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PAPER

Narrative skill in children with early unilateral brain injury: a possible limit to functional plasticity

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Abstract

Children with pre- or perinatal brain injury (PL) exhibit marked plasticity for language learning. Previous work has focused mostly on the emergence of earlier-developing skills, such as vocabulary and syntax. Here we ask whether this plasticity for earlier-developing aspects of language extends to more complex, later-developing language functions by examining the narrative production of children with PL. Using an elicitation technique that involves asking children to create stories de novo in response to a story stem, we collected narratives from 11 children with PL and 20 typically developing (TD) children. Narratives were analysed for length, diversity of the vocabulary used, use of complex syntax, complexity of the macro-level narrative structure and use of narrative evaluation. Children's language performance on vocabulary and syntax tasks outside the narrative context was also measured. Findings show that children with PL produced shorter stories, used less diverse vocabulary, produced structurally less complex stories at the macro-level, and made fewer inferences regarding the cognitive states of the story characters. These differences in the narrative task emerged even though children with PL did not differ from TD children on vocabulary and syntax tasks outside the narrative context. Thus, findings suggest that there may be limitations to the plasticity for language functions displayed by children with PL, and that these limitations may be most apparent in complex, decontextualized language tasks such as narrative production.

Introduction

Children with pre- or perinatal unilateral brain injury (PL) exhibit marked plasticity for language, even when their lesions impinge on classical language areas (e.g. Bates & Dick, 2002; Feldman, 2005; Stiles, Reilly, Paul & Moses, 2005; Woods & Teuber, 1978). After an initial delay in getting language off the ground, these children, on average, perform in the low-normal to normal range in the early stages of language development on measures assessing lexical and syntactic skills (e.g. Bates, Thal, Finlay & Clancy, 1992; Bates, Thal, Trauner, Fenson, Aram & Eisele, *et al*. 1997; Feldman, Holland, Kemp & Janosky, 1992; Rowe, Levine, Fisher & Goldin-Meadow, 2009; Sauer, Levine & Goldin-Meadow, in press; Thal *et al*., 1991). Because studies of language development in this population have focused mainly on the emergence of early skills, little is known about the limits and extent of this plasticity for more complex, decontextualized aspects of language, such as narrative production, which begin to emerge in the preschool years and continue to develop as children progress through school (e.g. Bamberg, 1987; Berman & Slobin, 1994; Peterson & McCabe, 1983). Moreover, conclusions about later language skills in children with PL appear to conflict. That is, some studies of children with PL report that by about school age, initial language delays are overcome (e.g. Bates *et al*., 2001; Marchman & Thal, 2004; Reilly, Losh, Bellugi & Wulfeck, 2004). In contrast, others report deficits at later ages, especially on more complex tasks such as narrative production or comprehension of complex syntactic constructions (e.g. Alexander 1999; Dick, Wulfeck, Bates, Saltzman, Naucler & Dronkers, 1999; Feldman, MacWhinney & Sacco, 2002; MacWhinney, Feldman, Sacco & Valdés-Pérez, 2000; Weckerly, Wulfeck & Reilly, 2004; Wulfeck, Bates, Krupa-Kwiatkowski & Saltzman, 2004).

In the present study, we ask whether the plasticity exhibited for early-developing aspects of language extends to more complex, later-developing language functions by examining the narratives produced by 5- to 8-year-old children with PL in relation to those produced by typically developing control children. Narrative development has an extended developmental trajectory. Narrative skill emerges as early as two years of age in children's mention of past events (Applebee, 1978; Botvin & Sutton-Smith, 1977). Three- to 4-year-olds are able to combine two or more events in their narratives, and 5-year-olds' narratives tend to include basic components of a narrative, for example an action sequence and an outcome, and be organized around goals of the story characters. Children's narratives continue to

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improve during the school years in terms of length, linguistic complexity and narrative structure, and this developmental trajectory extends well into adolescence (Berman & Slobin, 1994; Peterson & McCabe, 1983; Stein, 1988). Producing a good narrative is challenging because it involves paying attention to multiple aspects of language, including linguistic structure, narrative structure and evaluation of narrative content. It also involves talk that is extended, explicit, and beyond the here-and-now; that is, it involves talk that is decontextualized (e.g. Dickinson & Tabors, 1991). Moreover, narrative production is important in every-day interchange and is a significant predictor of later school achievement (e.g. Dickinson & McCabe, 2001), and therefore provides an ecologically valid way to examine the extent and nature of language plasticity in the context of a complex language task (e.g. Berman & Slobin, 1994; Brown, 1973).

Narratives can be analysed at the levels of linguistic and narrative structure. In terms of linguistic structure, narratives involve lexical encoding of information about the events and the characters as well as the use of appropriate morphosyntactic structures (Reilly, Bates & Marchman, 1998). In terms of narrative structure, adults' judgments indicate that good narratives include a protagonist, a temporal and causal structure, and goal-directed actions (Stein & Policastro, 1984). A simple story, thus, contains an initiating event that creates a problem for the protagonist. The protagonist forms a goal in response to this event, and carries out planned actions to achieve the goal. The protagonist's attempts lead to attainment or non-attainment of the goal, the outcome. This goal–action–outcome sequence forms the framework for a basic story episode. Furthermore, according to Labov and Waletzky (1967), good narratives fulfill an evaluative function, such that the narrator comments on the significance of the events in addition to providing information about the characters and the events. That is, 'good' narratives include cognitive inferences about the protagonist's motivations, express the goals behind his/her actions, and provide information about the causal relations of the events. They also convey information about the affective states and/or the behaviours of the protagonist. Because narratives have an extended developmental trajectory, rely on multiple aspects of language and include the use of decontextualized language, narrative production might present a particular challenge for children with PL over and above their performance on earlier-developing, basic aspects of language such as vocabulary and syntax.

