Language Abilities After Left Hemisphere Brain Injury: A Case Study of Twins

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This paper describes the language abilities of two twin pairs in which one twin (the experimental subject) suffered brain injury to the left cerebral hemisphere around the time of birth and one (the control) did not. One pair of twins was initially assessed at age 23 months, the other at about 30 months, and they were subsequently evaluated in their homes three times at about 6-month intervals. The results showed that subjects scored at or above the normal range on all formal tests. Their scores were similar to the controls' on the Bayley Scales of Infant Development, the Peabody Picture Vocabulary Test, and the receptive scale of the Sequenced Inventory of Communicative Development (SICD) but lower than the controls' on the Expressive One Word Test and the expressive scale of the SICD. Analysis of language samples revealed that the subject in one pair used a smaller vocabulary and shorter, less complex sentences than his twin, but progressed at a similar rate. In these cases the subtle differences in language abilities following perinatal left hemisphere brain injury were detected only through comparisons of brain-injured children to extremely well-matched controls. The relative difficulties experienced by one subject in syntactic skills were compatible with other studies on the sequelae of left hemispheric damage, but the difficulties in this case appeared to be a developmental delay, not deficit.

This paper describes the language abilities of two twin pairs in which one twin suffered injury to the left cerebral hemisphere at the time of birth and the other was spared. The observations here expand the study of language after early left hemispheric damage in two dimensions; subjects were preschool-aged, and they were followed lon-

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gitudinally. In new areas of inquiry, detailed analyses of individual subjects provide valuable insights into basic phenomena. However, such case studies run the risk of mistaking idiosyncratic results for general truths. In this regard, the twins presented a rare opportunity: The brain-injured children, the experimental subjects, could be compared to controls, the uninjured twins, who shared environmental circumstance and genetic endowment but differed in respect to brain injury. Case studies of so-called dissimilar twins have historical precedence; differences between such twins have demonstrated the selective nature of motor, intellectual, and academic impairments and the developmental course after brain injury (Bradway, 1937; Davis, Tooley, & Hunt, 1987; Jenkins, 1935).

We acknowledge that the twins in this study differed by more than just brain injury. Both pairs were dizygotic, and thus shared only half of their genetic material. In one pair the children were opposite sexes. One brain-injured child underwent a short period of speech and language therapy. Despite these differences, we found similar patterns across the pairs and results compatible with descriptions in the literature. Thus, we considered these findings most likely related to the brain injury.

For most adults, damage to the left hemisphere disrupts language abilities, affecting syntactic processing, semantic interpretation, and/or the motor output of speech production. Damage to the right or non-dominant hemisphere, by contrast, usually has limited impact on language functioning. An important question is whether this hemispheric specialization is innate or acquired after language learning (Kinsbourne & Hiscock, 1983). The traditional view, attributed to Lenneberg (1967), is that the young brain is equipotential for language abilities. Both hemispheres contribute to early language functioning. Plasticity of the young nervous system allows the right hemisphere to assume language functioning in the event of damage to the left.

Recent studies of language after early left hemisphere injury have challenged this traditional view. The studies demonstrate selective impairments of syntactic comprehension and production following early left hemispheric damage (Aram & Ekelman, 1986; Aram, Ekelman, Rose, & Whitaker, 1985; Kiessling, Denckla, & Carlton, 1983; Rankin, Aram, & Horwitz, 1981). In one fascinating set of studies, Dennis and colleagues studied children with only a single cerebral hemisphere; their other hemisphere had been surgically excised due to a severe congenital malformation and seizure disorder (Dennis & Kohn, 1975; Dennis & Whitaker, 1976). The subjects with an isolated left hemisphere demonstrated an advantage over the subjects with an isolated right hemisphere in multiple aspects of syntactic processing.

The issue of hemispheric specialization bears further study. Most of the subjects in previous studies have been assessed at school age or older. In this project we were able to study the children during the preschool years, the period of most rapid language development. One twin pair was 23 months and the other 30 months when first tested. Furthermore, studies to date have analyzed children at a single point in time. In this study we were able to visit the children three times at approximately 6-month intervals, providing a limited picture of developmental trends.

