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LEXICAL LEARNING AND LANGUAGE ABILITIES IN PRESCHOOLERS WITH PERINATAL BRAIN DAMAGE

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Studies of children with early-acquired brain damage have noted limitations on language development following such damage and have raised questions regarding the process by which these children acquire language skills. The purpose of this study was to examine the effects of perinatally acquired brain damage on early language abilities and on lexical development through the use of standard assessments, language samples, and a miniature linguistic system approach to teach a novel lexicon. Four children, ages 26–41 months, with localized, perinatal brain lesions documented on ultrasound or CT scan were selected for this study and were compared to 4 matched controls. The results show no differences in the pattern of scores and learning in children with right and left brain damage. With the exception of phonological development, subjects scored below controls on all formal language measures; however, the subjects often scored at or above test norms. Brain-injured subjects were similar to controls with respect to the number of novel words that they initially learned on comprehension and production tasks and the number that they consistently comprehended. Brain-injured subjects generally acquired fewer words when the criterion was consistent accurate production. Interestingly, subjects required more exposures to novel lexical items than did controls before reaching a given level of proficiency. Production seemed to be more difficult for all children, but more so for the brain-injured subjects. It appears that the effects of early damage have an impact on many aspects of language development and that these apparent deficits may reflect the child's need for greater exposure to language skills and structures before acquiring them.

Children with early-acquired brain damage generally have limitations on language skills, particularly if the damage involves the left hemisphere (Aram, Ekelman, Rose, & Whitaker, 1985; Aram, Ekelman, & Whitaker, 1986; Dennis & Kohn, 1975; Dennis & Whitaker, 1976; Rankin, Aram, & Horwitz, 1981). These findings support the theory of early specialization of the left hemisphere for processes involved in language, especially syntactic skills. However, these studies provide a static picture of the brain-injured child's language ability, primarily during the school-age years or later. They do not address questions about the process by which the children acquire language and by which the observed deficits arise.

This study was designed to (a) describe the children's language at an early developmental stage, (b) examine an active phase of lexical learning, and (c) compare the effects of left- and right-brain damage on these measures. Standard language testing and language-sample analysis were combined to provide information about the children's language abilities under formal, structured conditions and under more informal, child-regulated conditions. A novel lexicon was taught to the children to examine active language learning.

The area of lexical learning was chosen for several reasons. Lexical learning is a very dramatic process during the preschool years, central to increasing linguistic competence. According to recent theories of lexically based rules (cf. Bresnan, 1982), the acquisition of words may have important consequences for the acquisition of other aspects of language including syntax. Secondly, there is a precedence in the literature examining the acquisition of novel lexical items by normal and language-impaired children (Dollaghan, 1987; Leonard et al., 1982). These studies suggest that children with such impairments have more difficulty acquiring novel lexical items than do the normal learners. Finally, we felt we could expose children at risk for language difficulties to a circumscribed set of new words without adding substantial burden to their overall task of language acquisition.

We conceived of the acquisition curve for the novel words as having three primary variables: the onset, the rate, and the asymptote or final level of proficiency. Conceivably, any or all of these variables might be affected by early damage. Evidence in the literature argues for a delay in the onset and/or a decreased rate of acquisition as factors contributing to "deficient" language abilities in children with early-acquired brain damage. For example, school-aged children with early-acquired lesions performed below age expectations on the Token Test (Rankin et al., 1981), whereas adults with early-acquired brain damage performed normally on the same test (Dennis & Kohn, 1975). This discrepancy led Rankin and colleagues to hypothesize that there might be a delay in skill acquisition, as opposed to ultimately deficient skills, which is responsible for the poor early test performance.

Using a miniature linguistic system (MLS), we defined onset, rate, and ultimate level of proficiency within an

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experimental setting. The onset was the child's first correct response to a comprehension and production probe and was called "initial learning." The final level of proficiency was consistent correct responses to three consecutive probes for the same word and was called "mastery." With these definitions, we calculated the number of times a novel word was presented by the investigator before the child achieved initial learning and mastery.