A few prior studies have examined narrative skills in children with PL using story-retelling tasks. Reilly and colleagues (Reilly *et al*., 1998) asked 3;6- to 10-year-old children with PL and typically developing (TD) control children to relate a narrative using a picture book, *Frog Where Are You?* Although a diverse set of language measures was assessed, performance at the level of macro-structure was not assessed. Children with left and with right hemisphere lesions performed worse than TD children of the same age on a wide range of measures, including number of propositions, word tokens, word types, morphological errors, amount and diversity of complex syntax, number of story components mentioned, and reiteration of the main theme of the story. In a follow-up study (Reilly *et al*., 2004), 10- to 12-year-old children with PL performed as well as TD children on measures of morphological errors and complex syntax, but continued to lag behind on story length. (Other measures were not assessed in this study.)

Using a story-retelling task, Chapman, Max, McGlothlin, Gamino and Cliff (2003) assessed narrative skill in 8- to 19-year-old children with focal unilateral brain injury and a control group consisting of children with orthopedic injury. Children were asked to listen to a relatively lengthy story (235 words consisting of two episodes) told by the experimenter. Following this, the children were asked to retell the story to the experimenter. After the retelling, children were asked to give a general lesson that could be learned from the story. Children with unilateral brain injury included both those whose lesions occurred early, namely prenatally up to 12 months of age postnatally, and those whose lesions occurred later, namely from 12 months of age to 13 years of age. The brain-injured and control children did not differ in the amount of language they produced. However, children with brain injury produced significantly shorter utterances as measured by their MLU (mean length of utterance). The two groups also differed on measures of information structure. Children with brain injury included fewer core propositions, gist propositions, episodic components (e.g. setting or complicating action) and macro-level interpretations of the narrative (e.g. general lesson to be learned from the story). Furthermore, the early-age-at-injury group performed at a lower level than the later-age-at-injury group on some of these measures (amount of language produced, information structure measures, and on the macro-level interpretation measure).

The current study

The current study aims to extend our understanding of the plasticity of later-developing language skills in children with PL by examining the narrative skills of this group of children at the lexical, syntactic and macro-structure levels. Our study differs from previous studies of narrative skills in children with PL in several important ways. First, we use a narrative elicitation technique that involves creating narratives *de novo*, in response to a short story stem. Previous studies have, in contrast, mainly used story-retelling tasks, sometimes involving picture books. Such retelling tasks tap multiple skills, including picture processing, story comprehension and story recall. Thus, the difficulties of children with PL on these narrative tasks might be related to one or more of these factors. By examining stories that are created *de novo*, the current study minimizes demands on picture processing, comprehension, and recall of presented materials. On the other hand, research with other clinical child populations, such as children with language disabilities or learning disabilities, suggests that story generation is more difficult than story retelling (Gazella & Stockman, 2003; Morris-Friehe & Sanger, 1992; Seung & Chapman, 2003). Thus, our task may be more challenging than the kinds of narrative tasks that have been used to date in studies of children with PL. Second, our study also differs from previous studies examining narrative skills in children with PL in terms of our measures. In previous studies, narratives have been analysed mainly at the word and clause levels. In the current study, we analyse narratives at these levels as well as at the macro-level by applying the story grammar model developed by Stein and Glenn (1979). This model provides a graded scale of story structures and considers a good, well-structured story to be one that is organized around the goals of the protagonist. Finally, the current study examines whether narrative difficulties of children with PL arise from more general problems in language processing or whether linguistic difficulties are specific to the narrative context. Thus, in contrast to previous studies in the literature, we relate children's performance on the narrative task to their performance on language measures from outside the narrative context to examine whether narrative production presents a particular problem for children with PL over and above their language performance in other contexts.

We focused on a group of children with pre- or perinatal unilateral lesions who ranged in age from 5 to 8 years at the time of assessment, as well as on a group of TD control children. This age range was chosen because it is in this time period that TD children show major developmental changes in narrative skills. That is, at about 5 years of age, TD children transition from organizing their stories in terms of descriptive or temporal sequences to organizing their narratives in a hierarchical way, around a character trying to achieve a goal (e.g. Berman, 1988; Peterson & McCabe, 1983; Stein & Albro, 1997). To examine whether this is also true of children with PL, we examined their narratives at the macro-level, moving beyond the word and clause level. Importantly, macro-level structure measures have been found to be better predictors of long-term language outcomes in children with traumatic brain injury than other language measures (Chapman, Sparks, Levin, Dennis, Roncadin, Zhang & Song, 2004).

In sum, we examine whether the plasticity for language found in children with pre- or perinatal injury extends to later-developing, decontextualized language abilities by assessing these children's performance on a narrative production task. Specifically, we ask the following questions. (1) Do narrative production skills, as characterized by narrative length, vocabulary, syntax, narrative structure and narrative evaluation measures, differ between 5- to 8-year-old children with pre- or perinatal brain injury and TD children? (2) Do narrative productions cause additional problems for the children with PL over and above their language performance on vocabulary and syntax tasks outside the narrative context? The answers to these questions have implications for theories about language plasticity following early brain lesions and also have practical implications for developing remediation and educational supports for children with PL.