Our method combined the analysis of formal test results with the analysis of conversational language to provide descriptions of multiple language components in line with current neurolinguistic approaches. In this report we addressed the following questions:

1. Did the brain-injured children perform differently from their unaffected twins?

2. In what components of language were differences observed? We assessed aspects of lexicon (vocabulary), syntax (rules of sentence formation), and pragmatics (social conversation) in this study. We also compared expressive and receptive skills.

3. Did the differences change over time?

Methods

Subjects

The two twin pairs were identified by research and clinical activity (see Table 1). The H twins, MH and KH, were identified through a medical chart review of children admitted to the Neonatal Intensive Care Unit at Magee Women's Hospital in Pittsburgh. Parents identified no clinical problems with either child. Family and physicians assumed the pair was dizygotic because of two complete fetal sacs, but blood testing was not done. The S twins, TS and BS, were identified through clinical activity at the Child Development Unit, Children's Hospital of Pittsburgh, when their parents requested a developmental assessment for TS. TS is a boy and BS a girl, so this pair is unequivocally dizygotic. Sex differences have been reported in studies of sequelae of strokes in adults but not in children.

The two affected children had different lesions but neither child had a neuromotor disability. MH, the second born, suffered a unilateral left intraventricular hemorrhage as a complication of prematurity. The

Table 1. Twin Pair Subjects

	H Twins	
	Brain-damaged	**Control**
Name	MH	KH
Gender	F	F
Gestational age at birth	30	30
Birthweight in grams	1,070	1,190
Lesion	Left Grade II IVH on ultrasound	Normal ultrasound
Age in months at enrollment	30	30
	S Twins	
	Brain-damaged	**Control**
Name	TS	BS
Gender	M	F
Gestational age at birth	37	37
Birthweight in grams	2,600	2,500
Lesion	Left intracerebral hematoma with blood in ventricles and subarachoid space. Neonatal seizures.	Normal ultrasound
Age in months at enrollment	23	23

hemorrhage was identified with cerebral ultrasound and resolved prior to hospital discharge without persistent ventricular enlargement. TS, also the second born, suffered a left parietal intracerebral hematoma during a difficult forceps delivery. The hemorrhage was identified on CT scan. Some blood coursed around both hemispheres and into the ventricles. TS had seizures in the neonatal period and was treated with phenobarbital for his first year of life.

Procedures

Initial Testing. Children were initially tested at the Child Development Unit, Children's Hospital of Pittsburgh, using the Bayley Scales of Infant Development, Mental Scale (Bayley, 1969). This instrument surveys multiple developmental skills and provides a Mental Development Index (MDI) with a mean of 100 and standard deviation of 15. The parents provided a developmental history to that time.

Home Visits. The children were subsequently seen for three visits in their homes. Visits were scheduled every 6 months, with delays due to illness and inclement weather. Sessions included formal testing and procedures to generate a language sample.

Formal Testing. Language assessments included the following three well known instruments: Peabody Picture Vocabulary Test (PPVT) (Dunn & Dunn, 1981), a standardized measure of receptive lexicon, provides a standard score with a mean of 100, standard deviation of 15. Expressive One Word Test (EOWT) (Gardner, 1979), a standardized measure of expressive lexicon, provides a standard score with a mean of 100, standard deviation of 15. Sequenced Inventory of Communicative Development (SICD) (Hendrick, Prather, & Tobin, 1975) has two subscales, a receptive scale and an expressive scale. The results are expressed as an age equivalent in months.

Language Sample. A semistructured play protocol was administered to generate a language sample. One parent played with one child at a time under the direction of a trained research assistant. We were interested in spontaneous conversation in preschoolers for two reasons: (a) It allowed for a functional assessment of language skills in a conversational context, and (b) multiple language subsystems could be analyzed from the same transcript without subjecting the children to excessive formal testing. We were aware that many of the subtle difficulties in language functioning in older brain-injured subjects were revealed from formal testing and not from casual conversation, but for youngsters just learning to speak, measures from language samples are an excellent index of functioning (Miller, 1981).