The differential effects of left- versus right-hemisphere damage on the process of lexical learning and language development were investigated by examining subjects with primarily right- or left-brain damage. Recent literature has argued against the equipotentiality hypothesis in favor of the early specialization of the left hemisphere for language (Annett, 1973; Aram et al., 1985; Dennis & Kohn, 1975; Dennis & Whitaker, 1976; Rankin et al., 1981; Woods & Carey, 1979; Woods & Teuber, 1978). However, subjects with right-hemisphere damage also have evidenced difficulty with certain aspects of language function, including expressive and receptive syntax and lexicon (Aram et al., 1985; Dennis & Whitaker, 1976; Rankin et al., 1981). Aram et al. concluded that lesions to either hemisphere may impair cognitive and mental development. Insofar as lexical learning is heavily influenced by overall cognitive skills, there may be comparable difficulties after right- and left-hemisphere damage.

Thus, the following three questions were investigated.

1. Will subjects and controls differ at this early age on standard testing or language-sample analyses?
2. Will subjects and controls differ in their acquisition of a novel lexicon?
3. Will there be differences in the nature of the learning between subjects with left- versus right-brain damage?

METHOD

Subjects

Four children, ages 26–41 months, with localized, perinatal brain lesions documented on ultrasound or CT scan were selected for this study from the records of Magee-Women's Hospital in Pittsburgh and at the Child Development Unit, Children's Hospital of Pittsburgh. Two children sustained left-hemisphere lesions, and 2 sustained right-hemisphere lesions. The nature and location of the lesions are reported in Table 1.

All subjects were matched with a sibling or family friend on the basis of gestational age, socioeconomic status (SES) as determined by the Hollingshead Index (Hollingshead, 1957), gender, and age at the time of testing (within 3 months). Subject-Control Pair 3 was not matched for gender. This was a twin pair and it was felt that the common early experiences and environment provided appropriate matching. Subject-control comparisons can be found in Table 2.

Procedure

General procedure. Each child was seen at home for four 1-hr sessions conducted twice per week for 2 weeks. All sessions were video and audio recorded using a video cam-corder (Quasar VM-10) and a standard cassette tape recorder (General Electric 3-53525). These recordings were used for transcription of the language samples and the calculation of intraobserver reliability. The number of presentations of each new word and the child's responses to probes were recorded on-line by the investigator each session.

The first three sessions for each child began with a 10-min warm-up period in which the experimenter and the child engaged in free play with a standard set of five toys. The first two 10-min periods were transcribed for the purpose of obtaining a spontaneous language sample. The final visit began with the administration of the Peabody Picture Vocabulary Test—Revised (PPVT—R; Dunn & Dunn, 1981).

Language assessment. Syntactic, lexical, and phonological features of the children's language were measured by analysis of spontaneous language samples collected during the sessions. Expressive syntax was measured using the 21 syntactic measures of the Sequenced Inventory of Communicative Development (SICD; Hedrick, Prather,

TABLE 1. Nature and location of lesions in brain-damaged subjects.

Subject 1	*Right* intraventricular hemorrhage involving the occipital horn of the lateral ventricle, right subarachnoid hemorrhage, and temporal-occipital hemorrhage documented on CT scan at 1 and 3 days of age Neonatal seizures VP shunt Anticonvulsants for 1 year
Subject 2	*Right* occipital infarct and right peri-ventricular leukomalacia documented by ultrasound at 4 days of age
Subject 3	*Left* intracerebral hematoma over the parietal-occipital region with some blood in the occipital horns of the ventricles documented on CT scan at 1 day of age. Neonatal seizures Anticonvulsants for 1 year
Subject 4	*Left* Grade II intraventricular hemorrhage documented by ultrasound at 1 week

TABLE 2. Subject-control (S-C) comparisons in the lexical learning study.

	S1	*C1*	*S2*	*C2*	*S3*	*C3*	*S4*	*C4*
Lesion side	R		R		L		L	
Age at testing in months	34	34	28[a]	31[a]	31	31	41[a]	41[a]
Gestational age in weeks	39	40	29	31	37	37	30	30
Gender	M	M	F	F	M	F	F	F
SES[b]	5	5	3	3	4	4	4	4

[a]Chronological age uncorrected for prematurity. [b]SES = socioeconomic status.

& Tobin, 1975) and mean length of utterance (MLU) in morphemes. The expressive age was determined by calculating the ECA of the SICD from the 21 syntactic measures obtained from the language sample. Phonology was examined with the Natural Process Analysis (NPA; Shriberg & Kwiatkowski, 1980). Utterances were transcribed with broad phonetic transcription and coded according to the guidelines of the NPA. A process was considered to be present if it occurred at least once in the coded words. Vocabulary development was assessed with the PPVT—R and the size of the child's lexical inventory in a sample of 50 utterances. Normative test scores were calculated based on the child's chronological age.