Methods

Participants

Eleven children with PL (M = 6.1 years, SD = 1.08 years) and 20 TD children (M = 5.50 years, SD = .17 years) participated in the study. All children in this study were participating in a larger study of language development in the greater Chicago area. The 11 children with PL (8 girls, 3 boys) were recruited by contacting pediatric neurologists in the greater Chicago area and neighbouring states, and through parent support groups in the area (Childhood Stroke and Hemiplegia and Stroke Association). All of the children with PL were Caucasian. Parental education ranged from 12 to 18 years

Table 1 *Neurological information about children with pre- or perinatal brain injury*

ID	Age at visit (yr)	Sex	Side	Size	Type	Seizure	Areas affected	Premature
30	5.52	F	L	L	CI	No	F, T, P, O, subcortical	No
35	6.33	F	L	M	Pv	No	Subcortical	36.5 wk
46	5.82	F	R	L	CI	Yes	F, T, P, subcortical	34 wk
93	5.65	M	R	S	Pv	Yes	Subcortical	No
94	6.32	F	R	S	Pv	No	T, P, IC, subcortical	No
98	8.96	M	L	S	CI	Yes	F, T, subcortical	No
99	7	M	L	L	CI	Yes	T, P, O, IC, subcortical	No
117	5.96	F	R	M	CI	Yes	F, T, P, subcortical	No
132	5.64	F	L	S	Pv	No	T, subcortical	No
135	5.13	F	R	S	CI	No*	F, P	No
150	5.25	F	L	S	Pv	No	WM, subcortical	No

Note: Codes are Sex (F, female; M, male), Side (L, left; R, right), Size (S, small; M, medium; L, large), Type (CI, cerebrovascular infarct; Pv, periventricular), Seizure (Y, history of seizures; N, no history), Areas affected (F, frontal; T, temporal; P, parietal; O, occipital; IC, internal capsule (white matter in the frontal area); WM, white matter); periventricular lesions involve the thalamus, basal ganglia, the medial temporal lobe and/or white matter tracts. * Neonatal seizures resolved without medication.

($M = 14.9$, $SD = 1.64$), and annual family income ranged from $25,000 to $100,000 ($M = \$76,250$, $SD = \$25,310$). Information on neurological profiles of children with PL can be found in Table 1. The 20 TD children (11 girls, 9 boys) were recruited through direct mailings and an advertisement in a free monthly parent magazine, and had no known medical conditions. The TD children were socioeconomically and ethnically diverse. Annual household incomes varied from less than $15,000 to over $100,000 ($M = \$60,875$, $SD = \$32,830$). The sample consisted of 2 African-American, 1 Latino and 13 Caucasian children, and 3 children of mixed race. On average, parents of the TD children had 16.1 years of education ($SD = 1.77$; range = 12 to 18 years) when they entered the study. All TD and PL children were being raised as monolingual English speakers.

Lesion information came from clinical MRI films (10 children), or detailed medical reports (1 child) provided by families. In addition, 7 children were scanned using a 3-tesla GM Scanner at the University of Chicago when they were 5 years of age or older (i.e. when scans could be obtained without sedation). All clinical and experimental scans were evaluated by two pediatric neurologists, who coded lesions according to location, size and type.

The specific lesion characteristics considered in the current analysis include lesion laterality (left, right), lesion size (small, medium, large) and lesion type (periventricular, cerebrovascular infarct). Regarding lesion laterality, 6 children with PL had left hemisphere lesions, and 5 children with PL had right hemisphere lesions. Lesions were also classified according to size on the basis of the following criteria. Small lesions affected only one lobe, or minimally affected subcortical regions. Medium lesions extended into more than one lobe or subcortical region. Large lesions affected three or four lobes and were typically cerebrovascular infarcts; these lesions affected multiple cortical areas and often involved the thalamus and subcortical regions. Using these criteria, 6 children had small lesions, 2 had medium lesions and 3 had large lesions. Children with small and medium lesions were categorized into a single group, as previous findings indicated that the two groups did not differ from each other on various language measures (Brasky, Nikolas, Meanwell, Levine & Goldin-Meadow, 2005). Regarding lesion type, cerebrovascular infarcts (CV) were infarcts of the middle cerebral artery territory, and tended to affect the inferior frontal and/or superior temporal regions. Periventricular lesions (PV) were primarily subcortical and involved white matter tracts, the thalamus, basal ganglia and/or the medial temporal lobe. Although periventricular leukomalacia in very low-birthweight, prematurely born children has been the focus of much previous literature, periventricular lesions also occur in full-term children (Krägeloh-Mann & Horber, 2007). In our study, one child was born at 36.5 weeks (#35), one child was born at 34 weeks (#46), and the other children in our sample were born at or near term according to parental report. Thus, our sample of children with periventricular lesions differs from samples of very premature children with periventricular leukomalacia. Five of the children had periventricular lesions involving white matter tracts and enlarged verticles, and 6 had lesions that resulted from cerebrovascular infarcts.

Procedure

All children were assessed in their homes. They were asked to tell three stories. Each began with the experimenter presenting a story stem. After each stem, the child was asked to make up his/her own story about the character in the stem. The three stems, previously used by Stein and Albro (1991) to study narrative development in TD children, were as follows. (1) Once there was a big grey fox who lived in a cave near a forest. (2) Once there was a little girl named Alice who lived in a house near the ocean. (3) Once there was a little boy named Alan who had many different kinds of toys. The order of stems was counterbalanced. Neutral prompts such as 'anything else' were used until the children reported that they were done with their storytelling.

Transcription and coding

Children's narratives were videotaped, transcribed and analysed on the following dimensions: narrative length, vocabulary diversity, syntax complexity, macro-level narrative structure and narrative evaluation (Table 2). Two children with PL were given only two story stems owing to experimental error, and one child with PL refused to produce story-relevant clauses for two of the story stems. In addition, three TD children refused to produce story-relevant clauses for one of the story stems. Narrative length measures included total number of word tokens and total number of clauses in the story. A word token is defined as any word included in the story (e.g. 'the' is counted five times if it is said five times). A clause is defined as a subject (noun phrase or its equivalent) and its predicate (verb phrase and other accompanying elements such as object or complement). Only clauses that included a predicate and that contributed to the story were included in the analyses (i.e. clauses that concerned side comments, e.g. 'I need a drink', and clauses that did not include a predicate, e.g. 'blue', were not counted). For each child, the total

Table 2 *Narrative measures*

Level of analysis	Measure
Length	Number of word tokens
	Number of clauses
Vocabulary diversity	Number of word types
Syntactic complexity	Proportion of dependent clauses
Macro-level structure	Story-structure score
	Number of goal-based stories
Evaluation	Number of stories with cognitive inference
	Number of stories with affective inference

numbers of clauses and word tokens were tallied for each story, and then averaged across stories.