All home visits were videotaped for later transcription and analysis by trained speech and language pathology graduate students. For this paper, language was assessed from three segments of parent-child interactions that included the greatest diversity of language and conversation forms. The activities were warm-up play, in which parents and children played with small toy people and a tea set; coloring, in which parents and children worked with crayons and paper; and book reading, in which parents and children looked at a colorful picture book. We attempted to hold each activity to 5-minute time periods. Variability across children and visits was due to the children's varying levels of interest and to variable distractions in the environment. The language samples used for this analysis represent approximately 10 minutes of spontaneous conversation at each visit (with the exception of TS and BS at the first visit, in which only 6 minutes of interaction was available on each child).

Language Measures. The language of child and caretaker was transcribed at the level of words using English spelling. We followed the conventions of the Child Language Data Exchange System (MacWhinney & Snow, 1985), a system of computerized language analysis designed specifically for language research. The text of what was said is recorded on a *main text line* and multiple codes are recorded on *dependent tiers.* Computer programs analyze either the text or the codes. Reliability for transcription from video tapes and coding of conversation consisted of two research assistants transcribing and coding 25% of the data and yielded over 90% agreement between observers. Differences were discussed until agreement was reached.

The following language measures were obtained from each transcript:

Lexical Size and Diversity. The total number of words (tokens) and the number of different words (types) were used to assess the lexical size. Type-Token Ratio (TTR), the ratio of different words to total words, was used to assess lexical diversity; the lower the number, the more frequently the word appeared in multiple contexts. TTR is influenced by the number of utterances as well as lexical diversity (Richards, 1987). We calculated TTR-50, the type-token ratio of the first 50 words in the sample, to equate the number of words per sample.

Syntactic Complexity. Syntactic development was assessed with the Mean Length of Utterance (MLU), the total number of morphemes (words and meaningful subunits of words) divided by the total number of utterances (Brown, 1973; Miller, 1981). For young, English-speaking language learners, the MLU has been used extensively as an indicator of syntactic development. The measure shows orderly development in the young child but declines in usefulness as children progress linguistically (Klee & Fitzgerald, 1985). Mean Length of Utterance 5 (MLU5), the average number of words in the 5 longest utterances, was also included as an indicator of syntactic development. It reflects skills at the upper boundary of development and is not contaminated by short utterances such as answers to questions, which are appropriate in conversation but not reflective of advanced skills.

Conversational Skills. In order to assess conversational participation, we coded the verbal utterances and communicative nonverbal gestures and actions of parent and child according to the role the utterance played in the conversation. Similar to the approach used by Garvey and Hogan (1973), we defined the following roles: Initiations represented verbal or nonverbal introduction of a new topic (a new action, new object, or new actor); responses represented elaborations of the topic by the other speaker; and continuations were the elaboration of the topic by the same speaker without an intervening comment by the partner. For example, here is a small segment of transcript from KH at age 38 months:

	Text	Code
FATHER:	Let's draw something.	Initiation
KH:	Okay.	Response
KH:	Get another piece (of paper).	Continuation
FATHER:	(Gets paper)	Response (action)
FATHER:	What do you want to draw?	Continuation
KH:	Mmm, how about, how about a triangle?	Response
FATHER:	Okay.	Response
FATHER:	Is that a triangle?	Continuation
FATHER:	Huh?	Continuation
KH:	But my nose is stuffed up.	Initiation
FATHER:	Yeah, you have a little cold.	Response
KH:	My nose is stuffy.	Response
FATHER:	Yeah.	Response
FATHER:	You need a tissue.	Continuation
KH:	I have a cough.	Response
KH:	Now (points to paper to resume drawing)	Initiation

From this coding scheme we calculated the percentage of the child's total initiations, when he or she introduced the topic of conversation. A low percentage indicates that the parent directed the conversation, a very high percentage that the child controlled the conversation.

