as potential indicators of ongoing special education need. It was hypothesized that (1) lowered performance on formal standardized achievement measures of reading, spelling, and arithmetic would be observed; and (2) persisting impairment of memory and speed of information processing would be indicative of need for special education 2 years after injury.

METHODS

Research Participants

The participants were 29 children selected from consecutive admissions to the emergency departments of either the Royal Children's Hospital, Melbourne, or the Adelaide Children's Hospital, Adelaide, Australia over a 2-year period. These 29 children were selected from an initial sample of 51 children who were described in our previous 1-year follow-up study (Kinsella et al., 1995). As in the 1-year prediction analysis, we excluded all children who were receiving special education prior to injury (2 in the mild group, and 1 in the severe group). A further 2 children (1 from the mild injury group, and 1 from the severe injury group) had already withdrawn from the study by 1-year follow-up. These 46 children formed the group for the 1-year prediction analysis and the pool of children for the 2-year assessments. Due to a lack of financial resources, it was decided to focus efforts on maintaining follow-up of the moderate and severe injury groups and to confine assessment of the mild injury group to the first 14 children in the series. There were no significant group differences in *t*-tests and chi-square tests between the selected ($N = 14$) and unselected ($N = 14$) groups of mild injury children in all 3-month post-injury measures reported in Tables 1 and 3—although the chi-square test results for SES and injury type may be untenable, due to the low expected cell frequencies. Finally, a further 2 moderate injury children and 1 severe injury child withdrew from the study by the 2-year assessment. In summary, this provided a sample of 29 children for 2-year follow-up (14 mild, 5 moderate, and 10 severe).

As reported in our previous paper (Kinsella et al., 1995), all children had sustained a TBI resulting in loss of consciousness or a period of posttraumatic amnesia (PTA) and were admitted to hospital for at least 24 hr. Consistent with previous research findings (Dalby & Obrzut, 1991), there were considerably more boys than girls with TBI. Children were age 9 to 15 years at the time of the accident ($M = 11.59$, $SD = 1.99$) and had no previous history of head injury, neurological disorder, or psychiatric dysfunction, as shown by parent report or medical records. Eligibility for

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Table 1. Demographic, injury characteristics and education needs, in terms of means (*SD*) and counts, of children with mild, moderate, and severe head injury

	Mild (*N* = 14)			Moderate (*N* = 5)			Severe (*N* = 10)		
Variable	*M*	*N*	(*SD*)	*M*	*N*	(*SD*)	*M*	*N*	(*SD*)
Age (years)	11.79		(2.33)	11.40		(1.34)	11.80		(2.39)
Sex									
Male		10			3			6	
Female		4			2			4	
Family SES									
Nonmanual		2						2	
Skilled manual		10			4			4	
Unskilled manual		2			1			4	
GCS on admission	14.43		(0.85)	10.40		(1.67)	5.40		(2.27)
LOC	2.07*		(3.10)	.60*		(1.34)	3.40**		(6.48)
PTA (days)	.84		(2.14)	2.29		(3.27)	16.55		(13.68)
Hospitalization (days)	5.93		(7.17)	10.20		(6.69)	26.50		(18.98)
Cause of injury									
Motor car accident		2						1	
Pedestrian					1			6	
Cyclist		2			2			1	
Fall		7			1			1	
Other		3			1			1	
Educational needs									
Regular		14			3			3	
Special		0			2			7	

* = min
** = days
GCS = Glasgow Coma Scale
LOC = length of coma
PTA = posttraumatic amnesia
SES = socioeconomic status

the study required parents and children to be English speaking. Demographic characteristics of the children and their families for each severity group are given in Table 1.

Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) scores were recorded for each child on admission to hospital and throughout the first 24 hr after admission. Length of coma (LOC), defined as the number of days between injury and ability to respond reliably to simple commands, and duration of posttraumatic amnesia, defined as the number of days after resolution of coma before the child was oriented in person, place, and time, and aware of daily living activities, were also measured by specialist trauma nursing staff using systematically repeated clinical observation. In order to provide a clinical description of this research sample the children can be classified into three injury groups: (1) *mild* ($n = 14$), if LOC was less than 20 min and GCS score on admission was 13 to 15 without subsequent deterioration from this range by 24 hr postadmission and without evidence of focal neurological deficit or intracranial abnormality as detected by CT scan; (2) *moderate* ($n = 5$) if the initial GCS score was between 9 and 12, with no deterioration below this range, or higher GCS with evidence of neurologic deficit or CT scan abnormality; and, (3) *severe* ($n = 10$) if the lowest GCS score at admission, or within the first 24 hr, was 8 or less. Injury data for each group are presented in Table 1.

Measures

Neuropsychological tests

The neuropsychological battery consisted of the following commonly used tests of memory, learning, and speed of information processing (see Kinsella et al., 1995 for a full description of these measures). Measurement of IQ as a separate index of neuropsychological status was not undertaken as within this small sample analysis the focus of investigation was to identify the contribution of markers of memory and learning skills to prediction of academic outcome.

1. *Rey's Auditory Verbal Learning Test (AVLT; Rey, 1964)* was given to assess verbal memory and learning, using Lezak's (1995) scoring protocol. Forrester & Geffen (1991) provide norms for school-aged children for numerous aspects of memory function on this task. Measures of memory obtained from the AVLT were as follows

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(Geffen et al., 1994): (1) Verbal Learning Index: the total number of words recalled across the 5 learning trials; (2) Short-delay Free Recall: the total number of words recalled at the first delay trial; (3) Long-delay Free Recall: the total number of words recalled at the 30-minute delay trial; (4) Recognition Performance: performance on the recognition trial was assessed in the method suggested by Geffen et al. (1994).

2. *The Austin Maze (Lezak, 1995)* assessed visuospatial learning. The procedure outlined by Walsh (1985) was employed. The task consists of an electronically activated "stepping-stone" maze. Participants are required to learn the 28-choice hidden pathway on a trial-and-error basis, by pressing illuminated buttons that display green for correct and red for incorrect responses. Participants attempted to eradicate errors over trials until two successive error-free trials had been achieved, or the cutoff of 20 trials had been surpassed. The total number of trials to reach two consecutive error-free trials provided the index of visuospatial learning (Tucker et al., 1987).
3. *The Symbol Digit Modalities Test (SDMT; Smith, 1973)* provided an index of speed of information processing. The oral administration was used in the present study, and performance on the task was recorded as the number of items completed correctly.
4. *The Controlled Oral Word Association Test (COWAT or Verbal Fluency; Benton & Hamsher, 1978; Benton et al., 1983)* provided a further measure of speed of information processing and is often used as a measure of executive dysfunction. Performance was recorded as the sum of the number of correct words produced across all three letter trials.

Academic measures

The Wide Range Achievement Test–Revised (WRAT–R, Jastak & Wilkinson, 1984) provided standard scores for reading, spelling, and arithmetic.

Special educational placement preinjury and at 2 years was classified as either (1) full-time schooling without an aide or additional tutoring, or (2) full or part-time schooling with the help of an aide or additional tutoring. These special educational services, by way of integration aides and additional learning support programs, were provided either by the school or educational agencies outside the school.

Procedure

Parents and children who agreed to take part were given an information sheet describing the study, and parents were asked to sign an informed consent form. The parents were also required to sign a "Consent for Release Information" form that allowed the research assistant to extract medical information from the child's case notes and to contact the child's school principal to enlist teacher support for the study. Neuropsychological and academic measures were obtained at 3 months, 12 months and 2 years after injury. The model of prediction from 3 months to 2 years is reported in this article.