Vocabulary diversity measures consisted of number of word types. A word type is defined as a unique word (e.g. 'the' is counted as one type, even if it is said five times). Syntactic complexity was assessed by analysing the proportion of all dependent clauses out of the total number of clauses. A dependent clause is a clause that is syntactically dependent on another clause. Dependent clauses include subordinate and embedded clauses. One main clause and one or more subordinate and/or embedded clauses make a complex sentence. A subordinate clause is defined as a clause that needs to be accompanied by a main clause, and can be part of a sentence only when it is dependent on the main clause. An embedded clause is defined as a clause that functions as a constituent of a phrase. Adverbial clauses (e.g. '*If they leave*, they die'), verb complements (e.g. 'All the girls said *that he was weird*'), and relative clauses (e.g. 'He was trying to catch the fox, *which bit him*') are the most common types of dependent clauses. The number of dependent (subordinate and embedded) clauses was divided by the total number of clauses (main, subordinate and embedded) to obtain the proportion of dependent clauses in each story for each child. These measures were then averaged across the stories produced by the children.

Narrative structure was assessed using Stein and Glenn's (1979) model of story complexity. Stein and Glenn define a 'good' story as one organized around a goal plan of action of the story protagonist. According to their model, narratives are built out of four features, which determine the goodness of the organization. These features are (1) an animate protagonist, (2) temporal structure, (3) causal structure and (4) goal-direction action. The presence of each successive feature in this list is contingent upon the presence of earlier features, and stories with more features are considered to be more complex than stories with fewer features. Based on analyses of these features, each story was placed into one of the following seven categories: (1) *A story with no structure* either repeats the stem and adds no information or includes only one sentence; (2) *A descriptive sequence* is a story that consists only of the physical and personality characteristics of an animate protagonist whose actions are not constrained by temporality; (3) *An action sequence* is a story with temporal order (events follow one another in time), but in which story events are not causally organized; (4) *A reactive sequence* contains actions that are causally organized, but does not include the protagonist's goal (the intention of the protagonist to act to achieve a specific end); (5) *An incomplete goal-based story* contains a goal statement and/or an attempt, but no outcome following the goal; (6) *A complete goal-based story with one episode* includes not only temporal and causal structure, but also a goal of the protagonist, an attempt to achieve the goal and an outcome of these attempts; (7) *A complete goal-based story with multiple episodes* includes multiple goal–attempt–outcome sequences. Goals can be overtly stated with a mental-state verb, for example 'He wanted to trick the fox', or in an infinitive attached to an attempt to realize a goal, for example 'He went out to find food'. A goal can also be inferred from the reported sequence of events in the form of the initiating event, attempt and outcome. In the following example, 'He saw a little squirrel, and when the squirrel wasn't looking, he started chasing him really carefully', one can infer that the goal (catching the squirrel) led to the attempt (chasing the squirrel). Examples of each kind of story are provided in the Appendix. Each child's scores were then averaged across the stories the child produced to arrive at a mean story-structure score for each child. We also noted the number of goal-based stories (those scored as 5, 6 or 7) each child told and the score for the story with the highest complexity.

In order to assess the extent to which children were able to evaluate the content of their narratives, we coded the cognitive and affective inferences children included in their narratives. Cognitive inferences were defined as references to protagonist's motivations (e.g. I want to live), mental states (e.g. He didn't know what it was) and causality (e.g. He went out to go eat his food). Affective inferences were defined as references to emotional states (e.g. He liked his toys) or emotion-related behaviours (e.g. He started crying) of the protagonist. The number of stories that included cognitive and affective inferences was tallied for each child.

For those children who did not complete all three story stems, scores were pro-rated to calculate the number of goal-based stories, the number of stories with cognitive inferences and the number of stories with affective inferences they produced. For example, for the child who produced only one story, the number of goal-based stories was multiplied by 3, and for children who produced two stories overall, the number of goal-based stories was multiplied by 1.5.

We established reliability for our speech transcripts by having a second individual transcribe 20% of the children's stories. We then measured reliability on all of our measures. Agreement between coders was 100% for word tokens, 94% for number of clauses, 89% for word types, 100% for number of subordinate clauses, 88% for story-structure score, 100% for number of stories with cognitive inferences, and 100% for number of stories with affective inferences. Disagreements were resolved through discussion.

To examine children's language performance outside the narrative production task, we also assessed children on a standardized vocabulary comprehension measure, the Peabody Picture Vocabulary Test – Third Edition (PPVT-III, Dunn & Dunn, 1997), and on a syntax comprehension measure at 54 months of age. One of the TD children did not receive the syntax comprehension measure, and one of the children with PL did not receive either of the measures. We used the children's standard score on the PPVT-III as a measure of vocabulary comprehension at 54 months, and the child's score on a syntax comprehension task developed by Huttenlocher, Levine and Vasilveya (unpublished) as a measure of syntax comprehension at 54 months. In this task, children are asked to point to the one picture out of three that depicts the relationship expressed in sentences read by the experimenter. The sentences covered a range of syntactic forms and varied in complexity from sentences involving single, simple clauses (e.g. The boy is behind the girl) to those involving multiple simple clauses (e.g. The boy is looking behind the chair for the girl, but she is sitting under the table), to those involving dependent clauses (e.g. The dog who the cat is licking is raising his paw). To make sure that the two groups of children did not differ in general intellectual functioning, we also administered a nonverbal abstract reasoning test, namely the Matrix Reasoning subtest, which is on the Performance Scale of Wechsler Preschool and Primary Scale of Intelligence – Third Edition (WPPSI-III, Weschler, 2002), when children were 5 to 6 years old.

