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Cognitive and linguistic correlates of children's discourse after closed head injury: A three-year follow-up

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Abstract

The discourse of 91 children who had sustained severe (n = 68) or mild (n = 23) closed head injury (CHI) was examined at least three years postinjury. The groups' retellings of a narrative story were analyzed according to two domains, information and language. In comparison to the mild CHI group, the severe group produced stories characterized by reduced content and information, impaired organization, fewer words, and less complex sentences. The relationships between discourse production and the groups' performance on measures of language, executive function, memory, and processing speed were examined. Correlations were found between discourse production and general verbal ability including verbal fluency. Correlations were also found for discourse performance and executive function measures associated with problem solving and working memory. Site and extent of lesion were not useful in predicting discourse production. These findings indicate that children who sustain a severe closed head injury during early to middle childhood are at risk for persisting deficits in discourse processing and other cognitive abilities. (*JINS*, 2000, *6*, 741–751)

Keywords: Closed head injury, Children, Discourse

INTRODUCTION

Language Deficits in Children Following Traumatic Brain Injury

Neurobehavioral outcome studies of traumatic brain injury (TBI) have identified linguistic impairments in children who sustained severe head injuries. Investigation of the effects of severe brain injury in school-aged children and adolescents within six months postinjury has revealed dysnomia (Levin & Eisenberg, 1979), increased latency in object naming, and reduced verbal fluency (Chadwick et al., 1981). Problems in writing to dictation and copying sentences (Ewing-Cobbs et al., 1987) as well as reduction in speed of production and length and comprehensiveness of written stories (Yorkston et al., 1997) have been noted. Persisting deficits including problems in verbal fluency, object naming latency, and confrontation naming were identified in severely injured children and adolescents one or more years postinjury (Chadwick et al., 1981; Jordan et al., 1988; Winogron et al., 1984), with late sequelae (Gaidolfi & Vignolo, 1980) suggesting a generalized reduction in linguistic skills (Jordan & Murdoch, 1994). More recently, studies of language in children with brain injury have focused on narrative discourse.

Discourse Deficits in Children Following Traumatic Brain Injury

Discourse deficits identified in children following brain injury have included primarily problems at a macro level, involving maintenance of global coherence and organization of information, and secondarily at a micro level, involving amount and complexity of language. Although head-injured children have been described as producing sentences characterized by reduced complexity (Campbell & Dollaghan, 1990), this finding has not been consistently supported (Chapman et al., 1992). Children with severe closed head injury (CHI) have been found to produce story narratives characterized by less language, impaired episodic structure, and reduced global content (Chapman et al., 1992;

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Chapman et al., 1997). Children with language problems during the acute phase of moderate to severe brain injury demonstrate fewer propositions and more errors sequencing propositions relative to brain-injured children without language impairment when seen for follow-up three years later (Ewing-Cobbs et al., 1998).

Attention and Memory Deficits in Children Following Traumatic Brain Injury

Although deficits in attention are considered common in children after brain injury (Johnson & Roethig-Johnson, 1989), few studies have focused on attention. Children with severe TBI have been found to perform more poorly than children with mild or moderate TBI on a computerized continuous performance task, suggesting attentional inefficiency (Kaufmann et al., 1993). Persisting problems on a variety of attention tasks have been observed in children with mild, moderate, and severe TBI, with variations in performance across tasks associated with variations in the demands of the tasks as well as within-subject factors such as the age of the child at injury and the time elapsed since injury (Dennis et al., 1995). Memory has been identified as the most frequently disrupted ability following severe brain injury in children (Levin & Eisenberg, 1979). Relative to controls and children with mild TBI, children with severe TBI have been found to demonstrate a slower rate of learning and to acquire less information over trials on a word list learning task administered one month to two years following injury (Jaffe et al., 1992; Levin et al., 1994; Roman et al., 1998; Yeates et al., 1995).

Mechanisms of Disturbance in Children's Discourse Following Traumatic Brain Injury

Investigators have attempted to identify the mechanisms of discourse problems in children following TBI. Dennis and Barnes (1990) examined the relationship between performance on a standardized discourse measure and measures of general ability, language, and recognition memory. They found verbal intelligence to be strongly related to a composite discourse measure, with word knowledge and word fluency predictive of processing of verbal ambiguity and working memory predictive of inferencing ability. Chapman et al. (1992) examined the relationship between performance on story retelling tasks and selected measures of vocabulary, problem solving, and semantic memory and noted a trend for a significant relationship between discourse and expressive vocabulary. In a study of children 3 and 12 months post-head injury, Chapman et al. (1995) found a significant relationship between receptive vocabulary and discourse performance, but the relationships between nonverbal problem solving and verbal memory with discourse performance were inconsistent.