Novel lexical learning. The lexical-training sessions were conducted by the investigator with the child and one parent in attendance; however, the parent participated only as an observer unless assistance was needed to obtain the child's cooperation.

A novel lexicon consisting of a maximum of six novel common nouns and six novel transitive verbs was taught to each child. The nouns and verbs and their referent objects and actions are presented in Table 3. The final set of 12 objects and actions was chosen on the basis of their novelty as determined during preliminary sessions with normal language learners of comparable ages to those in this study. None of the children in these preliminary sessions evidenced any familiarity with the novel words, nor did they have labels for the novel actions and objects. The phonological complexity of the words was varied so that two groups of "easy" words and one group of "hard" words resulted: (a) consonant-vowel-consonant (CVC) with early-developing phonemes, (b) CVCV with early-developing phonemes, and (c) various patterns with consonant clusters and late-developing phonemes. There were two nouns and two verbs for each of these groups, resulting in the 12 test words.

After the warm-up, lexical teaching began. While playing with the child, the investigator introduced, in turn, the objects and actions and their associated vocabulary items. Three nouns and three verbs were initially presented. Nouns followed the carrier phrase "Here is the ____" while the object was handed to the child or placed in front of him or her. Verbs were presented using the phrase "I'm ____ing the doll" while the action was performed. The investigator did not name the objects or actions except in the formal presentations.

Following presentation of the words, the child's comprehension and production of the words was assessed. Productive competence was examined by presenting the object or action and asking, "What/Who is this?" or "What am I doing to the doll?" respectively. After the child's productive competence was examined, comprehension of the words was assessed. For objects, the child was asked to find, point to, or put in a box, the desired object from an array of five familiar objects and three or six unfamiliar objects. Verb comprehension was tested by asking the child to "Show me how to ____ the doll."

The number of presentations of each word was dependent upon the child's performance on the assessments and on his or her requests for repetition of a label. An incorrect response on a probe resulted in another presentation by the investigator. When the child demonstrated comprehension of all three nouns or verbs on the same trial, the next three were added. Subject-Control Pair 3 and S2 failed to comprehend the first six words sufficiently to be presented the remaining words. On average, each child received three presentations for each word during a session.

Reliability

Intraobserver reliability was determined by comparing

TABLE 3. Novel words and referents in lexical learning study.

		Nouns
Tib	=	A green plastic monster
Snoodge	=	A troll/Wishnik with red stripes
Grung	=	A triangular rubber pencil grip
Dugoy	=	A bungie cord
Bufie	=	The plastic bulb from a lens brush
Mog	=	A runner's wrist wallet with velcro and a zipper
		Verbs
Bobe	=	To move an object in a circular motion through the air
Pumi	=	To bounce an object upside down across a surface
Glanch	=	To turn an object on to its side
Mep	=	To squeeze an object between hands with fingers extended
Neekay	=	To slide two objects together and lift them into the air
Flezh	=	To slide an object along the table and then fling it in

the on-line data collection to that collected from reviews of the videotapes of four testing sessions for 2 children. Reliability measures were calculated for comprehension and production by the child as well as for the number of times each word was presented. The reliability was calculated by the following formula:

$$\frac{\text{No. of agreements} - \text{No. of disagreements}}{\text{Total no. of agreements}} \times 100$$

Using the formula above, the intraobserver reliability was 100%.

Interobserver reliability on the novel learning task was evaluated by comparing the on-line data collection of the investigator and a trained observer who attended all training sessions for one subject and one control. As for intraobserver reliability, measures were calculated for comprehension and production by the child as well as for the number of times each word was presented. The average reliability score was 97%.

Data Analysis

The number of presentations required by each subject and respective control to reach initial learning and mastery for comprehension and production was compared with a one-tail Mann-Whitney U test. A two-tail Mann-Whitney U was used to compare the number of trials required by the right-brain-damaged versus the left-brain-damaged subjects on the same measures.

RESULTS

The results of language development measures are shown in Tables 4 and 5. No differences were found with respect to phonological development as shown by the presence and absence of phonological processes. All errors in the children's productions were readily explained by the coded processes.