RESULTS

Special Educational Modifications

Children requiring special education prior to injury (2 mild, 1 severe) had already been screened from this sample to decrease the contamination of preexisting academic failure in this small-sample analysis. By 2 years following injury, all the children had returned to school, but 7 of the 10 children forming the severe group were receiving special education, compared to 2 of the 5 children forming the moderate group, and none of the 14 children forming the mild group. Four of the children receiving special education postinjury were attending school on a part-time basis with a reduced curriculum. Two of these children, together with a further 5 children who were able to attend school full-time, were receiving assistance within the classroom from integration teaching aides.

Demographic information, injury characteristics and education placement are shown in Table 1 for the children comprising the mild, moderate, and severe groups. As an orientation aid, these statistics are recalculated and shown in Table 2 for children receiving regular and special education at 2 years postinjury.

Early Predictors of Special Education

Logistic regression analyses were performed to assess the relative efficiency of injury severity and early recovery data in predicting the need for special education at 2 years postinjury. Given in Table 3 are means and standard deviations of neuropsychological and WRAT–R measures obtained at 3 months postinjury for children in regular and special education. Greater injury severity, as indexed by a lower GCS score, is evidenced in children who received special education. These children also performed worse in neurophysiological tests, with the exception of Austin Maze, and in academic achievement tests. The Rao's Score statistic, shown in Table 3, was used to test the contribution of each predictor to special education before and after adjusting for injury severity. Due to the low power associated with the small sample size, alpha was set at .05, despite the redundancy inherent among these multiple tests. Results of these significance tests suggest that potential contributors to the prediction of education placement are the GCS, measures of the verbal learning and memory, speed of information processing, spelling, and arithmetic. Since injury severity was the primary cause of differences between groups, the predictive efficacy of each neuropsychological and academic achievement measure was reevaluated after adjusting for GCS. The adjusted Rao's Scores show that only verbal learn-

Table 2. Demographic, injury characteristics and education needs, in terms of means (*SD*) and counts, of children receiving regular and special education at 2 years postinjury

	Regular education (N = 20)			Special education (N = 9)		
Variable	*M*	*N*	(*SD*)	*M*	*N*	(*SD*)
Age (years)	11.75		(2.29)	11.67		(1.94)
Sex						
Male		12			7	
Female		8			2	
Family SES						
Nonmanual		4				
Skilled manual		14			4	
Unskilled manual		2			5	
GCS on admission	12.80		(3.07)	5.78		(2.68)
LOC (days)	.10		(0.45)	3.56		(6.86)
PTA (days)	2.13		(5.14)	16.22		(14.15)
Hospitalization (days)	7.50		(8.08)	27.67		(18.95)
Cause of injury						
Motor car accident		2			1	
Pedestrian		3			4	
Cyclist		2			3	
Fall		8			1	
Other		5				
Injury severity						
Mild		14				
Moderate		3			2	
Severe		3			7	

GCS = Glasgow Coma Scale
LOC = length of coma
PTA = posttraumatic amnesia
SES = socioeconomic status

ing significantly predicted subsequent education placement beyond the contribution by GCS.

A combinatorial hierarchical–stepwise logistic regression analysis was performed to assess possible joint contributions by predictors; that is, special education was first regressed on injury severity, before stepwise selection of neuropsychological predictors. In this analysis, the forced entry of GCS into the equation resulted in a substantial and significant reduction in the uncertainty index ($-2LL$) of the model [$\chi^2(1) = 18.94$, $p < .0001$]. In the subsequent stepwise phase, verbal learning was selected as a significant addition to GCS in the prediction equation [$\chi^2(1) = 6.93$, $p = .0085$]. After this, no additional neuropsychological measure was selected [residual $\chi^2(6) = 6.01$, $p = .4217$). This is consistent with the pattern of moderate intercorrelations between predictor variables (see Tables 4 and 5); that is, the entry of GCS and verbal learning into the prediction equation may have rendered additional contributions from the other neuropsychological variables redundant. In a separate analysis, WRAT–R were also assessed in this manner but no WRAT measures were selected after GCS was entered into the equation predicting special education [residual $\chi^2(3) = 1.59$, $p = .6617$].

