Language Outcome After Perinatal Stroke: Does Side Matter?

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LANGUAGE OUTCOME AFTER PERINATAL STROKE: DOES SIDE MATTER?

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The goal of this study was to examine structured language skills in children with perinatal strokes. Participants were 28 school-age children with early focal brain lesions (17 with left hemisphere [LH] damage, 11 with right hemisphere [RH] damage), and 57 controls. A standardized test of language (Clinical Evaluation of Language Fundamentals–Revised) was administered. Receptive, Expressive, and Total Language scores, as well as subtest scores, were analyzed. Control participants scored within the normal range, whereas the LH and RH groups scored significantly more poorly than did controls. There were no differences between the LH and RH groups on any of the language scores, and all scores were below the 14th percentile. Within the lesion group as a whole, scores were not related to lesion laterality, site, or severity. Results also were not accounted for by socioeconomic status or IQ. However, children who experienced seizures demonstrated significantly poorer performance than did children who did not experience seizures. Damage to either the LH or RH early in development adversely affects later language abilities, particularly on tasks with structured and complex linguistic demands. Although lesion side has little effect, the presence or absence of seizures is a major contributor to language outcome.

INTRODUCTION

Since Broca’s seminal observation more than 100 years ago that aphasia was associated with a large left hemisphere (LH) stroke (Broca, 1865), it has been well documented that LH strokes in adults typically result in aphasia, whereas right hemisphere (RH) strokes are likely to spare propositional language (Benson, 1986, 1993; Broca, 1865; Shallice, 1988). During the period of active brain development, however, the results of unilateral brain injury may be quite different. Children with perinatal (28 weeks gestation to 28 days after birth) focal brain damage may demonstrate language delays early in development, regardless of the hemisphere involved (Bates, 1997, 1999; Bates, Dale, & Thal, 1995; Marchman, Miller, & Bates, 1991; Nass, 1997; Reilly, Bates, & Marchman, 1998; Stiles, 1995; Thal et al., 1991). Under the age of 5 years, children with perinatal LH
lesions are likely to have particular expressive language deficits, whereas children with RH lesions are more likely to have comprehension or receptive language deficits (Bates, 1992). In general, however, children with LH or RH lesions go on to attain good functional language abilities (i.e., these children use language in the context of everyday communication without marked impairment) by school age (Aram, 1988; Aram & Ekelman, 1987; Bates, Thal et al., 1997; Dall’Oglio, Bates, Volterra, DiCapua, & Pezzini, 1994; Kiessling, Denckla, & Carlton, 1983; Riva & Cazzaniga, 1986; Riva, Cazzaniga, Pantaleoni, Milani, & Fredrizzi, 1986; Stiles, 1995). These findings are consistent with the concept of neural plasticity, the ability of the brain to reorganize in the face of damage (Bates, 1998, 1999; Lennenberg, 1967; Stiles, 1995; Thal et al., 1991).

Despite reasonable functional recovery of language by the school-age years, is there a linguistic “price” to be paid for damage to part of the brain early in development? When children with focal brain damage are challenged with more complex language tasks (e.g., structured question-and-answer formats; formal aspects of language form and content, including word meanings, word and sentence structure, and recall and retrieval), are they able to perform at an age-appropriate level? There have been relatively few systematic studies of complex language in the school-age years. Aram and Ekelman (1987) found persisting language deficits in school-age children with either LH or RH lesions on a test of auditory comprehension, though they speculated that impairments may also have been related to memory or attentional problems. Kiessling et al. (1983) found preserved basic language skills in children with hemiplegic cerebral palsy, but impairments in “high-level” language in children with right hemiparesis, inferring that left hemisphere brain damage produced these findings. Studies of narrative discourse in children with early-onset stroke have found evidence of less competent language skills into the school years for children with either LH or RH lesions, as compared with controls (Chapman, Max, Gamino, McGlothlin, & Cliff, 2003; Reilly et al., 1998). As with other studies, however, these differences were relatively mild and the children were able to engage in narrative discourse to some extent.