Results

All analyses were performed using SPSS for Mac version 16 (SPSS Inc., Chicago, IL). Prior to any statistical analysis, arc-sine transformations were performed on all measures that were based on proportions. In cases of inhomogeneous variance, adjusted degrees of freedom was used. Our analyses of the children with PL did not reveal differences between children with left versus right hemisphere lesions, between children with small/medium lesions versus large lesions, or between children with periventricular lesions and cerebrovascular infarcts on any of the narrative measures. Thus, all children with PL are grouped together in our analyses. Because the number of children in each lesion characteristic category was small, these findings must be regarded with caution. Although prior studies with larger samples also have not found significant differences regarding lesion laterality on many language measures, lesion size and type differences have been reported (Rowe, Levine, Fisher & Goldin-Meadow, 2009; Sauer, Levine & Goldin-Meadow, in press). Preliminary analyses revealed no significant effects involving gender for TD children or for children with PL. Age was marginally significantly related to only one of the measures for TD children: on average, TD children who told two or more goal-based stories ($M = 5.61$, $SD = .18$) were significantly older than TD children with no goal-based stories ($M = 5.40$, $SD = .14$), $t\,(12) = 2.437$, $p = .031$. Age was not related to any of the other measures for TD children or for children with PL. Thus these two factors were not included in the subsequent analyses. Our analyses also did not reveal any effects of the particular story stem presented on any of our measures. Thus, the measures described below are averaged over the stories administered to each participant. Neither the education nor the income level was significantly different for the families of TD children and of children with PL (Education: $t\,(29) = 1.835$, $p > .05$; Income: $t\,(28) = 1.297$, $p > .05$). Finally, the two groups of children did not differ on our measure of nonverbal abstract reasoning, the Matrix Reasoning subtest on the Performance Scale of Wechsler Preschool and Primary Scale of Intelligence – Third Edition (WPPSI-III) (TD: $M = 12.10$, $SD = 3.34$; PL: $M = 11.56$, $SD = 3.61$), $t\,(27) = .395$, $p > .05$.

Narrative length

Two-tailed *t*-tests examined whether the number of word tokens and whether the number of story clauses (averaged over the stories administered) differed between children with pre- or perinatal lesions and TD children. Children with PL produced significantly fewer word tokens (TD: $M = 37.62$, $SD = 27.81$; PL: $M = 12.97$, $SD = 7.77$) ($t\,(23.860) = 3.709$, $p = .001$, Cohen's $d = 1.21$), and significantly fewer story clauses (TD: $M = 6.39$, $SD = 4.73$; PL: $M = 2.26$, $SD = 1.26$) ($t\,(23.469) = 3.678$, $p = .001$, Cohen's $d = 1.19$) than TD children (Figure 2).

Narrative vocabulary and syntactic complexity

Two-tailed *t*-tests were used to examine whether PL and TD children differed on our narrative vocabulary measure (word types) or on our syntactic complexity measure (proportion of dependent out of total story clauses). Again, these measures were obtained by averaging over the number of stories produced by each child. TD children produced a significantly higher number of word types ($M = 22.43$, $SD = 13.05$) than the children with PL ($M = 10.38$, $SD = 5.32$), $t\,(27.447) = 3.619$, $p = .001$, Cohen's $d = 1.17$ (Figure 2). Although children with PL produced a lower proportion of dependent clauses than TD children did, this difference between the groups failed to reach significance (TD: $M = .18$, $SD = .16$; PL: $M = .11$, $SD = .11$, $t\,(29) = 1.407$, $p > .05$, Cohen's $d = .51$).

Narrative structure

Two-tailed *t*-tests were used to compare TD children and children with PL on a macro-level measure of story structure. On average, TD children produced stories of higher complexity ($M = 3.89$, $SD = 1.64$) than children with PL ($M = 2.12$, $SD = .98$), $t\,(29) = 3.350$, $p = .002$, Cohen's $d = 1.31$ (Figure 2). In order to ascertain whether the pattern found across groups resulted from a few individual children, we examined the number of children in each group who told no goal-based story, one goal-based story, or at least two goal-based stories. The Mantel–Haenszel statistic, which is appropriate when one of the variables is a dichotomous variable and the other is an ordinal variable, was calculated for each measure. The number of children who produced zero,

Table 3 *Proportion of children who produced 0,1 or 2 or more stories*

	Number of stories					
	0 stories		1 story		2–3 stories	
Measure	PL	TD	PL	TD	PL	TD
Goal-based stories	0.82	0.35	0.18	0.30	0.00	0.35
Cognitive inference	0.73	0.30	0.18	0.40	0.09	0.30
Affective inference	0.73	0.65	0.18	0.30	0.09	0.05

PL, children with pre- or perinatal brain injury; TD, typically developing children.

one or at least two goal-based stories differed by group (TD vs. PL), M^2 (1, N = 31) = 6.991, p = .008. More than half of the TD children told at least one goal-based story (13/20), whereas only two of the children with PL produced a goal-based story (2/11). Table 3 summarizes the results. The best performance of children at the individual level of analyses is plotted in the distribution of scores for TD children and children with PL in Figure 1. As shown in this figure, a high percentage of TD children (80%) produced stories with at least a causal structure; that is, reactive sequences or goal-based stories. On the other hand, only a low percentage of the children with PL (28%) told stories that at least had a causal structure. Rather, for the majority of children with PL, the highest-complexity story produced had either a descriptive structure, or a temporal structure, or no structure at all.