The results of the formal language measures show that controls scored higher on all measures with the exception of Pair 4 on the PPVT. Although the subjects scored below their controls on these measures, they scored at or above the norm on some of the measures.

TABLE 4. Presence (+) or absence (−) of phonological processes in spontaneous language samples.

Phonological process	*S1*	*C1*	*S2*	*C2*	*S3*	*C3*	*S4*	*C4*
Cluster reduction	+	+	+	−	+	+	+	+
Liquid simplification	+	+	+	+	+	+	+	+
Final consonant deletion	+	+	+	+	+	+	−	+
Progressive assimilation	−	−	−	−	−	−	+	+
Regressive assimilation	−	−	−	−	−	−	+	+
Unstressed syllable deletion	−	−	−	+	−	−	−	+
Stopping	−	−	−	−	−	−	−	+

Note. S = subject. C = control.

TABLE 5. Scores of subjects (S) and controls (C) on formal tests and standard language measures.

	S1	*C1*	*S2*	*C2*	*S3*	*C3*	*S4*	*C4*
Side of damage	R		R		L		L	
Age (months)	34	34	28[a]	31[a]	31	31	41[a]	41[a]
PPVT—R[b] standard score	83	127	97	117	105	114	106	105
Expressive age	36	48	20	28	28	32	32	36
Lexical size (50 utterances)	61	72	29	61	40	52	47	74
MLU[c]	2.68	3.66	1.44	2.51	1.76	2.27	2.35	3.20

[a]Chronological age, uncorrected for prematurity. [b]PPVT—R = Peabody Picture Vocabulary Test—Revised. [c]MLU = mean length of utterance.

Qualitative evaluation of the new-word learning revealed no differences in the nature of the errors exhibited by the subjects and controls. At no time did the children confuse the novel objects with the common ones, nor did they confuse the novel objects with the novel actions. On production probes, children tended to provide no response during the initial trials. They then confused the novel words in one class until they correctly associated the label with its referent. At no time did they confuse novel nouns with novel actions or novel words with common words on production probes.

Table 6 shows the number of words acquired by each child for a given level of proficiency. Subjects and controls were similar with respect to the number of words learned for initial comprehension, initial production, and mastery of comprehension. Contrary to this pattern of similarity, 3 of 4 subjects learned fewer words than their controls when the criterion measure was mastery of production. In fact, one subject "mastered" the production of only one word, whereas another failed to reach that criterion level for any of the six novel words to which he was exposed.

The mean number of presentations of novel lexical items required by each subject-control pair to reach a given criterion level is presented in Figures 1–4. For all subject-control pairs at all levels of proficiency, subjects required more exposures to the novel lexical items before attaining a given level of proficiency. These differences reached statistical significance for 5 of 16 comparisons including: initial learning on production probes for Subject-Control Pairs 1 and 2 (U = 39.5, and U = 1.5, respectively; $p < .05$), initial learning on both comprehension and production probes for Subject-Control Pair 3 (U = 2.5, U = 0.5, respectively; $p < .05$), and mastery of production for Subject-Control Pair 4 (U = 2, $p < .01$).

There was no apparent difference between children with right-hemisphere damage and children with left-hemisphere damage on the standard language measures and on the number of words learned. Statistical analysis of the number of trials required to achieve initial learning or mastery on comprehension and production probes revealed no significant differences between the two groups (two-tail Mann-Whitney U, $p > .05$; Figure 5).

There was a trend for subjects with left-hemisphere damage to require more presentations, especially to master production.

DISCUSSION

The results show that brain-injured subjects in this sample performed below controls on all language aspects measured except phonology. It therefore appears that early damage may have an impact on many aspects of language and that these effects are present at the earliest stages of development. Although deficits in syntactic skills are typically attributed to the effects of left-hemisphere damage, there is previous evidence that they follow right-hemisphere damage as well (Aram et al., 1985; Rankin et al., 1981). In addition, lexical difficulties have been reported as sequelae of early brain damage to either hemishpere (Annett, 1973; Aram et al., 1985; Rankin et al., 1981). Thus, the performance of the subjects in this study on measures of language development is consistent with the findings of earlier research.

