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## COGNITIVE STRENGTHS AND WEAKNESSES IN LANGUAGE-IMPAIRED CHILDREN: ONE MORE LOOK

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The hypothesis-testing abilities of 15 language-impaired and 15 normally developing children matched for mental age were investigated using discrimination-learning tasks. The subjects in both groups were presented with two sets of discrimination-learning problems. One set of problems featured explicit input concerning the correct response choice. The other set of problems featured nonexplicit input. The results revealed both differences in the performance of the MA-matched and language-impaired children and differences in performance on the two types of problems. The children in both groups solved more of the explicit input problems than the nonexplicit input problems. In addition, the MA-matched children performed significantly better than the language-impaired children, particularly on the nonexplicit problems. The findings suggested that the language-impaired children exhibited deficits in solving discrimination-learning problems. The deficits exhibited by the language-impaired children seemed related to deficits in their ability to encode information.

The cognitive strengths and weaknesses of children with specific language impairments have become clearer in the last few years. There is now considerable evidence, for example, that language-impaired (LI) children per-

form poorly on anticipatory imagery tasks, symbolic play tasks, and other tasks that tap symbolic representational abilities (Johnston & Weismer, 1983; Kamhi, 1981; Kamhi, Catts, Koenig, & Lewis, 1984; Savich, 1984). There is also some evidence that language-impaired children have low-level perceptual deficits in their ability

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to process rapidly changing acoustic information (Tallal & Piercy, 1978) and have a broad deficit in processes related to short-term memory (Kirchner & Klatzky, 1985). On the other side of the ledger, language-impaired children perform at age levels on various performance intelligence tasks (e.g., the Leiter and Columbia), and assorted nonstandardized conceptual tasks (e.g., Kamhi, 1981).

Recently, the hypothesis-testing abilities of language-impaired children have also been examined. The tasks used to assess these abilities seem promising because they share properties with performance intelligence tests, on which language-impaired children are age appropriate, and imagery tasks, on which these children have problems. As on the Columbia, for example, the child must determine if a visual stimulus fits a pattern. As in imagery tasks, however, the child must base his or her judgment on memory of previous items.

Unfortunately, only a few studies have examined the hypothesis-testing abilities of language-impaired children, and the results of these studies are inconclusive. The limitations of these studies have involved too few items and a failure to match groups for performance intelligence (Hoskins, 1979) and the use of items that were too demanding even for the normal children in the study (Kamhi et al., 1984; Kamhi, Nelson, Lee, & Gholson, 1985). In the present study, these methodological problems were eliminated in order to gain a clearer picture of the hypothesis-testing abilities of language-impaired children.

## METHOD

### Subjects

Subjects were 15 normal and 15 language-impaired children matched for mental age (MA), as measured by the Columbia Mental Maturity Scale (Burgemeister, Blum, & Lorge, 1972). All of the children were monolingual native English speakers, and all were enrolled in an urban city school or preschool that drew from upper-lower- and lower-middle-class homes. The mean age of the language-impaired group was 6:2 years with a range from 5:2 to 7:0. The mean age of the MA-matched control group was 6:1 years with a range from 5:3 to 6:8. Each group included 8 boys and 7 girls.

All of the language-impaired children were previously diagnosed by a certified speech-language pathologist and were enrolled in a special program for language-impaired children in the local city school system. These diagnoses were supplemented by test scores on the receptive portion of the Northwestern Syntax Screening Test (Lee, 1971), the Sentence Imitation subtest from the Test of Language Development (Newcomer & Hammill, 1982), the Peabody Picture Vocabulary Test (Dunn, 1965), and the Expressive One-Word Picture Vocabulary Test (Gardner, 1979). The scores of the language-impaired children fell at or below the 10th percentile on the NSST-R and TOLD Sentence Imitation subtest. The

language-impaired children's scores fell at or below the 21st percentile on the PPVT and EOWPVT. Table 1 presents the group means for CA, MA, and the receptive and expressive language measures. As shown in this table, the mean CA and MA for the language-impaired and MA-matched children were almost identical. However, the language-impaired children performed significantly below the MA-matched children on the measures of expressive and receptive language abilities.