Concurrent Indicators of Special Education

Given in Table 6 are means and standard deviations of concurrent neuropsychological and WRAT–R measures obtained at 2 years postinjury for children receiving regular and special education at 2 years postinjury. In both groups of children, the means of measures taken at 2 years postinjury are generally higher than those taken at 3 months postinjury. These concurrent indicators were analyzed by the same procedure described above for early predictors. The pattern of significant concurrent indicators of education needs, as shown by the Rao's Score tests, is similar to that of significant early predictors of education needs.

In a combinatorial hierarchical–stepwise logistic regression analysis, special education was regressed on injury severity first, before stepwise selection of neuropsychological indicators. In stepwise selection following the initial entry of GCS, no neuropsychological measure was selected [residual $\chi^2(7) = 4.96$, $p = .6651$]. WRAT–R indicators were also examined in this manner and, likewise, none was selected after GCS had been entered into the equation predicting special education [residual $\chi^2(3) = 3.24$, $p = .3563$].

Table 3. Means and *SD*s of early[a] neuropsychological indices and WRAT–R standard scores of children receiving regular ($N = 20$) and special ($N = 9$) education at 2 years postinjury. Included are Rao's Scores of each variable predicting education placement before and after adjusting for GCS

Variable	Regular ed. *M*	Regular ed. (*SD*)	Special ed. *M*	Special ed. (*SD*)	Rao's score	Adj. Rao's score
Injury severity						
GCS	12.80	(3.07)	5.78	(2.63)	16.36***	
Neuropsychological indices						
Verbal Learning	54.25	(7.43)	37.89	(6.01)	16.06***	4.85*
Short Delay Recall	10.80	(2.95)	7.22	(1.39)	8.85**	3.25
Long Delay Recall	11.20	(2.91)	8.44	(2.07)	5.64*	0.21
Recognition	0.95	(0.05)	0.89	(0.07)	6.32*	1.60
Austin Maze	14.64	(4.77)	17.89	(4.65)	2.84	0.03
COWAT	30.30	(9.32)	19.78	(7.45)	7.17*	1.13
SDMT	46.45	(11.10)	37.56	(11.36)	3.69	0.01
WRAT–R standard scores						
Reading	108.40	(15.70)	100.67	(13.02)	1.68	0.71
Spelling	102.45	(12.19)	92.00	(11.42)	4.32*	0.40
Arithmetic	101.45	(18.03)	81.33	(16.64)	6.68**	1.37

[a]Neuropsychological indices and WRAT–R scores at 3 months postinjury.
$*p \leq .05$, $**p \leq .01$, $***p \leq .001$.

DISCUSSION

One of the primary aims of this study was to provide information that would assist in identification of children most likely to encounter problems in academic performance at 2 years postinjury. Although all of the children had returned to school by 2 years postinjury, rates of special educational support were higher for the severely injured children than for the children with mild TBI. Following injury, 70% of the children in the severe injury group participated in school only on a part-time basis or required special support upon their return to school, compared to 40% of the moderate group and none of the mild group. By 2-year follow-up, special educational assistance was initiated for 9 of the 29 children in the sample.

Results of logistic regression revealed that the initiation of placement in special education was associated with lower GCS score on admission to hospital and lower performance measures of verbal learning and memory (AVLT) and slower speed of information processing (COWAT), although only verbal learning contributed further to the prediction after adjusting for the GCS score. The failure of the other variables to enter the prediction equation was potentially accounted for by the significant correlations between verbal

Table 4. Stepwise logistic regression selection of early predictors of children receiving regular ($N = 20$) and special education ($N = 9$) at 2 years postinjury, adjusted for severity of head injury (GCS)

Predictor	*B*	(*SE*)	e^{B}	$-2LL$	*p*
Neuropsychological predictors					
Null model				35.92	
GCS (forced entry)				16.98	<.0001***
GCS	−.58	(.20)	.56		
Verbal Learning selected				10.05	.0085**
GCS	−.26	(.21)	.77		
Verbal learning	−.39	(.25)	.67		
WRAT–R predictors					
Null model				35.92	
GCS (forced entry)				16.98	<.0001***
GCS	−.58	(.20)	.56		
None selected					

$*p \leq .05$, $**p \leq .01$, $***p \leq .001$.