The relationship between functional language abilities and the potentially intervening variables of lesion laterality, site, or severity are not well established in children with early onset stroke (Aram, Ekelman, Rose, & Whitaker, 1985; Bates, Reilly et al., 2001; Bates & Roe, 2001; Stiles, 1995). For example, some studies that examine lesion laterality in school-age children indicate that there are no LH versus RH differences on any language measures (Bates et al., 2001; Dick et al., 1999; Kempler, van Lancker, Marchman, & Bates, 1999), whereas other studies have found hemisphere-specific differences in language performance (Riva et al., 1986; Woods & Teuber, 1978). There have also been mixed findings regarding the role of lesion severity on cognitive outcome, with some studies finding a relationship between larger lesion size and greater impairment (Montour-Proulx et al., 2004; Vargha-Khadem, Isaacs, & Muter, 1994; Vargha-Khadem, Isaacs, Van Der Werf, Robb, & Wilson, 1992), another hypothesizing a U-shaped curve with the smallest and largest lesions leading to better outcome than intermediate size lesions (Bates, 1997), and yet other studies finding no relationship between lesion size and level of impairment (Ballantyne, Scarvie, & Trauner, 1994; Dall’Oglio et al., 1994; Vargha-Khadem, O’Gorman, & Watters, 1985). In light of the inconsistency of previous findings, there is as yet no clear-cut relationship between language after early stroke and the predictor variables of lesion laterality, site, or severity. Certainly, differences in subject-selection criteria, numbers of children included in the study, and the language or cognitive measures used may contribute to this lack of clarity.
To better delineate the potentially adverse consequences of early unilateral brain damage on language outcome, the present study examined expressive and receptive language abilities in a large group of school-age children who had experienced perinatal unilateral strokes. We used a standardized test of complex language (Clinical Evaluation of Language Fundamentals–Revised; CELF-R; Semel, Wiig, & Secord, 1987) and analyzed the results in relation to other cognitive variables (Wechsler IQ, single-word vocabulary), lesion characteristics (side, size, site, severity), neurological characteristics (seizure status), and age at testing.

MATERIALS AND METHODS

Subjects

Participants were 28 children with focal brain lesions (FL) (17 with LH damage, 11 with RH damage) and 57 controls. Participants ranged in age from 5 years 0 months to 16 years 6 months, with the mean ages of the LH group, RH group, and controls being 6 years 10 months, 9 years 1 month, and 7 years 8 months, respectively. See Table 1 for demographic information on the FL and control groups.

Only participants with single, unilateral lesions that were the result of perinatal strokes (occurrence between 28 weeks gestation and 28 days after birth; infarct or hemorrhage) were included in the lesion group. Children with bilateral, generalized, or evolving (e.g., tumor) brain damage, as well as those with traumatic brain injuries, were excluded from the study. Each child was identified as having a perinatal, unilateral focal lesion by review of medical history and neuroimaging results, including Magnetic Resonance Imaging (MRI) or Computed Tomography (CT). A clinical neuroradiologist, blinded to subject status, performed a clinical assessment of each neuroimaging study, providing documentation of lesion location and lesion severity. Severity was rated qualitatively on a 5-point scale (adapted from Vargha-Khadem et al. [1985]), with 1 being the smallest lesion and 5 being a lesion involving multiple lobes (see Table 2). Control children were recruited from

| Table 1 Summary of Demographic Variables for the Focal Lesion and Control Groups. |
|---------------------------------------------|--|
| Focal Lesion \((n=28)\)                      | Control \((n=57)\) |
| Mean Age at Testing                         | 7 yrs. 9 mos. ± 2 yrs. 4 mos. | 7 yrs. 8 mos. ± 2 yrs. 5 mos. |
| Mean Socioeconomic Status*                  | 1.79 ± .92                   | 1.65 ± .86                     |
| Sex                                          | 16 males, 12 females         | 24 males, 33 females           |
| Handedness                                   | 15 left, 13 right            | 7 left, 50 right               |

*Based on the Hollingshead Four Factor Index of Social Status (Hollingshead, 1975), with 1 being the highest and 5 being the lowest socioeconomic status.