### Stimulus Materials

Each problem included a series of 20 stimulus cards with two pictures displayed on each card. The stimulus pictures were shapes (e.g., circle, square, triangle, tree) that were cut from colored construction paper and glued to 5 × 8-in. cards. The two pictures on each card were clearly separated by a line drawn down the vertical midline. All of the problems were two-dimensional with variations on two of the following dimensions: color, size, shape, and position of a black line. Following Gholson's (1980, p. 98) procedures, some problems used different

TABLE 1. Group means and standard deviations for measures of CA, MA, and expressive and receptive language.

Variable	Language disordered	MA matched	t test
Age (in months)			
Mean	73.93	73.20	0.36
SD	6.16	4.66	
Columbia-MA <sup>a</sup>			
Mean	69.40	69.40	0.00
SD	7.68	7.68	
Columbia-ADS <sup>b</sup>			
Mean	95.00	97.27	1.24
SD	3.91	5.92	
PPVT-VA <sup>c</sup>			
Mean	45.07	76.67	9.53*
SD	9.13	9.03	
EOWPVT-VA			
Mean	52.20	74.93	6.10*
SD	8.39	11.76	
NSST-R (no. correct)			
Mean	22.73	32.13	7.34*
SD	4.30	2.47	
Sentence Imitation (age)			
Mean	39.07	74.80	9.75*
SD	2.40	14.20	

<sup>a</sup>MA was extrapolated from the children's mental maturity age on the Columbia. An "L" on the Columbia refers to a score within the lower half of the year and was assumed to equal 3 months. A "U" refers to a score within the upper half of the year and was assumed to equal 9 months. A child who obtained a score of 6L would thus have an MA of 6:3 or 75 months. <sup>b</sup>ADS refers to the standard score equivalents from the Columbia that have a mean of 100 and a standard deviation of 15. <sup>c</sup>The age equivalent scores from the PPVT, Table 2 (Dunn, 1965, p. 12), and the EOWPVT, Table 9 (Gardner, 1979, p. 31), were reported as vocabulary age scores rather than mental age scores.

\* $p < .01$ .

combinations of colors and shapes with size and/or line position held constant. Other problems used variations in size and line position with the other dimensions held constant. For example, if the two relevant dimensions were shape and size, the shape and size of the figures were varied across trials while the color of the figures and the absence of a black line were constant over the 20 trials. For each problem a simple object cue (i.e., color, shape, size, or line position-top/bottom) was arbitrarily designated as the correct answer. The picture sets were randomly assigned to the explicit and nonexplicit tasks with the condition that each set of stimuli included the same number of problems that varied color, shape, size, or line position.

### General Procedures

All of the children were seen individually in their school for three test sessions. The Columbia and several of the language measures were administered during the first session. The discrimination-learning (hypothesis-testing) problems and remaining language measures were administered during the second and third sessions. Each subject received both the explicit input and nonexplicit input problems. Administration of the two kinds of problems was counterbalanced. Eight of the subjects in each group received the problems with nonexplicit input during the second session and problems with explicit input during the third session. The remaining subjects in each group received the problems with explicit input during the second session and problems with nonexplicit input during the third session.

For both the problems with explicit input and nonexplicit input, each child was presented individually with a series of 10 two-choice problems. The children were told that there were two pictures on each card and that one picture contained the correct answer to the problem. Sometimes the experimenter would tell (or show) them the correct answer, and sometimes it would be their turn. When it was their turn, they should *show* the experimenter the correct answer. Sometimes they would be told whether their response was correct or wrong and sometimes they would not. The experimenter also told the children that they should always try to be correct because she was marking their answer on her (data) sheet.

Before administering either the explicit input problems or the nonexplicit input problems, a comprehension pretest was administered to determine whether the subjects could understand the terms that could describe each picture. For example, comprehension of terms for size and shape was tested by showing a child the first card from the problem and asking him/her to point to "the big one," "the circle," "the square," and "the little one." All of the children in both the language-impaired and normal groups understood the descriptor terms for each problem. The comprehension pretest was administered before both types of problems to make certain that administra-

tion procedures were the same for the explicit input problems and nonexplicit input problems.

The sequence of exemplar trials, feedback trials, and probe trials for the first 10 trials of a two-dimensional (size and shape) problem is illustrated in Figure 1. The sequence was constructed according to specific criteria. Each of the problems consisted of a total of 20 trials. Within these 20 trials there were 4 feedback trials (Trials 5, 10, 15, and 20), two sets of exemplar trials (Trials 1-4 and 11-14), and two blank-trial probes (Trials 6-9 and 16-19). On each of the feedback trials, the experimenter confirmed or disconfirmed the subject's choice and provided the appropriate type of feedback, either explicit verbal feedback or nonexplicit verbal feedback and pointing.