In summary, studies of children with TBI have identified discourse problems primarily at a macro level, involving maintenance of global meaning and organization of information, and secondarily at a micro level, involving the lexical–semantic and syntactic aspects of words and sentences. However, sample sizes of most studies have been small, reducing the power of statistical analyses and the appropriateness of generalizability to other populations. The contribution of other linguistic and cognitive deficits to discourse problems in children with TBI remains poorly understood; however, evidence suggests that children who demonstrate acute and/or residual language impairment following injury are at greater risk for problems in discourse processing. Impairment in the semantic aspects of language has been implicated, even though the magnitude of discourse impairment has not been well correlated with clinical language deficits identified on standard measures of naming, fluency, and vocabulary (Chapman et al., 1992; 1995; Dennis & Barnes, 1990). Chapman et al. proposed that, in the absence of language impairment, discourse problems in children with CHI may be attributed primarily to disruptions of organizational schema which guide discourse formulation and are associated with lesions to specific regions of the frontal lobes (Chapman et al., 1992; 1998).

Purpose of Study

The primary purpose of this study was twofold: (1) to describe the discourse of school-aged children who were long-term survivors of severe CHI sustained during early to middle childhood and (2) to identify the linguistic and cognitive deficits contributing to disruptions in their discourse processing. Children who had sustained severe injury were compared to children with mild injury, the expectation being that, relative to the mild group, the severe group would demonstrate marked reduction in macro-level structures reflecting general content, meaning (i.e., propositions, gist), and organization (i.e., episodes) and less impairment in micro-level structures reflecting amount and complexity of language (i.e., number of words, sentences, and dependent clauses). The relationship between both groups' discourse performance and performance on measures of language, executive function, memory, and processing speed were analyzed. We hypothesized that processing of narrative stories involves multiple cognitive systems which contribute to complex problem solving: language, memory, and executive functions. Language contributes to discourse processing at multiple levels and contributes to inferencing and formulation of mental models (Dennis, 1991). Executive abilities including planning, formulation and integration of mental representations, and inhibition contribute to macro-level processing. Working memory is necessary for maintenance of mental set, processing of incoming information, and self-monitoring. In association with working memory, attention and processing speed are important for the effective processing of oral language, which is time-limited (Frederiksen et al., 1990; Mandler & Johnson, 1977; Mross, 1990). We proposed that macro-level measures of story information, such as number of propositions, episodic structure, and gist (Ulatowska & Chapman, 1994), would be particularly sensitive to disruptions of executive cognitive abilities in children with severe CHI (Chapman et al., 1992), and that micro-level measures, such as total number of words and sentences and complexity of sentences, would be associated with impairments in language.

Our findings of the relationship between focal brain lesions and cognitive performance (Chapman et al., 1992; Levin et al., 1994; 1997) have shown a relationship between volume of lesion in the prefrontal lobes and degree of deficit. Therefore, we hypothesized that discourse deficits in children with severe brain injury might be associated with lesions of the prefrontal lobes.

This study was part of a larger, comprehensive, longitudinal project and thus provided the opportunity to:

1. analyze the relationship between discourse performance and other linguistic and cognitive abilities at long term follow-up,
2. examine the contribution of factors considered influential in head injury outcome in children, and
3. replicate and extend previous discourse findings in a well-defined, relatively large sample.

METHODS

Research Participants

Participants for this study were selected from a larger project investigating the long-term recovery of cognition in children with CHI. Children in the larger study were recruited from consecutive admissions to neurosurgery services for CHI at three University of Texas medical centers: Hermann Hospital in Houston, Parkland Hospital and Children's Medical Center in Dallas, and John Sealy Hospital in Galveston. Children with either mild or severe head injury, based on the lowest postresuscitation Glasgow Coma Scale (GCS) score of Teasdale and Jennett (1974), were included if they met the following selection criteria: (1) aged 5 to 18 years at the time of testing; (2) nonpenetrating head trauma due to sudden acceleration or deceleration of the freely moving head or being struck with a blunt object; (3) no preinjury history of a diagnosed neurologic or psychiatric disorder; and (4) English as their primary language. Exclusion criteria included (1) injury due to child abuse; (2) a history of substance abuse, mental retardation, or learning disability; and (3) previous head injury resulting in hospitalization. In addition**,** children in this study represented a narrower age range (8–16 years) relative to the larger longitudinal project. We defined severe CHI as a GCS score of 3 to 8, irrespective of brain imaging results. Mild CHI was defined as a GCS score of 13 to 15, duration of unconsciousness less than 30 minutes, no brain lesion on computed tomography (CT) within 24 hours of injury, and no focal brain lesion on magnetic resonance image (MRI) performed as part of this study. A total of 17 of the 23 (74%) children in the mild group and 38 of the 68 (56%) children in the severe group were studied longitudinally after their injury. The current article is based on data obtained at their 36-month assessment. Discourse data, based on the same procedure but different stories and obtained at the 3- and 12-month assessments, have been previously reported on a subgroup of these children (Chapman et al., 1992; 1995; 1997; 1998). A total of 6 (26%) children in the mild group and 30 (44%) children in the severe group composed a retrospective cohort who were assessed once three or more years postinjury.