| Table 2 Grading System for Rating Severity of the Focal Brain Lesion. |
|-----------------------------|--|
| Rating                      | Lesion Description                      |
| 1                           | Focal ventricular dilation or atrophy seen on <3 cuts on CT or MRI |
| 2                           | Focal ventricular dilation or atrophy seen on >3 cuts on CT or MRI |
| 3                           | Focal porencephaly involving one lobe only, <3 cuts on CT or MRI |
| 4                           | Focal porencephaly involving one lobe only, >3 cuts on CT or MRI |
| 5                           | Porencephaly or cortical atrophy involving multiple lobes |

Note: CT, computed tomography; MRI, magnetic resonance imaging.
the community through advertisements and from the University of California, San Diego (UCSD) subject pool. Complete medical and family histories were obtained for all children. All controls included in the study had normal medical and developmental histories and scored within normal limits on measures of cognition, language, and academic skills. For all participants, information on socioeconomic status (SES) was obtained using the Hollingshead Four Factor Index of Social Status (Hollingshead, 1975).

**Procedure and Measures**

Participants were tested as part of a larger, 20-year longitudinal study of cognitive, spatial, and linguistic development in normal and neurologically impaired children. The Clinical Evaluation of Language Fundamentals–Revised (CELF-R) (Semel et al., 1987) was administered to all participants during a 10-year period (1991 to 2001) for continuity of longitudinal data collection. The CELF-R is a standardized test that comprehensively assesses receptive and expressive language skills, including competency in word meanings (semantics), word and sentence structure (morphology and syntax), and recall and retrieval of spoken language (memory), in children ages 5 through 16 years. The test has nine core subtests across the entire age range, for which scaled scores (Mean=10, SD=3) are calculated. The receptive subtests are: Linguistic Concepts, Sentence Structure, Oral Directions, Word Classes, and Semantic Relationships. The expressive subtests are: Word Structure, Formulated Sentences, Recalling Sentences, and Sentence Assembly. Receptive Language, Expressive Language, and Total Language Standard Scores (Mean=100, SD=15) are derived. See Table 3 for a description of each subtest and the language skill area assessed, as described by the CELF-R Technical Manual (Semel et al., 1987).

**Table 3** CELF-R Core Subtests, Task Requirements, and Language Skill Areas (Semel et al., 1987).

<table>
<thead>
<tr>
<th>Scale/Subtest</th>
<th>Task Requirement</th>
<th>Language Skill Area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Receptive</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linguistic Concepts</td>
<td>Interpret oral directions which contain linguistic concepts requiring logical operations such as “and,” “either…or,” and “if…then.”</td>
<td>Content (Semantics)</td>
</tr>
<tr>
<td>Word Classes</td>
<td>Perceive the associative relationships between word concepts.</td>
<td>Content (Semantics)</td>
</tr>
<tr>
<td>Sentence Structure</td>
<td>Knowledge of structural rules at the sentence level.</td>
<td>Form (Syntax and Morphology)</td>
</tr>
<tr>
<td>Semantic Relationships</td>
<td>Interpret different semantic relationships in sentences.</td>
<td>Content and Form Integrated (Semantics, Syntax, and Morphology)</td>
</tr>
<tr>
<td>Oral Directions</td>
<td>Interpret, recall, and execute oral commands of increasing length and complexity.</td>
<td>Memory</td>
</tr>
<tr>
<td><strong>Expressive</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Structure</td>
<td>Knowledge of morphological rules.</td>
<td>Form (Syntax and Morphology)</td>
</tr>
<tr>
<td>Formulated Sentences</td>
<td>Formulate compound and complex sentences.</td>
<td>Content and Form Integrated (Semantics, Syntax, and Morphology)</td>
</tr>
<tr>
<td>Sentence Assembly</td>
<td>Assemble syntactic structures into grammatically and semantically acceptable sentences.</td>
<td>Content and Form Integrated (Semantics, Syntax, and Morphology)</td>
</tr>
<tr>
<td>Recalling Sentences</td>
<td>Recall and reproduce sentence surface structure of varying length and syntactic complexity.</td>
<td>Memory</td>
</tr>
</tbody>
</table>
In addition, all FL and control children received the age-appropriate Wechsler Intelligence Scale (WPPSI-R, WISC-R, or WISC-III; Wechsler, 1974, 1989, 1991), all FL children received the Peabody Picture Vocabulary Test–Revised (PPVT-R; Dunn & Dunn, 1981), and 24 FL children received the Expressive One-Word Picture Vocabulary Test–Revised or Upper-Extension (EOWPVT-R or EOWPVT-UE; Gardener, 1983, 1990).