The new-word learning task provides insight into the dynamic process of lexical acquisition by these children. Subjects and controls are similar on the number of novel words acquired when the criteria are initial learning on comprehension and production tasks and mastery on the comprehension task. Three of the 4 subjects, however, failed to produce as many words as their respective controls when the criterion was mastery. As is typical in young children, producing new words is generally more difficult than comprehending them. This difference is exaggerated in the performance of the brain-injured children when productive mastery is the criterion. The difference between comprehension and production for the initial learning criterion may be due to chance; however, this is probably not the case when mastery is the criterion because it requires three consecutive correct responses. Thus, the probability of reaching mastery by chance is either $(1/3)^3$ or $(1/6)^3$ depending on the number of novel words introduced. It is interesting to note that Dollaghan's (1987) study of fast lexical mapping in language-impaired children also found an impairment in the ability of such children to produce a novel word after one presentation. Comprehension of that same word was comparable to controls.

In all subject-control pairs, on all tasks, subjects required more exposures to a novel word in order to meet the criterion for learning. However, they did not make unusual errors compared to the control children's responses, and they generally acquired the same number of words with the exception of mastery of production. These findings provide support for the hypothesis that such children are delayed, not deviant, in their lexical learning and that the delay in skill level reflects the need for more exposures to the structure or words being learned.

TABLE 6. Number of words comprehended or produced to criterion by brain-injured subjects (S) and controls (C).

	S1	*C1*	*S2*	*C2*	*S3*	*C3*	*S4*	*C4*
	(12)	(12)	(9)	(12)	(6)	(6)	(12)	(12)
No. of words:								
Initial learning comprehension	12	12	9	11	6	6	12	12
Initial learning production	12	11	4	4	2	5	10	12
Mastery of comprehension	7	11	6	6	5	5	12	11
Mastery of production	7	7	1	3	0	3	3	10

Note. Numbers in parentheses refer to the total number of novel words presented to each child.

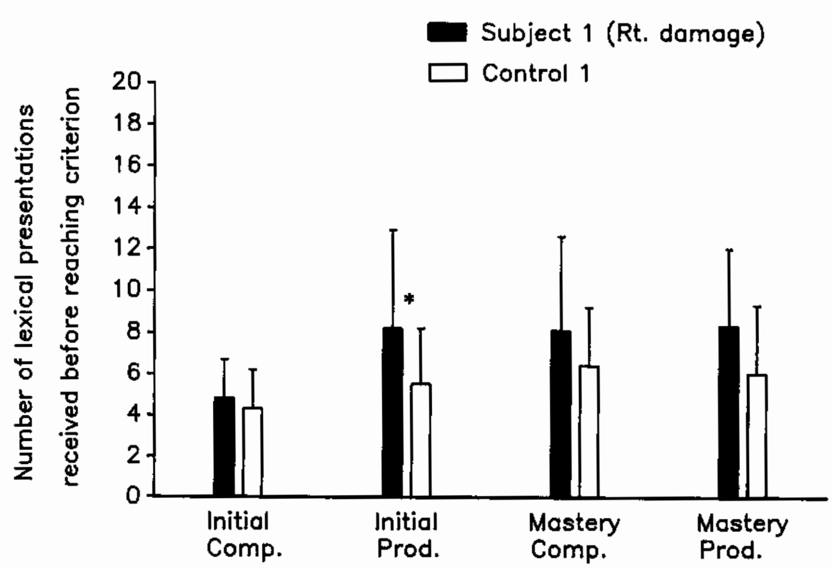

FIGURE 1. Mean number (± *SD*) of lexical presentations required by Subject-Control Pair 1 to achieve initial learning and mastery criteria on comprehension and production tasks. The number of words for which a given level of proficiency was reached may be found in Table 6. *$p < .05$ on Mann-Whitney *U* Test.