Table 1. Demographic and clinical features of the mild and severe CHI groups

	Mild CHI ($N = 23$)			Severe CHI ($N = 68$)		
Variable	*M*	*SD*	Range	*M*	*SD*	Range
Age at study (years)	11.68	2.39	8.1–16.9	12.19	2.58	8.0–17.0
Age at injury (years)	7.96	2.78	2.1–14.0	7.76	2.82	2.0–14.0
Injury–study interval (years)	3.72	1.60	3.0–8.3	4.42	2.13	2.4–11.0
Parental education (years)	15.00	2.32	12–18	14.14	2.12	12–20
GCS score	14.44*	.66	13–15	5.70*	1.74	3–8
Gender						
% boys	65.22			61.76		
Cause of injury						
% vehicle accident	30.43			41.18		
% struck by vehicle	8.70			30.88		
% bicycle accident	17.39			8.70		
Glasgow Outcome Scale						
% good recovery	95.24			39.39		
% moderate disability	4.76			59.01		
% severe disability	0			1.52		

*$p \leq .0001$.

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Table 1 presents the demographic and clinical characteristics of the two groups. Univariate analyses revealed no significant differences between the two groups for age at study, age at injury, injury–study interval, parental education, and gender distribution. As expected, there was no overlap in mean GCS scores. The interval between the time of injury and study was somewhat greater for the severe group due to the fact that more children in this group were from the retrospective cohort. Cause of injury differed between the groups. Approximately one-third of children in the mild CHI group and somewhat more than one-third of the severe CHI group had been injured in motor vehicle accidents. Whereas approximately one-third of the severe CHI group had been struck by a vehicle, the second most common cause of injury in the mild CHI group was bicycle-related. As would be expected, global outcome, assessed using a modified Glasgow Outcome Scale (Jennett & Bond, 1975) completed at the time of testing, indicated most of the children in the mild group and approximately one third of the children in the severe group had made a good recovery; however, almost two-thirds of the children in the severe group were judged to have moderate disability.

Procedures

Description of task

The experimental task involved a complex narrative story, "The Lobster and the Crab" (see Appendix), which contained 42 clauses and 285 words. This was one of two narrative retellings administered to children in the larger project. The story was read to the child in a quiet testing room. Prior to reading the story the examiner instructed the child to listen carefully so that the child would be able to retell the story in detail. No prompting was provided by the examiner during the child's retelling unless it was unclear whether the child had completed his/her rendition. After retelling the story, the child was asked to explain the central lesson or moral of the story. The story was audiotape-recorded and later transcribed verbatim for analysis of information and language structures using the same methodology described in previous reports (Chapman et al., 1992; 1995; 1997; 1998). Although the results of the current story have not been previously presented, the presentation, auditory taping, transcription, and analysis procedures are the same as those described previously.

Discourse measures

The stories were calculated according to two domains, language and information. Within the language domain the total number of words in each child's story was calculated by including all revisions and whole word repetitions but excluding extraneous verbalizations such as "um" or "uh." The t-unit, which is equivalent to a sentence, was defined as one independent clause and all of its modifying dependent clauses (Hunt, 1965). The total number of t-units containing dependent clauses was considered to provide a measure of sentence complexity. Within the information domain a proposition was defined as a unit of information consisting of a predicate (i.e., verbs, modifiers, and connectors) with one or more arguments (Kintsch & van Dijk, 1978). Analysis of propositions entailed segmenting the child's story into propositions and dividing the number of core propositions (essential information) by the number of propositions contained within the original story. Episodic structures form the basic building blocks of the narrative story and depict the temporal sequence of events (Roth & Speckman, 1986). Episodic boundaries are marked by the resolution of one episode and the introduction of a new episode through a change in time, place, or characters. Episodic structures analyzed in this study included (1) setting (i.e., identification of characters, time, and place); (2) action (i.e., sequence of events and turning point of story); and (3) resolution (i.e., final outcome of the characters' actions) (Labov, 1972). The total number of episodic structures contained in each child's story was divided by the number of episodic structures in the canonical story. Gist refers to the most important information in the story or global story content (van Dijk, 1980, 1985). In order to analyze story gist a set of 5 propositions from the 30 original propositions was identified based on the major setting, event, and resolution information for the episodes that conveyed the essential elements of the story. The total number of gist propositions contained in each child's story was divided by the number of gist propositions previously identified in the story. This approach provided a means to determine whether the child was able to provide the essential elements of the story.