Informed consent was obtained prior to testing each participant in accordance with Institutional Review Board procedures at the University of California, San Diego.

**Statistical Analyses**

Potential group differences (FL versus control) on the demographic variables of age at testing, socioeconomic status, and sex were analyzed using \( t \) tests. An Analysis of Variance framework (ANOVA and ANCOVA) was used to analyze the CELF-R data. IQ was assessed as a relevant covariate in all analyses. In the overall between-group analyses, the dependent variables were CELF-R test scores and the independent variables were group membership (FL versus control; LH versus RH). Profile analyses were used to examine subtest profiles (in terms of parallelism, levels, and flatness) for the LH, RH, and control groups. Follow-up subtest analyses were conducted using \( t \) tests. In an attempt to further characterize the strengths and weakness in the performance of the FL group, the subtests were examined to determine the ranges in which mean scores fell (e.g., average, below average, etc.). To assess potentially intervening variables, correlational analyses were used to examine relationships between age at testing and CELF-R Receptive, Expressive, and Total Language Scores; and \( t \) tests were used to examine the effect of lesion severity (i.e., single lobe versus multiple lobe involvement) on these CELF-R scores. The effect of seizures (seizures versus no seizures), lesion site (frontal, temporal, parietal, occipital, subcortical), and lesion side and site combined (e.g., left temporal versus all other lesions) on CELF-R scores were analyzed in a between-subjects ANOVA framework. The relationship between seizure status and lesion severity was assessed using a chi-square analysis. Within group analyses were used to compare scores within the LH and RH groups on the CELF-R and measures of single-word vocabulary. For all quantitative analyses, a statistical significance value of \( p < .05 \) was used.

**RESULTS**

Table 4 summarizes lesion and demographic information, as well as language (CELF-R Receptive, Expressive, and Total Language scores) and IQ (Full Scale IQ) performance for all participants in the Focal Lesion group.

**Comparison of FL and Control Groups on the CELF-R**

The focal lesion and control participants were not significantly different on the demographic variables of age at testing, socioeconomic status, or sex (see Table 1). As shown in Table 5, the control group was within the normal range for Receptive, Expressive, and Total Language scores. The FL group as a whole, as well as the LH and RH lesion subgroups, performed in the low average to below average range, and their mean scores were below the 14th percentile on all three indices. All of the lesion groups (FL, LH, RH) performed significantly more poorly than did controls and there were no significant differences between the LH and RH groups on any of the CELF-R indices (see Table 5).
Table 4  Focal Lesion Demographic Information, Lesion/Neurological Information, and Language and IQ Test Scores.

<table>
<thead>
<tr>
<th>Subject/Sex</th>
<th>Age at Testing (years)</th>
<th>Ethnicity</th>
<th>SES</th>
<th>Hand Preference</th>
<th>Gestational Age (weeks)</th>
<th>Lesion Laterality</th>
<th>Lesion Location</th>
<th>Lesion type</th>
<th>Severity</th>
<th>Seizures</th>
<th>Hemiparesis</th>
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<th>Age at Testing (years)</th>
<th>Ethnicity</th>
<th>SES</th>
<th>Hand Preference</th>
<th>Gestational Age (weeks)</th>
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<td>R</td>
<td>T-P</td>
<td>Infarct</td>
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<td>R</td>
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<td>R</td>
<td>T-P-S</td>
<td>Hemorrhage</td>
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Abbreviations. F=Female; M=Male; SES=Socioeconomic status (1=highest, 5=lowest); R=Right; L=Left; F=Frontal; T=Temporal; P=Parietal; O=Occipital; S=Subcortical; Severity (1=smallest, 5=largest); Y=Yes; N=No; RLS=CELF-R Receptive Language Standard Score; ELS=CELF-R Expressive Language Standard Score; TLS=CELF-R Total Language Standard Score; FSIQ=Full Scale IQ.
Full Scale IQ (FSIQ) was assessed as a covariate for all between-group analyses, and it contributed a significant portion of variance to CELF-R scores (FSIQ: LH=88.2 ± 23, RH=91.2 ± 21, Control=118.3 ± 12). Nonetheless, when FSIQ was partialled out all significant differences between the lesion groups (FL, LH, or RH) and control group remained. Due to the fact that the analysis of CELF-R scores with IQ as a covariate is somewhat artificial (i.e., the child is cognitively and linguistically a unitary whole), and significant differences remained even after covarying for IQ, the results presented below represent performance without IQ as a covariate.