To examine whether story-structure score is related to story length, we compared TD children's non-goal-based stories (those scored as 1, 2, 3 or 4) and goal-based stories (those scored as 5, 6 or 7) on our two story-length measures, namely word tokens and story clauses. On average, TD children's goal-based stories included a higher number of word tokens (M = 49.31, SD = 30.13) as compared to non-goal-based stories (M = 23.16, SD = 12.36, t (8) = 3.263, p = .011, Cohen's d = 1.14). Goal-based stories also included a higher number of clauses (M = 8.25, SD = 5.18) as compared to non-goal-based stories (M = 3.96, SD = 1.79, t (8) = 2.857, p = .021, Cohen's d = 1.11). Because of this difference, we

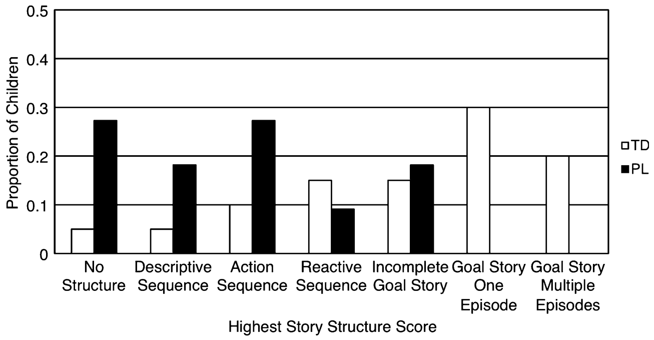

Figure 1 *Proportion of children in each story-structure category graphed as a function of the complexity of children's highest-complexity story and as a function of group.*

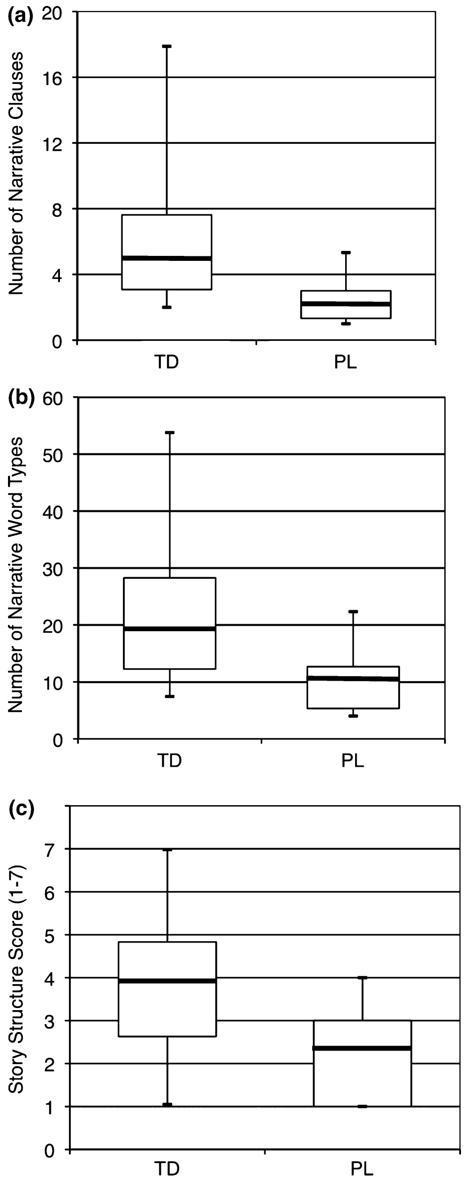

Figure 2 *Distribution of children's (a) narrative clauses, (b) narrative word types, and (c) story-structure score for typically developing (TD) children and children with pre- or perinatal brain injury (PL). The boxes in the graphs represent the inter-quartile range; the line in the middle of each box represents the median and the tails represent the 5th and 95th percentiles. Because three out of 11 children with PL obtained an average story-structure score of 1, the 5th and the 25th percentiles overlap.*

compared the story length of the two groups' narratives for non-goal-based stories only. These analyses revealed that the non-goal-based stories of TD children included more word tokens and clauses than those of PL children (Word tokens: M = 12.90, SD = 7.71, t (25) = 2.439, p = .022, Cohen's d = 1; Clauses: M = 2.23, SD = 1.25, t (25) = 2.773, p = .010, Cohen's d = 1.60). Thus, TD children tended to tell longer stories than children with PL, even when we compare them only on those stories that did not include goals. The shorter length of the stories produced by the children with PL may be related to the absence of goal-based stories in this group, as goal-based stories are generally longer than non-goal-based stories.

Narrative evaluation

To evaluate whether TD children and children with PL differed from each other on narrative evaluation, the children were first divided into three groups depending on whether they told 0, 1, or at least 2 stories that included a cognitive inference. The Mantel–Haenszel statistic was calculated for this measure. The number of children in these categories significantly differed by lesion status, M^2 (1, N = 31) = 4.440, p = .035. Fourteen out of 20 TD children (70%) included cognitive inferences in at least one of their stories, whereas only 3 out of 11 children (27%) with PL did so.

We next divided the children into three groups depending on whether they told 0, 1, or at least 2 stories that included affective inference. We also calculated the Mantel–Haenszel statistic for this measure. The number of children in these categories did not differ by lesion status, M^2 (1, N = 31) = .025, p = .875. Table 3 summarizes the results.