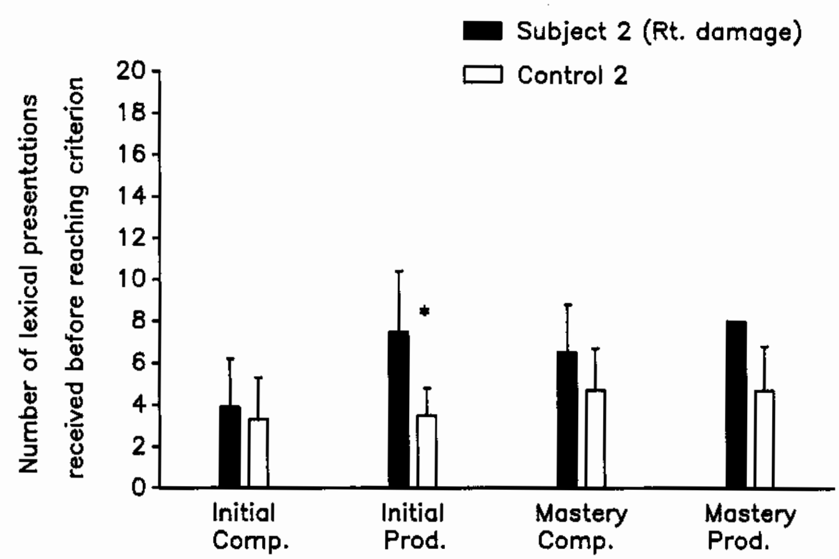

FIGURE 2. Mean number (± *SD*) of lexical presentations required by Subject-Control Pair 2 to achieve initial learning and mastery criteria on comprehension and production tasks. The number of words for which a given level of proficiency was reached may be found in Table 6. $^{*}p < .05$ on Mann-Whitney *U* Test.

The pattern of results suggests that brain damage delays the onset of learning and increases the children's susceptibility to increased task complexity. Dennis and Whitaker (1976) have discussed the possibility that brain-damaged children have more difficulty as the complexity of the task increases. We suspect that these children, secondary to the perinatal insult, arrive at the task of language and skill acquisition with limited neurological resources. Under normal circumstances, this limitation may not be obvious; however, as the task becomes more complex (e.g., production vs. comprehension) or the demands of the learning situation increase, the limited resources of these children may restrict the amount of information they can acquire from a given number of exposures.

Finally, the results show no statistically significant differences between the subjects with right-brain damage and those with left-brain damage. The lack of statistical significance may simply be a reflection of the small sample size; there was a consistent trend for the subjects with left-hemisphere damage to require more presentations of the words and to acquire fewer words than subjects with right-hemisphere damage. However, this trend should not overshadow the fact that the right-

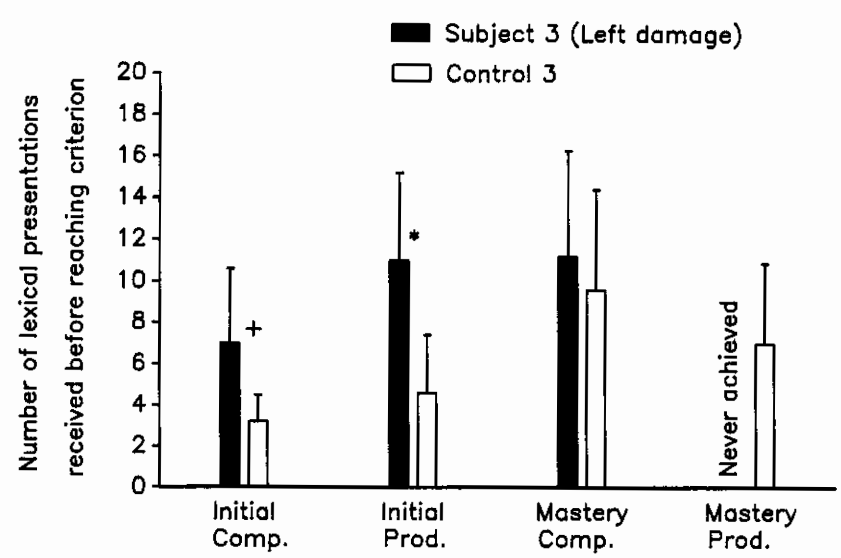

FIGURE 3. Mean number (± *SD*) of lexical presentations required by Subject-Control Pair 3 to achieve initial learning and mastery criteria on comprehension and production tasks. The number of words for which a given level of proficiency was reached may be found in Table 6. $^{*}p < .05$; $^{+}p < .01$ on Mann-Whitney *U* Test.