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Table 5. Correlations between early neuropsychological measures taken at 3 months postinjury ($N = 29$)

Measure	VL	SR	LR	R	AM	C	SY
GCS	.69	.47	.48	.39	−.36	.48	.43
Verbal Learning (VL)		.72	.63	.55	−.45	.58	.51
Short Delay Recall (SR)			.56	.33	−.27	.53	.49
Long Delay Recall (LR)				.59	−.47	.32	.41
Recognition (R)					−.33	.28	.37
Austin Maze (AM)						−.51	−.62
COWAT (C)							.63
SDMT (SY)							

learning and other neuropsychological variables. It should be noted that logistic regression when applied to small samples can provide unreliable results. Consequently, our results require replication and extension with further, large sample research studies. Nevertheless, this 2-year analysis is consistent with the direction of our 1-year analysis (Kinsella et al., 1995) and, as hypothesized, the early neuropsychological markers of memory and learning deficits are beginning to emerge, at 2 years postinjury, as contributing factors to prediction of long-term academic outcome.

The relationship between severity of injury and academic outcome was expected (Jaffe et al., 1993; Kinsella et al., 1995) and reinforces the view that severity of injury, as indexed by the GCS score, provides the strongest indicator for predictions of long-term educational handicap. However, if the purpose of early prediction of potential outcome is not only to identify children at risk, but also to identify features of their early presentation that can be addressed within a rehabilitation context, then the finding supporting a relationship between longer-term academic needs and more immediate neuropsychological postinjury deficits was more informative.

That early neuropsychological indices can predict subsequent need for special education suggests that classroom performance is weakened by limited skills in verbal learning, compounded by slowing in verbal fluency. Children requiring special education were impaired relative to the regular education group on verbal memory and learning indices (AVLT), indicating that the special education group was less efficient in learning new verbal information across repeated trials, and, subsequently, retaining this information over periods of delay. In addition, the special education group showed significant slowing in speed of information processing in oral word production on the COWAT. This was supported by the poorer performance on the Symbol Digit Modalities Test by the placement group and, though

Table 6. Means and *SD*s of concurrent [a] neuropsychological indices and WRAT–R standard scores of children receiving regular ($N = 20$) and special education ($N = 9$) at 2 years postinjury. Included are Rao's scores of each variable predicting education placement before and after adjusting for GCS

Measure	Regular ed. *M*	Regular ed. (*SD*)	Special ed. *M*	Special ed. (*SD*)	Rao's score	Adj. Rao's score
Injury severity						
GCS	12.80	(3.07)	5.78	(2.63)	16.36***	
Neuropsychological indices						
Verbal Learning	59.80	(5.63)	49.11	(7.13)	11.96***	1.16
Short Delay Recall	12.85	(1.57)	10.33	(2.18)	9.20**	2.87
Long Delay Recall	13.55	(1.32)	10.18	(1.67)	16.24***	2.32
Recognition	0.99	(0.02)	0.95	(0.04)	7.37**	0.88
Austin Maze	12.00	(4.33)	13.67	(4.06)	0.98	0.14
COWAT	36.30	(10.28)	25.00	(9.70)	6.47*	0.34
SDMT	55.50	(10.87)	44.11	(12.11)	5.35*	0.11
WRAT–R standard scores						
Reading	107.55	(10.88)	100.56	(14.14)	2.12	0.85
Spelling	102.20	(12.10)	91.11	(15.62)	4.02*	1.99
Arithmetic	101.00	(15.04)	88.44	(14.24)	4.11*	0.22

[a]Neuropsychological indices and WRAT–R scores at 2 years postinjury.
*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$.