Vocabulary and syntax comprehension

To evaluate whether TD children and children with PL differed from each other on language measures assessed outside the narrative production context, we compared PPVT-III and syntax comprehension scores of the two groups at 54 months of age. TD children and children with PL did not significantly differ from each other on their PPVT-III scores (TD: M = 112.45, SD = 17.61; PL: M = 105.40, SD = 19.28, t (28) = 1.002, p > .05, Cohen's d = .38) or on their syntax comprehension scores (TD: M = 44.16, SD = 8.75; PL: M = 43.30, SD = 10.59, t (27) = .233, p > .05, Cohen's d = .09) at 54 months of age (Figure 3). Using the scores on these tests as co-variates, all of the significant group differences on narrative production (the story length measures, the narrative vocabulary measure, the story complexity and cognitive inference measures) remained significant.

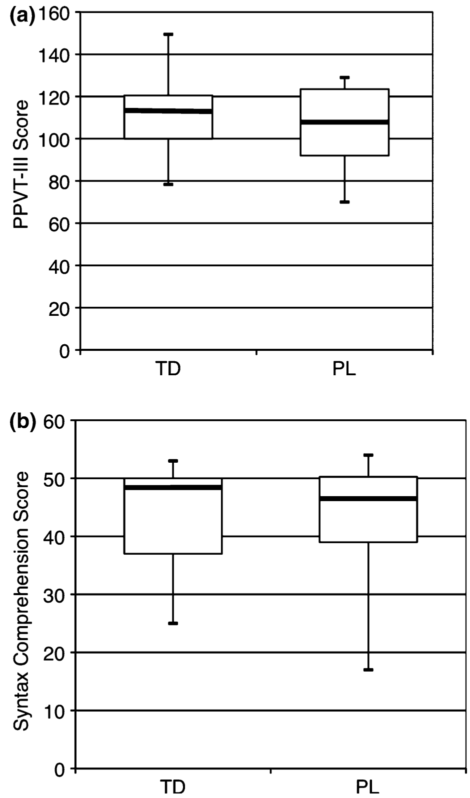

Figure 3 *Distribution of children's (a) Peabody Picture Vocabulary Test – Third Edition (PPVT-III), and (b) syntax comprehension scores for typically developing (TD) children and children with pre- or perinatal brain injury (PL). The boxes in the graphs represent the interquartile range; the line in the middle of each box represents the median and the tails represent the 5th and 95th percentiles.*

Discussion

Our findings show that young children with PL have difficulty creating structured narratives even though they do not significantly differ from TD children on vocabulary and syntax comprehension tasks outside of the narrative context. The difficulty that children with PL had on the narrative task was apparent on a variety of measures, including narrative length (word tokens and clauses), diversity of vocabulary used, and narrative structure. Furthermore, children with PL did not structure their stories around the goals of the protagonists, and also expressed fewer inferences about the cognitive states of the protagonists than TD children. Of note, the lower performance of the children in the PL group was found even though on average children with PL were older then TD children.

The current study did not reveal any influence of lesion characteristics on children's narrative productions. The absence of differences between left-hemisphere- and right-hemisphere-injured children on the narrative production task is in line with previous findings in the literature, which suggest that early side or site-specific effects on the language development of children with PL are resolved by age 5 (Reilly *et al.*, 1998). Such findings have been hypothesized to reflect the importance of bilateral neural networks for early language development, and the plasticity of language functions after early unilateral brain injury (Feldman, 2005; Chapman *et al.*, 2003; Reilly, Levine, Nass & Stiles, 2008; Stiles, Nass, Levine, Moses & Reilly, in press). We also failed to find an effect of lesion size or type on children's narrative performance. This contrasts with findings on a larger group of children with PL, where we found effects of lesion size and type on early language development. In this study, we found that children with larger lesions and those with cerebrovascular lesions (which tended to be larger) were delayed on word types and MLU during naturalistic speech to their primary caregiver as compared to TD children, whereas children with small and medium lesions and those with preventricular lesions did not significantly differ from TD children (Rowe *et al.*, 2009). Thus, the absence of lesion-size and lesion-type effects in the current study might be a result of our sample size. Another possibility is that at 5 to 8 years of age narrative production is very challenging even for children with smaller lesions, and that effects of lesion size and type on narrative skill will become apparent at later ages, as children with smaller lesions gain more skill on this difficult task than children with larger lesions.

Why might narratives cause particular problems for children with PL? In the current study, children's vocabulary and syntax skills were assessed by receptive language tasks, whereas narrative skill was assessed by a production task. However, children's difficulties on the narrative task cannot be attributed solely to this task difference. Bates *et al.* (2001) reported that in a structured biographical interview 5- to 8-year-old children with PL performed comparably to TD children on every measure assessed. This suggests that it is specifically the narrative genre, not just any language production task, that poses a challenge for children with PL. As previously discussed, producing a good narrative is a particularly demanding task because it involves an extended monologue, is generally about events that are removed from the here-and-now, and must be organized in a hierarchical manner. The difficulties that children with PL experience on narrative tasks may stem from constraints that brain injury places on their computational and storage capacities (Levine *et al.*, 2005). Consistent with this possibility, narrative tasks have been shown to engage a wide neural network (Nichelli, Grafman, Pietrini, Clark, Lee & Miletich, 1995), and Feldman (2005) has suggested that early brain injury may compromise engaging such wide networks. Studies on narrative skill in children with traumatic brain injury also suggest that the narrative genre is particularly vulnerable. In this group of children, vocabulary and syntax performance recover to normal or near-normal levels after injury, whereas problems in narrative production, especially in macro-level organization, are more permanent (Ewing-Cobbs, Brookshire, Scott & Fletcher, 1998; Chapman *et al.*, 2004). Thus, plasticity for certain aspects of language (e.g. vocabulary and grammar) may be greater than plasticity for other aspects of language such as narrative skills both after pre- or perinatal brain injury and after traumatic brain injury during childhood (Chapman *et al.*, 2003).