The profiles of CELF-R subtest scores for the LH, RH, and control groups are shown in Figure 1. Profile analyses indicated that the subtest profiles for the controls, LH, and RH groups were statistically parallel. Moreover, the LH and RH groups performed at a significantly lower level than did controls (p < .0001), and the LH and RH groups did not differ in level of performance. Follow-up analyses indicated that the LH and RH groups did not significantly differ on any of the receptive or expressive subtests. Lastly, although the profiles were not flat, indicating some variability across the subtests within each group, the small magnitude of the differences between subtests was not significant.

Table 5 Mean CELF-R Receptive, Expressive, and Total Scores for the Focal Lesion (FL), Left Hemisphere (LH), Right Hemisphere (RH), and Control Groups.

<table>
<thead>
<tr>
<th>CELF-R Index</th>
<th>FL* (n=28)</th>
<th>LH (n=17)</th>
<th>RH (n=11)</th>
<th>Controls (n=57)</th>
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<td>Receptive</td>
<td>82.54 ± 17.12</td>
<td>83.18 ± 16.66</td>
<td>81.55 ± 18.59</td>
<td>106.37 ± 12.51</td>
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<tr>
<td>Expressive</td>
<td>73.75 ± 16.79</td>
<td>73.06 ± 14.88</td>
<td>74.82 ± 20.11</td>
<td>101.02 ± 13.63</td>
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<tr>
<td>Total</td>
<td>76.93 ± 17.31</td>
<td>76.94 ± 15.39</td>
<td>76.91 ± 20.74</td>
<td>104.00 ± 12.58</td>
</tr>
</tbody>
</table>

Note: There were no significant differences between the LH and RH groups on any of the CELF-R indices.
*FL Group=LH & RH groups combined.
**Significance values for the lesion versus control comparison.

Figure 1 Profiles of CELF-R subtest scores for the Left Hemisphere (LH), Right Hemisphere (RH), and Control groups.
Note: The subtest profiles for the Control, LH, and RH groups are statistically parallel. LH and RH groups are at a significantly lower level than controls (p < .0001). LH and RH groups do not differ in level of performance.
(i.e., for each group [LH, RH] each subtest mean was not significantly different from the mean of all subtest scores for the group [Semel et al., 1987]).

Although each subtest mean was not significantly different from the mean of all subtest scores for each group, each subtest mean for the FL group was qualitatively examined to determine on which subtests the FL group performed below average (i.e., below a scaled score of 8). The means revealed that the FL group performed below average on the following subtests—Receptive: Word Classes, Semantic Relationships, and Oral Directions; Expressive: Word Structure, Formulated Sentences, Sentence Assembly, and Recalling Sentences. The FL group scored within the average range on only two subtests of the CELF-R and both were on the Receptive Language Scale (Linguistic Concepts and Sentence Structure).

**Examination of Potential Intervening Variables**

Although this study was cross-sectional, there were no significant correlations between test performance and age (i.e., scores did not systematically increase or decrease over age). There were no differences on any of the CELF-R indices as a result of severity of the lesion (single lobe versus multiple lobes). These results were found in both the FL group as a whole, as well as in the LH and RH groups individually.