For explicit verbal feedback, the experimenter would provide a three-term verbal description of the correct stimulus object. This description included terms for size, color, and shape or size, shape, and line position. For example, if a problem called for variations in shape and size, and the correct answer was "little," the descriptions would be either "The answer is in the picture of the little, black, square," or "The answer is in the picture of the little, black, circle." For nonexplicit feedback and pointing, the experimenter would say a nonexplicit carrier phrase, "The answer is in this picture," and simultaneously point to the correct stimulus picture.

The exemplar trials and blank-trial probes were a series of four cards that were presented in alternation with the feedback trials. On the exemplar trials, the experimenter showed and/or told the subjects the correct answer and turned the card over to reveal the next stimulus pair. The subjects made no overt response on exemplar trials but simply observed the experimenter. On the blank-trial probes, the subject made a selection, and the experimenter simply turned the card over to reveal the next

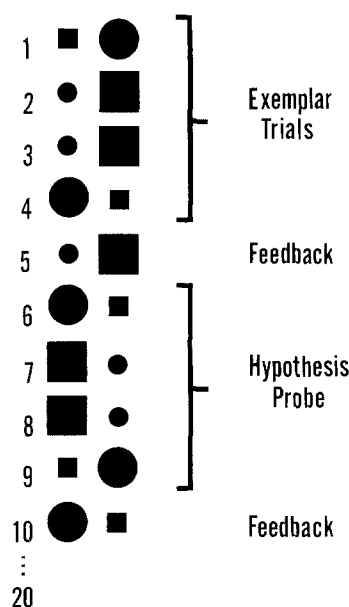


FIGURE 1. The first 10 trials from one problem illustrating the sequence of exemplar trials, feedback trials, and blank-trial hypothesis probes.

stimulus pair. No feedback was given on the blank trials. Inclusion of the exemplar trials made it possible for the subjects to determine the correct answer by noting the specific response pattern the experimenter used on each set of exemplars. Inclusion of the blank-trial probes made it possible for the experimenter to determine the actual hypotheses the children used to solve each problem by observing the specific response pattern a child used on the blank-trial probes.

To illustrate use of exemplar trials, feedback trials, and blank-trial probes, a set of sample responses for a nonexplicit input problem is described below. The stimuli are illustrated in Figure 1. The first four trials are exemplar trials. If the arbitrarily determined correct answer is "large," the experimenter will point to the large circle on the first trial, the large square on the second, the large square on the third, and the large circle on the fourth. The experimenter's response pattern is thus right-right-right-left (RRRL), which corresponds to the hypothesis "large." The next trial is a feedback trial, and the experimenter usually prompted the subjects with "your turn" before turning over the card for the feedback trial. The subject already has enough information to solve the problem and, therefore, he/she should select the correct picture, the large square, on the fifth trial. If the child selects the correct picture on Trial 5, he/she is told, "Yes, the answer is in this picture," as the experimenter points to the large square. The next four trials are the blank-trial probe. After the feedback trial, the experimenter simply turns over the next card, and the child makes a selection. If the child's hypothesis is "large," he/she will point to the large circle on the sixth trial, the large square on the seventh, the large square on the eighth, and the large circle on the ninth. The response pattern is LLLR, which corresponds to the hypothesis "large." The pattern of responses on the blank-trial probe (6-9) confirms whether or not the child has selected the correct hypothesis, which is "large."

The four cards in a set of exemplar trials or a blank-trial probe were sequenced in such a way that a specific hypothesis corresponded to a particular response pattern. There are 16 different combinations of left and right responses that are possible during the four trials that constitute either exemplar trials or a hypothesis probe. Of the 16 possible combinations, 12 corresponded to hypotheses involving simple object cues or alternations. Appearing in Table 2 are the response patterns associated with each of these 12 hypotheses as they apply to the stimuli in Figure 1. Of these 12, 4 represent simple object hypotheses (large, small, circle, and square), 4 represent object alternation hypotheses (large-small, small-large, circle-square, and square-circle), 2 represent simple position hypotheses (left side, right side), and 2 represent position alternation hypotheses (left-right, right-left). The remaining 4 of the 16 possible combinations cannot be interpreted as specific hypotheses. These represent hypothesis probes in which the subjects' responses were not consistent with any one hypothesis. Uninterpretable sequences occurred infrequently, representing less than 5% of the subjects' responses.