Because of the small sample size, no statistical analyses were performed.

Results

Formal Test Results

All 4 children were tested once with the Bayley Scales of Infant Development, Mental Development Scale (MDI), at the outset of the study. At 30 months of age, MH had an MDI of 117 and KH had an MDI of 122. At 23 months of age, TS had an MDI of 107 and BS of 102. Thus, the scores on this general developmental test were within the normal range and similar within each pair. The parents of TS and BS noted at the initial testing that their concerns about TS's overall development had decreased over time, though their concerns about language abilities persisted to the time of the study.

Table 2 shows the results of the lexical testing. Inspection of the table reveals that all 4 children scored within the normal range on all administrations of the PPVT. On 5 of the 7 paired observations, the within-pair difference was 5 points or less.

Scores on the Expressive One Word Test also fell within or above normal throughout the study, with the exception of the first administration to the S twins. The scores at this age were prorated because the

Table 2. Standard Scores on Formal Lexical Testing

	H Twins			
	Peabody Picture Vocabulary Test		Expressive One Word Test	
	MH	KH	MH	KH
30 mos.	92	92	102	111
37 mos.	102	111	131	137
41 mos.	106	105	—	—
46 mos.			128	136
	S Twins			
	TS	BS	TS	BS
23 mos.	87	90	57	74
25 mos.	82	97	82	108
30 mos.	104	99	127	114
38 mos.	116	118	117	138

Note. MH = brain-damaged subject; KH = twin control; TS = brain-damaged subject; BS = twin control.

children were below the recommended age, but the language sample corroborated a small productive vocabulary. Within the pairs over time there was general concordance of scores; both twins tended to score in the same stanine. For example, at age 3 MH and KH both performed in the superior range. However, the unaffected child scored 6 or more points higher than the brain-injured twin on 6 of the 7 administrations. The only exception to the trend was that TS outscored his sister on the EOWT at 30 months of age, when he was involved in speech therapy with an emphasis on vocabulary. Therapy had been discontinued by the third visit, when the unaffected twin again scored higher than the subject.

The SICD Receptive and Expressive Scales were administered separately at different visits (see Table 3). For both pairs, the scores on the Receptive subscale were identical. Unfortunately, the H pair were at the ceiling of the examination so that any difference within the pair could not be detected. However, TS and BS scored below the ceiling at the identical level. For both pairs, the scores on the Expressive subscale gave a slight advantage to the unaffected twin.

Thus, in summary, the data from formal testing shows that the children performed at or above normal on almost all measures across time. Within the pair, the twins performed at similar levels on all the measures. However, there were consistent differences in favor of the uninjured twin in expressive vocabulary and in overall expressive language skills.

Table 3. Age Equivalence in Months on Sequenced Inventory of Communicative Development

	H Twins			
	Expressive		**Receptive**	
	MH	KH	MH	KH
37 mos.	36	44		
41 mos.	32	36		
46 mos.			48	48
	S Twins			
	Expressive		**Receptive**	
	TS	BS	TS	BS
30 mos.	28	32		
38 mos.			40	40

Note. MH = brain-damaged subject; KH = twin control; TS = brain-damaged subject; BS = twin control.

Language Sample. An analysis of the expressive lexicon from the language sample can be found in Table 4. In the H twins, there was no trend across sessions in lexical size or diversity. The relative decline in output at the third visit for MH was due to fatigue in an evening home visit, rather than language functioning per se. In the S twins, the unaffected twin had the larger lexicon at each visit. Lexical diversity was measured by the TTR and TTR-50 was comparable at all sessions, suggesting that the children used vocabulary words in a variety of contexts.