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this effect size was substantive, it was not statistically significant. On the other hand, this sensitivity of the COWAT may be related to its multidimensional requirements (e.g., cognitive flexibility, verbal fluency, lexical access).

Mean WRAT–R scores obtained at 3 months postinjury were also able to reliably predict the children who would require special education by 2-year follow-up, though these indices were again unable to contribute to the prediction once GCS scores had been entered. Reading appeared relatively resilient to the effects of injury, though it should be noted that the WRAT–R index of reading may not be a fair indicator of the ability to read or comprehend long passages or complex text. On the other hand, indices of spelling and arithmetic were predictive of children who required special education. Arithmetic is a timed measure, and can be at least partially attributable to the observed deficit in speed of information processing (COWAT; Knights et al., 1991). Routes for disruption of spelling are more complex and, in addition to relating to a substrate of impairment on verbal learning and memory and speed of information processing, it may reflect additional neuropsychological deficits that have not been probed within this battery of tests, such as those monitoring the performance of the supervisory attentional system.

Our results suggest that early neuropsychological evaluation and academic achievement measures can be used by rehabilitation staff and the family to adjust expectations and improve the quality of decision-making in management post-TBI (Vogenthaler et al., 1989). Furthermore, identifying neuropsychological features as significant predictors of long-term academic outcome has immediate utility as the identified neuropsychological dysfunction may potentially be addressed at an intervention level. The impact of treating neuropsychological impairment may be to reduce academic disability and ultimately educational handicap.

In addition to early predictors of academic outcome, neuropsychological and WRAT–R performances were measured concurrently with documenting special education provision at 2 years postinjury. Results indicated that children requiring special education continue to display features of neuropsychological deficit that were initially apparent at 3 months postinjury. The discriminating profile of impairment in verbal learning, memory, and slowing in speed of information processing is broadly similar at 3-month and 2-year follow-up, apart from a nonspecific degree of generalized improvement across the sample. Further controlled intervention studies are needed to determine whether systematic intervention can significantly alter these hallmark features of significant TBI.

One of the major limitations of the present study is the small sample size, due primarily to the lack of resources to conduct follow-up testing of children over the extended period. One solution is to set up multicenter collaboration at both a research and clinical level, to ensure that sufficient resources and sample sizes are available for long-term investigations of outcomes (Levin et al., 1990). The reader should note, however, that despite the small sample size used in this study, the effects sizes were statistically significant for most of the neuropsychological and academic predictors (see Table 3) and indicators (see Table 6) of educational placement.

Further refinement of our measures of neuropsychological ability in children is necessary as an initial stage in understanding the role of neuropsychological deficit in the process of reintegration into the educational system. The children's needs related to the cognitive resources that will be recruited in skills application in the classroom. The study revealed that children requiring special education possess fragile verbal memory and learning skills. These skills are clearly critical in education, and these complex cognitive processes will require comprehensive evaluation to identify component areas of deficit and ability.

Other methodological limitations pertain to the need for more comprehensive measures of academic outcome. The classification of change in the educational process that was adopted in this study was relatively gross, because access to special education may be limited by geographical location (e.g., rural areas) and lower socioeconomic status.

In conclusion, the documentation of the ability of injury severity and early neuropsychological performance to predict later academic outcome, and the persistence of neuropsychological impairments in discriminating the children who require special education programs, is important for clinical management post-TBI. These results reinforce the critical need for systematic intervention directed to restoring or developing compensatory strategies for cognitive deficits, so that these disabled children may more easily participate in the educational system and continue to learn and develop skills. Within this context it will be instructional to document the children who are making apparently good progress and do not require special education. These observations will assist in determining strategies and resources that may prove crucial to the child's recovery from head injury.

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