TABLE 2. The 12 possible hypotheses and their corresponding response patterns for the set of exemplar trials and blank-trial probes shown in Figure 1.

<i>Hypothesis</i>	<i>Response patterns</i>	
	<i>Exemplar trial</i>	<i>Blank-trial probe</i>
Simple cues		
Large	RRRL	LLLR
Small	LLLL	RRRL
Circle	RLLL	LRRR
Square	LRRR	RLLL
Left side	LLLL	LLLL
Right side	RRRR	RRRR
Alternation patterns		
Large, Small . . .	RLRR	LRLL
Small, Large . . .	LRLL	RLRR
Circle, Square . . .	RRLR	LLRL
Square, Circle . . .	LLRL	RRLR
Left, Right . . .	LRLR	LRLR
Right, Left . . .	RLRL	RLRL

### *Scoring and Reliability*

The scoring procedures for the explicit and nonexplicit input problems were similar. These procedures were adapted from those used in previous studies of normal and language-impaired children (Cholson 1980; Kamhi et al., 1985). Three procedures were used in the data analysis. The first procedure was to determine the number of problems solved by each subject. A subject was credited with a problem solution if the correct hypothesis was exhibited on the final blank-trial probe (Trials 16-19) and the final feedback trial (Trial 20).

The second procedure was to determine the kinds of hypotheses exhibited on the blank-trial probes. Four types of hypotheses were possible: simple object, object alternation, simple position, and position alternation.

1. Simple object hypotheses: Include size, shape, color, or line position cues (e.g., large, circle, blue, line "on top").

2. Object alternation hypotheses: Involve alternations along one object dimension such as size, shape, color, or line position (e.g., large-small, circle-square, black-white, top-bottom).

3. Simple position hypotheses: Involve simple position cues (e.g., left, right). The subject consistently selects the picture on the right side of the card or the picture on the left side.

4. Position alternation hypotheses: Involve alternations in position responses (e.g., left-right, right-left). The subject consistently alternates selection of the picture on the right and left side.

A response pattern that did not correspond to one of these four types of hypotheses was scored as no hypothesis. All problem solutions involved simple object cues based on size, shape, color, and line position. Therefore, the correct answers to the problems were always simple object hypotheses. Subjects who consistently used other types of hypotheses would have difficulty solving the problems.

The final procedure involved calculating the *local consistency* of children's responses. Local consistency

was a measure of the children's responsiveness to information given on feedback trials and was considered present when the hypothesis exhibited on a blank-trial probe was consistent with information given on the immediately preceding feedback trial.

All of the response protocols were scored by the third author. Thirty response protocols for the explicit input problems and 30 response protocols for the nonexplicit input problems were selected at random and independently scored by the first author. The percentage of agreement between these two judges ranged from 98% for judgments of local consistency to 100% for correct problem solutions.

## RESULTS

### Order Effects

A preliminary analysis was conducted to determine whether order of presentation influenced the subjects' performance on the explicit input or nonexplicit input tasks. Separate group-by-order ANOVAs were conducted on the data from both tasks. The dependent variable was number of problems solved. The results of these analyses revealed no significant interaction or main effects involving order of presentation. The data were collapsed across order of presentation in the following analyses.

### Group and Task Differences

The performance of the subjects on the explicit input and nonexplicit input tasks was evaluated in three ways: (a) the number of problems solved, (b) the types of hypotheses used, and (c) the proportion of locally consistent responses. The number of explicit input and nonexplicit input problems solved by the language-impaired and MA-matched normal children is shown in Table 3. The MA-matched normal children solved a mean of 8.07 out of 10 nonexplicit input problems and 8.33 out of 10 explicit input ones. The language-impaired children solved a mean of 4.27 out of 10 nonexplicit input problems and 5.80 out of 10 explicit input ones. A 2 (Group)  $\times$  2 (Task) ANOVA revealed significant main effects for

TABLE 3. The performance of the language-impaired and MA-matched groups on the explicit and nonexplicit input problems for two of the dependent measures: (a) mean number of problems solved, and (b) proportion of locally consistent responses.