When the FL group was divided into seizure (those participants who had a history of seizures beyond the neonatal period) and non-seizure (those participants who had never had a seizure or who had seizures in the neonatal period only) subgroups, a salient pattern emerged. Figure 2 presents the effect of seizure status on performance within the focal lesion group. Children in the seizure group demonstrated significantly poorer performance than did children in the non-seizure group (Receptive \( p = .027 \), Expressive \( p = .031 \), Total Language \( p = .021 \)). However, children in the non-seizure group still performed significantly more poorly (\( p < .0001 \) for all indices) than did controls. Chi-square analysis

![Figure 2](image_url)

**Figure 2** CELF-R Receptive, Expressive, and Total scores for the Seizure, Non-seizure, and Control groups. Note: On all CELF-R indices, the Seizure group performed significantly more poorly than the Non-seizure group and the Control group; the Non-seizure group performed significantly more poorly than the Control group and significantly better than the Seizure group.
revealed no significant relationship between seizure status and lesion severity (single lobe versus multiple lobes), thus the variable of seizure status is not merely a proxy for lesion severity.

Within the FL group, analyses of lesion site (frontal, temporal, parietal, occipital, subcortical) indicated no significant relationship between site and CELF-R performance. Due to the fact that site specific deficits may also be related to the side of the lesion, analyses of side and site combined (e.g., left temporal lesion versus all other lesions, left temporal lesion versus left nontemporal lesions) were performed; these analyses also did not indicate any relationship with CELF-R scores.

**Supplemental Analysis of Single-Word Vocabulary in the Lesion Group**

The lesion group performed in the average range on tests of single-word receptive and expressive vocabulary (PPVT-R Mean=94.6 ± 22.9 and EOWPVT-R/UE Mean=93.7 ± 23.7). The PPVT-R (receptive test) was compared with the CELF-R Receptive Language score, and the EOWPVT-R/UE (expressive test) was compared with the CELF-R Expressive Language score in the lesion group. Within the lesion group, performance on the CELF-R was significantly poorer than performance on the single-word language tests, as shown in Figure 3 (Receptive \( p = .002 \), Expressive \( p < .0001 \)).

**DISCUSSION**

The present study examined complex language skills in school-age children with perinatal unilateral brain damage using a structured, standardized language task. Results indicate that regardless of the side of the lesion, deficits in complex language abilities are present in the school-age years. Children with focal lesions performed in the low average to below average range on a standardized test of language, the CELF-R, with mean Receptive, Expressive, and Total Language scores all below the 14th percentile (i.e., below

![Figure 3](https://example.com/figure3.png)

_Figure 3_ A comparison of single-word vocabulary versus complex language in children with focal lesions (FL). Note: Scores above dotted line represent performance within normal limits.
normal limits). Previous seminal studies of Bates and others (Bates et al., 2001; Bates et al., 1997) demonstrated that in free speech situations, children with FL had delays in the very early stages of language development, but normal or near-normal language by school-age (Bates et al., 2001; Bates & Roe, 2001; Stiles, 1995). The results of our study indicate that school-age children with FL may have intact basic abilities (e.g., single-word vocabulary), but they are notably impaired when required to meet the demands of more structured language tasks in both the receptive and expressive domains. These results have implications for the ability of the child to function in everyday life, particularly since linguistic demands increase over the school-age years. Children with early focal brain damage may face challenges in situations such as remembering or carrying out multi-step verbal instructions, interpreting nuances in conversation, and being able to adequately comprehend and/or express complex thoughts and ideas. Importantly, due to intact basic language skills and functional abilities in free-speech situations, these deficits may go unrecognized or be attributed to “laziness,” oppositional behavior, and/or attention deficits.

The similarity in language profiles between the LH and RH groups is in contrast to the laterality of language abilities that is evident after unilateral strokes in adults. A striking finding of the present study is the extent to which the LH and RH lesion groups are similar on structured language tasks. Typical development leads to the neuroanatomical distribution of language systems predominantly in the left hemisphere (Benson, 1986, 1993; Broca, 1865; Shallice, 1988). Therefore, it could be hypothesized that early LH damage would produce greater language impairment than RH damage. However, we found no differences in complex language performance based on the hemispheric side of the lesion. Similar performance between the LH and RH groups was seen across all indices studied (CELF-R Receptive, Expressive, and Total Language Standard Scores, as well as all individual subtest scores). This is consistent with other research that indicates left-right differences may be evident very early in language development but disappear in subsequent years (Vicari et al., 2000). In terms of subtest profiles, the LH and RH groups demonstrated statistically equivalent subtest performances. Although the profiles were not flat, indicating some variability across the subtests within each group, care must be taken to not overinterpret small subtest differences. All children demonstrate variability across CELF-R subtests and, moreover, these subtle differences may be due to measurement error (Semel et al., 1987). More striking than any specific subtest differences in the FL group is that the group consistently performed between 1 and 2 standard deviations below the mean on all subtests of the CELF-R (with the exception of the Linguistic Concepts and Sentence Structure subtests).