Our findings have theoretical, methodological and practical implications. In terms of theoretical implications, our findings and those of a few other studies (Levine *et al.*, 2005; Feldman, 2005; Reilly *et al.*, 2004; Stiles *et al.*, 2005) suggest that there may be limitations to the remarkable plasticity for language functions displayed by children with PL, and that these limitations may be most apparent on complex, decontexualized language tasks such as narrative production. Although the performance of children with PL on basic language functions such as vocabulary or syntax may be preserved, they appear to face more difficulties in the flexible use of language for more complex language tasks, such as narrative production.

Our findings leave open the question of whether the narrative difficulties experienced by the group of children with PL constitute transient delays or longer-lasting deficits, particularly with respect to their difficulty with macro-level narrative structure. That is, it may be the case that, as for earlier-developing language skills, children with PL have difficulty in getting those more complex language skills off the ground but that these deficits normalize over time. Consistent with this possibility, Reilly *et al.* (2004) reports that at the start of elementary school, children with PL significantly differ from TD children on a story-retelling task based on measures of morphological errors and syntactic complexity. However, these differences disappear by the end of elementary school. Thus, it may be the case that children with PL will catch up on macro-level narrative measures over time, a possibility we will test as we continue to follow our participants longitudinally.

Our findings also raise several other questions regarding the nature of the narrative difficulties experienced by children with PL. First, are children's macro-level narrative difficulties specific to story-generation tasks or do they extend to story-retelling tasks? Second, are children's narrative difficulties merely a production problem or do they extend to comprehending the features of a good story, which TD children can do by 8 years of age (Stein & Glenn, 1979)? Third, do children's omissions of goals or cognitive states of protagonists in their stories reflect a narrative-specific problem or a more general problem in attending to or understanding the cognitive states of others, that is, the goals and beliefs that regulate their behaviour?

In terms of methodological and practical implications, our findings suggest that multiple, diverse language tasks are needed to obtain a clear picture of the more resilient and fragile aspects of language in the face of early lesions. Our findings suggest that even though children with PL might not show deficits on basic language functions such as vocabulary or syntax, they may experience difficulties on more complex language tasks such as narrative production. Importantly, these difficulties on narrative tasks might have long-lasting ramifications, as narrative skills are related to school success in general and to reading achievement in particular (Feagans & Short, 1984; Tabors, Snow & Dickinson, 2001). In terms of practical implications, by delineating the linguistic strengths and weaknesses in these children, it may be possible to put appropriate supports in place even before children exhibit any problems. For example, maternal styles of narrative elicitation are related to children's developing narrative skill (Fivush, 1991). Thus, by augmenting exposure to narratives during the preschool years, it may be possible to mitigate the later-appearing difficulties that children with PL have in producing narratives. Such an approach seems promising, as our research with this population (Rowe *et al*., 2009) has shown that language plasticity is influenced not only by the biological characteristics of children's lesions but also by the language input they receive.

Appendix

Story examples from each story-structure category

1. Story with no structure

Example 1: Child with small lesion in the right hemisphere, 5 years 1 month, Alan stem.
Story: He gets boy stuff.
Example 2: Typically developing child, 5 years 8 months, Alan stem.
Story: He shared them with the poor.

2. Descriptive sequence

Example 1: Child with medium-size lesion in the left hemisphere, 7 years, Alan stem.
Story: He liked to play with his toys a lot. He played with his parents in the rain.
Example 2: Typically developing child, 5 years 9 months, Alan stem.
Story: He had a toy box too, and then he keep running around the house, and his box, it was heavy.

3. Action sequence

Example 1: Child with large lesion in the left hemisphere, 5 years 6 months, Fox stem.
Story: And he was gonna bite, and they kept walking, and saw two more bears.
Example 2: Typically developing child, 5 years 8 months, Fox stem.
Story: And a girl came by, and the fox waved to her, and she ate all the food, and she ate her loose tooth, and she ate her sweater and her underwear.

4. Reactive sequence

Example 1: Child with small lesion in the right hemisphere, 5 years 1 month, Alice stem.
Story: There were dogs on the seashore. They played with Alice, and then the dolphins came out of the water because they were cold.
Example 2: Typically developing child, 5 years 3 months, Alan stem.
Story: One of his favourite toys was a toy elephant, but he lost it, and he was very sad.

5. Incomplete goal-based story

Example 1: Child with small lesion in the right hemisphere, 5 years 8 months, Alan stem.
Story: He played with his toys, and then went outside to play with his toys.
Example 2: Typically developing child, 5 years 5 months, Alice stem.
Story: And everyday she went to the beach to play.

6. Complete goal-based story with one episode

None of the PL children produced a story in this category.
Example 1: Typically developing child, 5 years 4 months, Fox stem.
Story: He went out to get his bear friend, but his bear friend wouldn't come out.
Example 2: Typically developing child, 5 years 3 months, Alice stem.
Story: She met a fox and said she wanted to go across the river. So she said to the fox, can you please take me across the river? The fox said, yes. So he took the girl across the river to his cave in the big dark forest where he lived.

7. Complete goal-based story with multiple episodes

None of the PL children produced a story in this category.
Example 1: Typically developing child, 5 years 8 months, Fox stem.
Story: He went out to find a food, and he saw a little squirrel, and when the squirrel wasn't looking, he started chasing him really carefully, so he wouldn't scare him away, but the squirrel knew he was coming. He wanted to trick the fox. So the fox didn't know he was going to trick him. So he went real close to him, but the squirrel started running away, and he climbed up a tree, and the fox never found him again.
Example 2: Typically developing child 5 years, 8 months, Alice stem.
Story: She went outside, and went to the beach, and started swimming, but she saw a shark coming after her. So she ran out of the pool and went home. Bye bye. And she broke her leg, because the shark bit her.

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