Table 5 shows the measures of syntactic development, MLU and MLU5. MH and KH showed no consistent trends in syntactic measures through the course of the visit. A slight advantage for MH at the first and second sessions was reversed in the third visit. BS had the advantage in both syntactic measures compared to TS in all three visits. The difference was apparent in the first visit, when BS used word combinations but TS did not. At the third visit, TS was using complex sentences like his sister. The parents at that visit reported that their impression was that the differences between the twins seemed to be decreasing.

Measures of conversational skills from the language sample revealed no pattern within the twin pairs across visits. Table 6 shows the percentage of new topics initiated by the children. In both pairs, parents and children shared the role of initiating topics of conversation.

Table 4. Measures of Lexical Development from Language Samples

	H twins							
	No. of different words (types)		**Total no. of words (tokens)**		**TTR**		**TTR-50**	
	MH	KH	MH	KH	MH	KH	MH	KH
30 mos.	89	81	148	121	.6	.7	.7	.7
37 mos.	112	107	274	222	.4	.5	.6	.6
46 mos.	72	103	121	251	.6	.4	.7	.7
	S Twins							
	No. of different words (types)		**Total no. of words (tokens)**		**TTR**		**TTR-50**	
	TS	BS	TS	BS	TS	BS	TS	BS
25 mos.	13	17	24	30	.5	.6	.5	.6
30 mos.	71	86	156	167	.5	.6	.7	.5
38 mos.	50	80	86	129	.6	.5	.6	.7

Note. MH = brain-damaged subject; KH = twin control; TS = brain-damaged subject; BS = twin control; TTR = type-token ratio; TTR-50 = type-token ratio of first 50 words in sample.

Table 5. Measures of Syntactic Development from Language Sample

	H Twins			
	MLU		MLU5	
	MH	KH	MH	KH
30 mos.	2.12	1.99	5.4	4.6
37 mos.	3.71	3.19	8.8	9.0
46 mos.	4.49	4.89	8.0	9.6
	S Twins			
	MLU		**MLU5**	
	TS	BS	TS	BS
25 mos.	1.0	1.24	1.0	2.2
30 mos.	2.01	2.66	4.4	6.8
38 mos.	3.06	3.65	5.2	6.6

Note. MLU = mean length of utterance; MLU5 = average number of words in the 5 longest utterances; MH = brain-damaged subject; KH = twin control; TS = brain-damaged subject; BS = twin control.

Discussion

The two brain-injured children in this study had different types of perinatal brain hemorrhages, both detected through neural imaging studies in the perinatal period. MH had a Grade II intraventricular hemorrhage; the bleeding did not enlarge the ventricle or affect adjacent brain tissue. Other studies of minor intraventricular hemorrhages have reported variable developmental outcome (Krishnamoorthy, Shannon, DeLong, Todres, & Davis, 1979; Landry, Fletcher, Zarling, Chapieski, & Francis, 1984; Ment, Scott, Ehrenkranz, & Duncan, 1985; Papile, Munsick-Bruno, & Schaefer, 1983; Williams, Desmond, Wilson, Andrew, & Garcia-Prats, 1982). TS had a hemorrhage into brain tissue of the parietal section of the left cerebral hemisphere and blood coursed around the entire brain. There was no direct damage to the right hemisphere on CT scan, though it is difficult to assure that the right hemisphere was completely unaffected. Many previous studies have had similar problems in assuring the total integrity of the relatively unaffected side (Kiessling et al., 1983; Rankin, Aram, & Horwitz, 1981). TS also suffered neonatal seizures but was off anticonvulsant medication at the time of the study.