Examination of the performance of the FL group across the CELF-R subtests indicates that they performed below average on all expressive language tasks, encompassing the skill areas of language content (semantics), form (syntax and morphology), and memory. In the receptive domain, the FL group performed below average on tasks encompassing the skill areas of content (semantics), content and form integrated (semantics, syntax, and morphology), and memory. The only two receptive subtests on which the FL group performed within normal limits were Linguistic Concepts, which assesses content in a very concrete format (in contrast to Word Classes, which assesses content in a much more abstract format), and Sentence Structure, which assesses form. Therefore, the only two subtests on which the FL group performed within normal limits were among the most concrete and uncomplicated receptive tasks. When the receptive tasks became more complicated and integrated aspects of form, content, and memory, as well as for all expressive tasks, the FL group demonstrated difficulty.
Our current findings indicate that when faced with challenging linguistic tasks, children with focal brain damage (regardless of hemisphere) demonstrate performance that is below normal limits. When language is assessed with a simple, single-word vocabulary test (receptive or expressive), the focal lesion group performs in the average range. What are the neural implications of these findings? Children with focal brain damage have been noted to demonstrate some degree of neural plasticity (Bates et al., 2001; Stiles, 2000; Stiles, Reilly, Paul, & Moses, 2005) and brain reorganization (Mueller et al., 1998; Rutten, Ramsey, van Rijen, Franssen, & van Veelen, 2002; Staudt, Krageloh-Mann, Holthausen, Gerloff, & Grodd, 2004; Stiles et al., 2003). Our findings, however, suggest there are limits to the capacity of the brain to recover after early damage. Perhaps when damaged early in development, the brain is able to reorganize and find alternate pathways for language to emerge, but these alternate pathways may not be as efficient as the original “brain plan.” Therefore deficits may emerge when the system is challenged by complex linguistic tasks. Our findings are consistent with other studies that have found school-age LH and RH lesion subjects to have language deficits, particularly on challenging or complex tasks (e.g., Chapman et al., 2003; Kiessling et al., 1983; MacWhinney, Feldman, Sacco, & Valdes-Perez, 2000; Reilly et al., 1998).

In addition to examining language performance in children with focal lesions, this study aimed to evaluate the possible multi-factorial nature of performance level and outcome. Typical lesion characteristics such as laterality, site, or severity were not predictive of language performance in our focal lesion participants, nor were results attributable to IQ or socioeconomic status. The fact that language performance in the early-onset focal lesion population was not related to these intervening variables is consistent with other research (Bates, 1997; Bates et al., 2001; Chapman et al., 2003; Dall’Oglio et al., 1994; Kempler et al., 1999; Max, 2004; Reilly et al., 1998). Whereas the laterality of the lesion has traditionally been viewed as paramount (likely due to the significance of lesion laterality in adults with stroke), we found that, in children with early focal brain damage, more relevant than lesion side was seizure status.

Within the focal lesion group, a notable pattern emerged such that children who had a history of seizures performed more poorly than did children with a history of no seizures or neonatal seizures only. These data provide strong evidence for the detrimental effects of seizure activity on cognitive functioning. It is widely known that seizure activity may adversely affect cognitive functions in children without focal brain damage (Besag, 1988; Corbett, 1989; Masur & Shinnar, 1992; Rodin, Schmaltz, & Twitty, 1986; Seidenberg & Berent, 1992; Strauss et al., 1995; Trimble, 1990). Perhaps seizure activity results in diminished capacity for efficient brain reorganization in children with focal lesions. There may be variations in outcome that are associated with seizure focus, type, and medical/pharmacological treatment, and future research can serve to clarify these issues and can serve as the impetus for more effective treatments.