Scoring reliability for discourse measures

To establish reliability of the analyses, 25% of the stories were randomly selected and analyzed separately by two trained raters. Reliability scoring yielded point-by-point interrater agreements of 97% for words, 95% for t-units, and 93% for dependent clauses. For the information measures, the interjudge reliability for each measure was 94% for total propositions, 96% for gist, and 94% for episodic structure.

Linguistic and cognitive measures

To assess the contribution of specific language and cognitive abilities to discourse performance, data obtained at the 36-month assessment using measures administered in the larger project (Levin et al., 1991; 1996) were used. The measures were selected based on their significant contribution to a five-factor model of executive functioning in head-injured and normal children. Since the number of measures which best described a factor was variable, certain factors included only one measure whereas other factors included as many as four. The measures are listed in Table 2 according to their respective factors. It should be noted that Factor 1 (Discourse) was defined by discourse measures of information (i.e., core, gist, and episode), used as dependent vari-

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Table 2. Measures contributing to a five-factor model of cognitive function which were used to assess the contribution of specific language and cognitive abilities to discourse performance

Factor	Measure
Factor 1 (Discourse): defined by measures of essential information and verbal ability.	Peabody Picture Vocabulary Test–Revised (Dunn & Dunn, 1981).
Factor 2 (Executive Functions): included measures of working memory, planning, problem solving, and productivity.	Wisconsin Card Sort Test (Grant & Berg, 1948) Word Fluency Test (Benton & Hamsher, 1976). Porteus Maze Learning (Porteus, 1965). Divided Attention (Hiscock et al., 1987). Tower of London (Shallice, 1982).
Factor 3 (Processing Speed): composed of tasks considered particularly sensitive to performance time.	Rapid Automatized Naming (Denckla & Rudel, 1974).
	Semantic Memory Verification Speed (Baddeley & Wilson, 1988). WISC–R Coding (Wechsler, 1974). Go–No–Go Task (Drewe, 1975).
Factor 4 (Declarative Memory): included word recall measures involving episodic and semantic memory.	California Verbal Learning Test (Delis et al., 1986).

ables in the current study, as well as the Peabody Picture Vocabulary Test–Revised (PPVT–R), a measure of general verbal ability.

Magnetic resonance imaging

Due to the longitudinal aspect of the project, MRI technology has evolved, using various pulse sequences, thinner slices, and higher field magnets, since initial studies were completed in 1990. However, the protocol has consistently included T1-weighted sagittal images, T1-weighted coronal images, and T2 weighted coronal images. Beginning in August, 1991, patients were imaged in Dallas with a 1.5 Picker magnet (Picker International, Highland Heights, OH) to obtain 5-mm 3DFT T1-weighted sagittal and coronal images; 5-mm T2-weighted coronal images were done with no gap. A neuroradiologist reviewed all of the scans independent of the cognitive data. The findings were entered on a coding form that specified the anatomic location and pathology of each focal area of abnormal intensity as well as atrophy. Intracranial gray and white matter lesions were measured with a Jandel planimeter (Jandel Scientific, Rafael, CA) connected to a microcomputer (IBM, Armonk, NY). The area of each lesion was measured on successive slices and summed to obtain a total volume. All brain lesions were traced on templates developed for MRI coronal slices (Damasio, 1991).

Statistical analyses

Multivariate analysis of covariance was used to test group effects on the discourse measures. Age at injury and injury–test interval were used as covariates in all of the analyses. Spearman rank-order correlations were calculated to examine relationships between the discourse measures and the cognitive and linguistic measures. Multiple regression analyses were performed to determine whether the volume of focal gray matter lesion was related to discourse performance. A multiple regression was performed for each region of interest (i.e., left frontal, left extrafrontal, right frontal, right extrafrontal, left frontal plus right frontal) to assess the incremental contribution of lesion volume to severity group, age at injury, and the interaction of the two variables. Separate multiple regressions were also performed to assess total brain atrophy and total volume of white matter lesion.

RESULTS

Discourse Measures

The effects of severity of head injury (i.e., severe *vs.* mild) were analyzed for the language and information structure domains. Multivariate analysis of covariance, using age at injury and injury–test interval as covariates, was performed for the mild and severe CHI groups. Results are presented in Table 3. To assess the sensitivity of individual measures of information and language to severity of injury, univariate analyses of covariance were performed, using age at injury and injury–test interval as covariates.