Despite the differences in the type and location of the brain lesions, both brain-injured children had a good developmental outcome. Neither subject suffered a neuromotor disability, a factor generally associated

Table 6. Percentage of Topics Initiated by Child

	H Twins	
	MH	KH
30 mos.	22	14
37 mos.	36	51
46 mos.	39	62
	S Twins	
	TS	BS
25 mos.	44	48
30 mos.	51	33
38 mos.	46	49

Note. MH = brain-damaged subject; KH = twin control; TS = brain-damaged subject; BS = twin control.

with favorable outcome in other domains (Annett, 1973). Both subjects scored in the normal range and similarly to the controls on the test of overall developmental functioning, the Bayley Scales of Infant Development (Bayley, 1969). Perinatal injury, particularly to the left hemisphere, has been associated with intellectual deficits (Annett, 1973). Both pairs had the advantage of coming from upper middle class families with two college-educated, working parents, factors associated with favorable outcome in other at-risk populations (Cohen, Sigman, Parmelee, & Beckwith, 1982; Sameroff & Chandler, 1975; Werner & Smith, 1982).

Though the overall outcome was good, subtle but specific language differences were detected in the comparison of the brain-injured children to their twins. In expressive skills the brain damaged children scored in the normal range but below their twins both on expressive naming and on general expressive language skills. This finding did not reflect obvious motor-speech abnormalities in the brain-injured children.

Selective impairments of expressive vocabulary have not been reported in other studies of early left hemisphere damage. Difficulties with expressive vocabulary may have been missed in other studies that used instruments that were not age standardized (Dennis & Whitaker, 1976). A study that used the same instruments as used here (Aram et al., 1985) found that the mean scores for the PPVT were higher than the mean scores for the EOWT in both right- and left-brain-injured subjects. However, a few individual subjects reversed the pattern.

Two studies suggest that expressive vocabulary deficits may be related specifically to left hemisphere function. Kiessling et al. (1983) found a correlation between the degree of right hand function impairment, their measure of left hemisphere damage, and scores on a test of confrontational naming. Hecaen (1976) found that left-hemisphere-damaged patients with comprehension deficits usually had naming deficits, too. It will be interesting to attempt to replicate these results in future studies. Expressive vocabulary may be more vulnerable to brain injury because it is a skill that requires recall memory, while receptive vocabulary requires recognition. As a more demanding task, expressive vocabulary may require more neural substrate and, therefore, may be more sensitive to disruptions of neural integrity.

One of our subjects, TS, performed more poorly than his twin on measures of syntactic development, a finding compatible with several other studies on the sequelae of left hemispheric damage (Aram & Ekelman, 1986; Aram et al., 1985; Dennis & Kohn, 1975; Dennis & Whitaker, 1976; Kiessling et al., 1983). The longitudinal observations are of particular interest in this case. TS continued to make progress in syntactic development over the course of our observations. His rate of development was similar to his sister's and to the other twin pair's. Thus, his relative difficulties in syntactic development could be described as a developmental delay. His developmental course in syntactic skills was analogous to his overall developmental functioning; he got off to a slow start but progressed well and narrowed the gap with his sister. In a related study that included these children along with other brain-injured subjects and controls (Keefe, Feldman, & Holland, in press) we found a similar pattern in the acquisition of a minilinguistic system. The subjects took more trials to learn new words, especially when production was the criterion of learning. Further longitudinal research will be necessary to determine if early delays ultimately become skill deficits.

In summary, in providing a description of the language development of two preschoolers with perinatal left hemisphere brain damage, we have answered the three questions raised in the introduction, and raised additional issues for future research:

1. These brain-injured children scored in the normal range on formal testing, but had subtle difficulties in language functioning when compared to their twins. Though the differences were small during the preschool period, future research will be necessary to determine if early differences persist into school age and how they affect the child's functioning.

2. In both the twin pairs, the brain-injured children had lower scores in expressive language skills and expressive vocabulary. In one pair, the brain-injured child performed less well on syntactic measures, a finding compatible with other studies on the sequelae of left hemispheric

brain injury. In the aftermath of perinatal brain injury, expressive language and syntax are key developmental domains to assess in detail. The generality of expressive language difficulties after left hemisphere damage requires additional study.

3. Though the difference in syntactic measures in one twin pair persisted over the course of our study, the affected child made progress at a rate similar to his twin. The brain injury was initially associated with a developmental delay. Further longitudinal studies are warranted to determine if early delays subsequently become developmental deficits.

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