These findings highlight the importance of seizure status in the early FL population, and the necessity of taking this influential variable into account before assuming differences are caused by other lesion characteristics such as lesion side or site. Although seizure status is not considered in many FL studies, some researchers have also noted the importance of taking seizure status into account when interpreting the effect of lesion site on behavioral outcome (Dall’Oglio et al., 1994).

The present study indicates that IQ plays a significant role in language competence, as would be expected. However, when the effect of IQ was removed, children with focal brain lesions still performed significantly more poorly than did typically
developing children. Thus, language problems in the focal lesion population go beyond
general cognitive ability and relate specifically to the functional use of language. Hence
the assessment of IQ alone is not an adequate predictor of language abilities in these
children.

Interestingly, in this cross-sectional sample, there was no relationship between
CELF-R language performance and age. Hence there was no evidence for either the LH or
RH group systematically “catching up” or falling further behind over the school-age years.
However, longitudinal studies are clearly needed to clarify any trajectories of performance
over age.

Many existing studies of complex language abilities in children with early focal brain
injury have used experimental tasks of narrative discourse or online measures of language
processing (Bates et al., 2001; Chapman et al., 2003; Dick, Wulfeck, Krupa-Kwiatkowski, &
Bates, 2004; Feldman, MacWhinney, & Sacco, 2002; MacWhinney et al., 2000; Reilly,
Bates, & Marchman, 1998; Reilly, Losh, Bellugi, & Wulfeck, 2004). A noteworthy aspect
to the current study is that our results corroborate previous findings (Chapman et al., 2003;
Reilly et al., 1998) using a standardized measure that is easy to administer, to score, and to
interpret. Our findings parallel those of MacWhinney et al. (2000), who used four subtests
of the CELF-R (along with multiple computerized language measures) and found the
CELF-R subtests to be sensitive to deficits in language functioning in a heterogeneous
population of children with early brain damage, albeit less sensitive than the online com-
puter measures for particular subjects. In contrast to the MacWhinney study, however, the
present study examined performance on the entire CELF-R, including all core subtests as
well as Receptive, Expressive, and Total language indices, and found it to be quite sen-
sitive to language problems in the FL group. Moreover, the present study examined seizure
status, which our results indicate is an important predictor of language outcome in chil-
dren with early FL.

In conclusion, insult to either the LH or RH early in development adversely affects
performance on structured language tasks during the school-age years, and the presence of
seizures results in even greater risk for language impairment. Although these children pos-
sess normal single-word vocabulary and language that is basically “functional,” suggest-
ing a significant amount of brain reorganization after early damage, the deficits on
complex language tasks indicate a limit to neural plasticity. The presence of language dif-
ficulties has implications that go beyond language and into the psychosocial and academic
domains. For example, studies of linguistic and affective prosody (Trauner, Ballantyne,
Friedland, & Chase, 1996), behavioral functioning (Trauner, Panyard-Davis, & Ballantyne,
1996), and academic skills (Ballantyne & Trauner, 1994) indicate that school-age children
with focal brain damage are at risk for problems in these domains. The results of the
present study demonstrate the importance of a thorough language assessment in children
with early focal brain damage, in order to reduce the likelihood that potentially subtle but
significant language deficits may go unrecognized. A lack of recognition could lead to
misplaced attributions of the child’s social, academic, or behavioral difficulties to charac-
teristics such as laziness, inattention, or uncooperativeness. The present study also has
implications for the neural specificity of language in that early damage to either hemi-
sphere results in similar language outcomes. It also has implications for potential limita-
tions on plasticity such that no matter where the site of the lesion, the mere presence of a
focal brain lesion early in life results in less than optimal language outcome. Finally, these
findings indicate that there may be a detrimental impact of seizure activity on brain reor-
ganization after early damage. Future FL studies using more in-depth psycholinguistic
measures, as well as volumetric brain analyses, will further our understanding of language specialization, and how lesion volume and seizure activity may impact brain plasticity and the potential for reorganization in the developing brain.

REFERENCES