There was a significant effect of severity of injury for the combined information and language structures. Similar results were obtained for the information structures, and a trend toward a significant difference was noted for the language structures. Age at injury and injury–test interval were statistically significant in the three MANCOVA models. There

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Table 3. Summary of multivariate analysis of covariance and analysis of covariance for testing effects of severity of injury, age at injury, and injury-test interval on discourse measures

	Severity			Age at injury			Injury–test interval		
Measure	*F*	(*df*)	*p*	*F*	(*df*)	*p*	*F*	(*df*)	*p*
MANCOVA									
Information and language structures	3.64	(2,86)	.0303	6.46	(2,86)	.0024	6.62	(2,86)	.0021
Information structures	7.06	(1,87)	.0094	12.14	(1,87)	.0008	10.52	(1,87)	.0017
Language structures	3.34	(1,87)	.0709	5.12	(1,87)	.0262	2.69	(1,87)	.1045
ANCOVA									
Information structures									
Core propositions	9.24	(1,87)	.0031	12.34	(1,87)	.0007	5.22	(1,87)	.0247
Gist propositions	4.54	(1,87)	.0360	10.41	(1,87)	.0018	8.65	(1,87)	.0042
Episodes	5.38	(1,87)	.0227	7.87	(1,87)	.0062	11.67	(1,87)	.0010
Language structures									
T-units	.80	(1,87)	.3728	2.52	(1,87)	.1157	1.82	(1,87)	.1810
Dependent clauses	3.10	(1,87)	.0820	7.77	(1,87)	.0065	6.30	(1,87)	.013
Unedited words	3.48	(1,87)	.0654	4.95	(1,87)	.0286	2.44	(1,87)	.1219

Note. *F* tests are based on Wilks's Lambda.

were no statistically significant interactions for severity, age at injury, and injury–test interval. The ANCOVA results revealed statistically significant differences on the three information measures and a trend toward significance for severity of injury on the language measures of dependent clauses and unedited words. Greater severity of injury, reflected in lower GCS scores, was associated with lower scores on all measures. Age at injury was significant for the three information measures and two of the language measures, with younger age associated with lower scores. Injury-test interval was significant for the information measures and dependent clauses, with longer interval associated with higher scores.

As depicted in Figure 1, the stories of the severe CHI group differed from those of the mild CHI group in amount of essential information (i.e., core and gist propositions) and organization (i.e., episodes); their stories also contained fewer words and fewer complex sentences.

In order to assess the contribution of general verbal ability memory to severity group differences in discourse performance, MANCOVA using severity of injury, age at injury, the interaction of injury severity and age at injury, and the PPVT–R standard score as covariates, was performed. Results revealed the effects of severity of injury and age at injury were not significant for the combined information and language structures; however, the overall effect of the PPVT–R was statistically significant [$F(2,85) = 11.60$, $p = .0001$], indicating that general verbal ability contributed more to differences in discourse performance three years post-injury than factors associated with the head injury. Similar results were obtained for the PPVT–R and information and language structures and follow-up univariate analyses completed with the six discourse measures. The same procedures were also completed for the California Verbal Learning Test (CVLT–C) Monday List standard score (Delis et al., 1986) in order to assess the contribution of verbal memory to the discourse differences. The overall effect of the CVLT–C was also significant [$F(2,85) = 5.48$, $p = .006$], indicating that verbal memory contributed more than injury-related factors to discourse differences between the severe and mild groups. Similar results were obtained for the information and language structures and follow-up univariate analyses completed with the six discourse measures.

Performance on Cognitive Measures and Discourse Production

Table 4 presents the mild and severe CHI groups' mean scores on cognitive measures. Mean performance scores of the severe CHI group differed significantly from those of the mild CHI group on six of the twelve measures. Spearman rank-order correlations were calculated for the measures in Table 4 and the six discourse measures. Results revealed statistically significant ($p \leq .01$) correlations for the PPVT–R and Wisconsin Card Sort Test (Grant & Berg, 1948) and the six discourse measures, which were low to moderate (.27–.53). The Word Fluency Test (Benton & Hamsher, 1978) obtained significant ($p \leq .01$) and moderate correlations (.42–.43) with four of six discourse measures, and significant ($p \leq .01$), and low correlations (.26–.43) were obtained for the Porteus Mazes (Porteus, 1965) and CVLT scores with two to five measures. To assess the relationship between discourse performance and specific cognitive abilities, apart from general verbal functioning, Spearman rank-order partial correlations were calculated for the measures in Table 4 and the six discourse measures, adjusting for the PPVT–R standard score. Results, presented in Table 5, revealed statistically significant correlations for the Wisconsin Card Sort Test and five of six discourse measures and