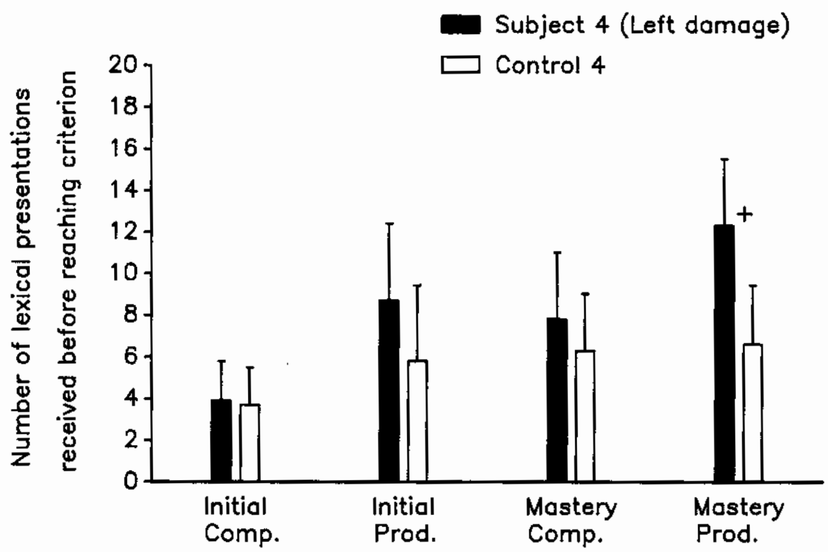

FIGURE 4. Mean number (± *SD*) of lexical presentations required by Subject-Control Pair 4 to achieve initial learning and mastery criteria on comprehension and production tasks. The number of words for which a given level of proficiency was reached may be found in Table 6. $^{+}p < .01$ on Mann-Whitney *U* Test.

hemisphere-damaged subjects were also poorer relative to their controls on the acquisition of the novel lexical items and showed the same pattern of performance on the lexical-learning task and on standard measures of language development. One could argue that damage incurred perinatally, because of the general vulnerability of the immature brain, adversely affects the left hemisphere, regardless of the apparent lateralization of the injury on anatomical studies, resulting in the language deficits. However, the diversity of the nature and the location of the damage in these 4 subjects, in addition to the similarity of their performances on the learning tasks, suggests that the integrity of the entire brain and the ability to utilize early, general, cognitive processes as the basis for language learning may be the critical components compromised by early damage.

The practical implications of this study relate to intervention strategies for children who have suffered early brain damage. First, it may not necessarily be apparent that the child has a language-learning problem. In this study, as well as in others, brain-damaged children have scored at or above their age level on standard language measures, although their scores were depressed relative to those of the controls. In addition, the static picture

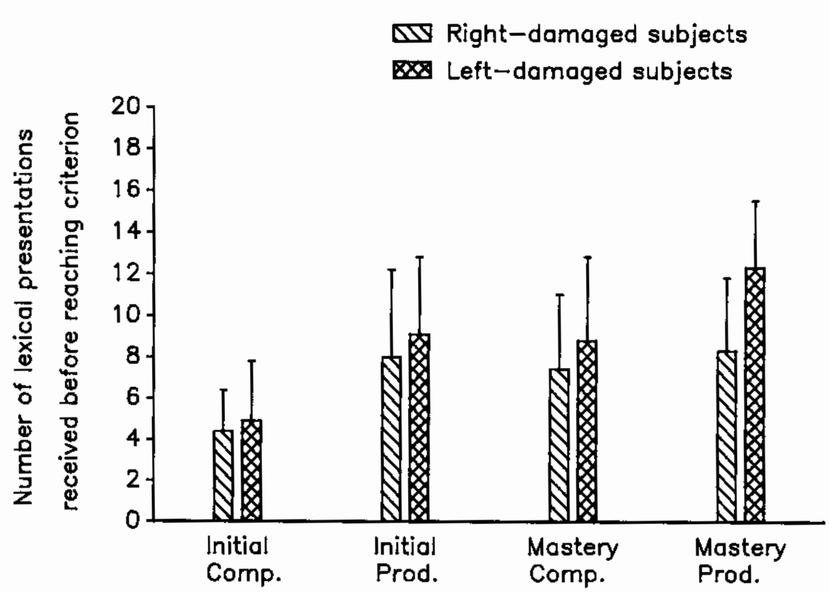

FIGURE 5. Mean number (± *SD*) of lexical presentations required by right- and left-hemisphere-damaged subjects to achieve initial learning and mastery criteria on comprehension and production tasks.

obtained from standard testing does not reflect the additional effort and input that may be required for the child to reach the observed level of proficiency. For some children who fall within the normal range, this need for greater effort and input may not necessarily be evident during the preschool years; however, as the child enters school, the demands to learn quickly from a limited number of exposures and in a limited period of time may stress the brain-damaged child's systems to such an extent that the effects of the slower learning rate are noticed.

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