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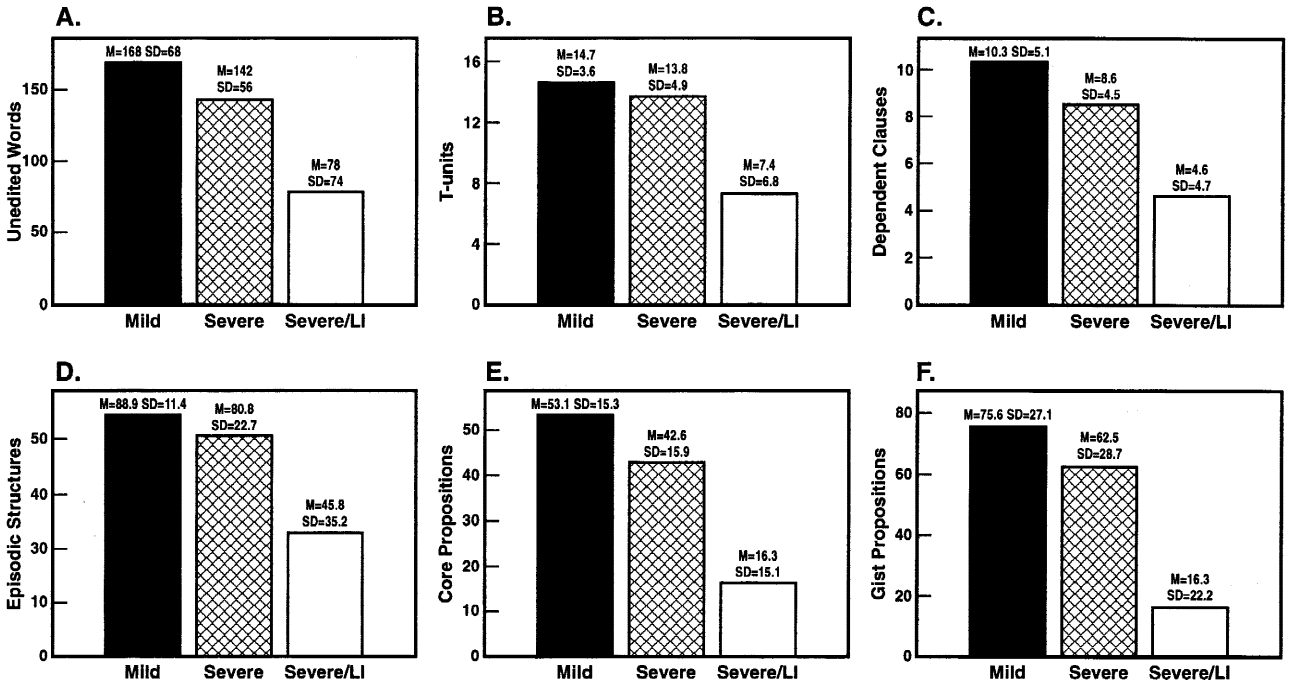

Fig. 1. Performance of the mild CHI, severe CHI, and severe CHI/LI groups on six discourse measures: A: Unedited Words; B: T-Units; C: Dependent Clauses; D: Episodic Structures; E: Core Propositions; F: Gist Propositions.

Table 4. Mean scores obtained on cognitive measures by mild and severe CHI groups

	Mild CHI (N = 23)		Severe CHI (N = 68)	
Factor/Measure	*M*	*SD*	*M*	*SD*
Discourse				
PPVT–R*	102.35	14.75	90.29	17.86
Executive Functions				
WCST	61.87	22.22	59.32	19.43
Word Fluency*	26.35	7.79	21.60	8.91
Porteus Mazes	6.13	1.91	5.52	2.11
Divided Attention*	56.54	8.35	50.51	11.95
Tower of London	98.19	4.32	97.02	5.37
Processing Speed				
Rapid Naming	44.22	8.31	52.55	16.24
Semantic Memory	.79	.42	.91	.33
WISC–R Coding	9.09	3.39	8.41	3.22
Reaction Time	.40	.13	.40	.14
Declarative Memory				
CVLT Total*	55.61	9.39	47.06	11.57
CVLT Cluster*	23.22	10.69	15.71	8.91

*$p \leq .05$.
Note. PPVT–R = Peabody Picture Vocabulary Test standard score (M = 100, SD = 15); WCST = Wisconsin Card Sort Test percent conceptual responses; Word Fluency = total number of words; Porteus Mazes = total number correct; Divided Attention = time in seconds; Tower of London = percent correct; Rapid Naming = time in seconds; Semantic Memory = verification time in minutes; WISC–R Coding = scaled score (M = 10, SD = 3); Reaction Time = time in minutes; CVLT Total = California Verbal Learning Test recall across Trials 1–5 of Monday List; CVLT Cluster = California Verbal Learning Test clustered responses across Trials 1–5 of Monday List.

Table 5. Spearman rank order partial correlations between discourse and cognitive measures for the mild and severe CHI groups

	Partial correlation coefficients					
	Information structures			Language structures		
Factor/Measure	Core	Gist	Episodic	Words	T-units	Clauses
Executive Functions						
WCST	.28*	.29*	.24*	.21	.25*	.27*
Word Fluency	.30**	.39***	.24	.18	.14	.34**
Porteus Mazes	.11	.26*	−.01	.05	.05	.11
Divided Attention	.05	.05	−.06	−.01	−.10	.21
Tower of London	−.13	−.04	.04	−.24	−.24*	−.12
Processing Speed						
Rapid Naming	−.20	−.17	−.23	−.02	−.03	−.15
Semantic Memory	−.13	−.02	.03	−.13	−.06	−.14
WISC–R Coding	.11	.08	−.10	.06	.09	.14
Reaction Time	−.14	−.07	−.17	.04	.02	.15
Declarative Memory						
CVLT Total	.17	.13	.17	.03	.04	.17
CVLT Cluster	.18	.17	.20	.05	.10	.15

*$p < .05$. **$p < .01$. ***$p < .001$.
Note. PPVT–R = Peabody Picture Vocabulary Test standard score ($M = 100$, $SD = 15$); WCST = Wisconsin Card Sort Test percent conceptual responses; Word Fluency = total number of words; Porteus Mazes = total number correct; Divided Attention = time in seconds; Tower of London = percent correct; Rapid Naming = time in seconds; Semantic Memory = verification time in minutes; WISC–R Coding = scaled score ($M = 10$, $SD = 3$); Reaction Time = time in minutes; CVLT Total = California Verbal Learning Test recall across Trials 1–5 of Monday List; CVLT Cluster = California Verbal Learning Test clustered responses across Trials 1–5 of Monday List.

for the Word Fluency Test and three of six measures (core, gist, and dependent clauses).

Effects of Locus and Volume of Lesion

Multiple regression models which incorporated the lesion volume on MRI were run to examine the usefulness of focal brain lesion volume in predicting discourse performance. Five sets of multiple regressions (i.e., left frontal, left extrafrontal, right frontal, right extrafrontal, and left frontal + right frontal) were run for each of the six information and language variables. Locus and volume of lesion did not significantly predict discourse performance. Similarly, multiple regressions which incorporated the extent of whole brain atrophy and the extent of white matter lesion were run for each of the six variables. Neither significantly predicted discourse performance.

DISCUSSION

Discourse Measures

The discourse abilities of children who had sustained severe TBI three years previously were analyzed. Relative to a mild CHI group, children with severe CHI produced narrative stories characterized by reduced content and information, impaired organization, fewer words, and less complex sentences. These findings are consistent with previous reports from this project documenting discourse problems in children with severe CHI three and twelve months postinjury (Chapman et al., 1995) and indicate that disruptions in discourse may persist for years after sustaining a severe CHI (Chapman et al., 1992). Reduction in amount and complexity of spoken language and difficulty in conveying the main ideas and essential meaning of narrative material are likely associated with other cognitive–communicative deficits which have been documented in children following severe head injury, including impaired understanding of the alternate meanings of words in context, reduced comprehension of figurative expressions, and difficulty bridging inferential gaps in spoken language (Dennis & Barnes, 1990).

Age at injury and injury–test interval were significantly related to discourse performance for both the mild and severe CHI groups; however, there was no interaction effect. These findings were expected due to the longitudinal aspect of the study and the correlation between age at injury and age at testing. Gronwall et al. (1997) suggested that mild head injury in young children may result in long-term cognitive deficits but noted that controlled prospective studies are needed to address this question. Several recent reports have also found that severe, diffuse brain injury may have more deleterious effects in younger children (Anderson & Moore, 1995; Anderson et al., 1997; Barnes et al., 1999; Dennis et al., 1995; Ewing-Cobbs et al., 1997; Levin et al., 1995; Taylor & Alden, 1997), particularly during early child-

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hood when language, due to its rapid rate of acquisition, may be especially vulnerable (Ewing-Cobbs et al., 1987).

Effects of Specific Linguistic and Cognitive Abilities on Discourse Production

Group differences in performance on a number of linguistic and cognitive measures were apparent. Of note was the relationship between general verbal ability (PPVT–R) and discourse performance. This finding is consistent with several studies which have identified the contribution of verbal ability to discourse performance. Chapman et al. (1995, 1998) found a significant correlation between receptive vocabulary and performance on two discourse tasks, one involving auditory retelling and the other retelling from visual memory. Dennis and Barnes (1990) found word knowledge, evidenced by performance on the WISC–R vocabulary subtest, to be associated with the ability to comprehend ambiguity and to produce alternate meanings for ambiguous words and sentences. Results of partial correlations, adjusting for general verbal ability, revealed a significant contribution of verbal fluency. Dennis and Barnes (1990) also found word fluency predictive of understanding of ambiguity and suggested that the ability to produce multiple words for a single phonological representation may be linked with the ability to comprehend and produce multiple meanings for the same word or sentence.

The relationship between the children's performance on the Wisconsin Card Sort Test (Grant & Berg, 1948) and their discourse production is consistent with the view that impairments in discourse are associated with deficits in executive functions (Coelho et al., 1995; Dennis, 1991) involving planning and the application of organizational schemata (Chapman et al., 1995). According to this view, story generation requires identification of a goal, formulation of a plan, and evaluation of the success or failure of the plan with regard to attainment of the specified goal. Identification of essential story elements requires the ability to make inferences about meaning by integrating a semantic representation of old knowledge with ongoing discourse information (Dennis, 1991). The significant relationship between performance on the CVLT–C (Delis et al., 1986), a verbal memory task, and the discourse measures supports current understanding of discourse processing as involving components of both long- and short-term memory. The fact that verbal memory ceased to be significantly associated with discourse performance after the variance associated with verbal ability had been taken into account may be considered to reflect the high intercorrelation of these variables. Both long- and short-term memory are postulated to be involved in the simultaneous processing of time-limited information and its integration with other material (Baddeley, 1987; van Dijk & Kintsch, 1983).

Effects of Locus and Volume of Lesion

Neither site or extent of gray and white matter lesions nor whole brain atrophy were useful in predicting discourse production. This finding was unexpected since focal lesion volume, as measured using similar procedures, has been predictive of performance on measures of executive function and episodic memory (Levin et al., 1993; 1994; 1997).

Limitations of the Study

A limitation of this study is the small number of children in the mild CHI group relative to the severe CHI group. Recruitment of children from neurosurgical ward admissions resulted in the accrual of fewer children with mild injuries. Since the focus of the study was on children with severe CHI, the mild CHI group was recruited for comparative purposes, the assumption being that their discourse performance would approximate normal levels as had been demonstrated in a previous study (Chapman et al., 1992); however, the story narrative used in this study was more complex than narratives previously analyzed from this project, and it is possible that deficits between the mild CHI and a normal control group might have been apparent.

Conclusions

Children who sustain a severe closed head injury during early to middle childhood are at risk for deficits in discourse processing which persist for years. Disruptions in discourse are associated with deficiencies in general verbal ability and verbal fluency, as well as problem solving and working memory. A better understanding of the nature of these processes and their contribution to complex behavior will facilitate the development of more effective interventions for children with CHI (Grafman & Salazar, 1995), who are at risk for long-term academic and social adjustment problems (Barnes et al., 1999; Ewing-Cobbs et al., 1998; Klonoff et al., 1995).

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APPENDIX

THE LOBSTER AND THE CRAB STORY

One stormy day, Mr. Crab was walking along the beach. It was clear that a bad storm was coming. He was surprised to see that Mr. Lobster was preparing to set sail in his boat. The Crab told Mr. Lobster that it was not a good idea to go sailing on a day like this. But Mr. Lobster loved to sail during a storm. Well, the Crab decided that he would not let Mr. Lobster face such danger alone. So, the Lobster and Crab set out to sail together.

It wasn't long before Mr. Crab and Mr. Lobster found themselves far from shore. Their boat was tossed and thrown about by the rough waters. Mr. Lobster was so thrilled. He loved the fierce splashing of the ocean against the boat. The crashing of every wave excited him. Mr. Crab, on the other hand, was frightened. All he could think about was that the boat was sinking. Furthermore, Mr. Lobster was no comfort at all. He told Mr. Crab that, of course, they were sinking, because the old boat was full of holes. Mr. Lobster saw no reason to be afraid since they were both creatures of the sea. In the end, the little boat did indeed capsize and sink. The Crab was horrified, shaken, and very upset, but not Mr. Lobster. He was full of so much excitement. Mr. Lobster took the Crab for a relaxing walk along the ocean floor. The Lobster talked about how brave they both were and what a wonderful adventure they had. Mr. Crab began to feel somewhat better. Although he usually enjoyed a quieter existence, he had to admit that the day had been pleasantly out of the ordinary.