	Subjects	
	MA matched	Language impaired
Number of problems solved		
Explicit input	8.33	5.80
Nonexplicit input	8.07	4.27
Proportion of local consistency		
Explicit input	97.87	95.80
Nonexplicit input	98.53	86.67

group [ $F(1, 28) = 53.81, p < .05$ ] and for task [ $F(1, 28) = 4.77, p < .05$ ]. The normal children solved significantly more problems than the LI children. Both groups solved significantly more problems with explicit input than with nonexplicit input. The group-by-task interaction was not significant at the .05 level.

The second analysis compared the types of hypotheses used by the language-impaired and MA-matched subjects. Four general types of hypotheses were identified: simple object, object alternation, simple position, and position alternation. The mean number of simple object, object alternation, simple position, and position alternation hypotheses used by the subjects in each group for explicit and nonexplicit input problems are shown in Table 4. Because each problem included two blank-trial probes for identifying the child's hypothesis, there were 20 possible hypotheses ( $10 \times 2$ ) when responses were totaled across all 10 of the problems in each set. The language-impaired children tended to use fewer simple object hypotheses and more object alternation, simple position, and position alternation responses than the normal children. For example, the MA-matched subjects used a mean of 17.80 simple object and 0.47 simple position hypotheses in explicit input problems and 18.40 simple object and 0.73 simple position hypotheses in nonexplicit input problems. However, the language-impaired subjects used a mean of 14.60 simple object and 2.47 simple position hypotheses in explicit input problems and 12.00 simple object and 3.27 simple position hypotheses in nonexplicit input problems.

A multivariate analysis of variance procedure was used to determine whether there were significant differences in the types of hypotheses used by the language-impaired and MA-matched normal children on the explicit and nonexplicit feedback problems. The data were analyzed first using a 2 (Group)  $\times$  2 (Task)  $\times$  4 (Hypothesis) MANOVA. This analysis indicated that there was a significant difference between the two groups [ $F(4, 25) = 5.86, p < .01$ ] and a significant group-by-task interaction [ $F(4, 25) = 2.89, p < .05$ ]. The main effect for task was not significant at the .05 level. Separate univariate and post hoc analyses were then run to determine which tasks and

TABLE 4. The mean number of simple object, object alternation, simple position, and position alternation hypotheses used by the language-impaired and MA-matched subjects on the explicit input and nonexplicit input problems.

Problems	Subjects	
	MA matched	Language impaired
Explicit input		
Simple object	17.80	14.60
Object alternation	0.73	0.87
Simple position	0.47	2.47
Position alternation	0.33	0.40
Nonexplicit input		
Simple object	18.40	12.00
Object alternation	0.27	1.33
Simple position	0.73	3.27
Position alternation	0.33	1.60

hypotheses were contributing to the overall significant differences found with the MANOVA. Three of these univariate analyses were significant. The one for simple object hypotheses revealed significant differences between the two groups [ $F(1, 28) = 26.22, p < .01$ ] and a significant group-by-task interaction [ $F(1, 28) = 5.11, p < .05$ ]. The one for simple position hypotheses revealed significant differences between the two groups [ $F(1, 28) = 7.35, p < .01$ ], and the one for position alternation hypotheses revealed a significant group-by-task interaction [ $F(1, 28) = 5.01, p < .05$ ]. To follow up the significant interactions, post hoc comparisons were made using Tukey's Honest Significant Difference procedure (Kennedy, 1978). The results of the post hoc analysis revealed that the MA-matched group used significantly more simple object hypotheses and significantly fewer position alternation hypotheses than the language-impaired group on the nonexplicit input problems. Differences in the use of simple object and position alternation hypotheses in explicit input problems were not significant at the .05 level. In addition, the univariate analysis revealed that the language-impaired group used significantly more simple position hypotheses on both the explicit input and nonexplicit input problems.

The third analysis compared the proportion of locally consistent responses used by the language-impaired and MA-matched subjects. The subjects demonstrated local consistency when the hypothesis exhibited on a blank-trial probe was consistent with information given on the immediately preceding feedback trial. The results for local consistency are also shown in Table 3. The performance of the two groups was similar on the explicit input problems; however, the MA-matched control group used a higher percentage of locally consistent responses than the language-impaired group on the nonexplicit input problems. The proportion of local consistency for the language-impaired subjects was 95.80% on the explicit input problems and 86.67% on the nonexplicit input problems. The proportion of local consistency for the MA-matched subjects was 97.87% on the explicit input problems and 98.53% on the nonexplicit input problems. These percentage data were transformed using the arcsin transformation. A group-by-task ANOVA using these transformed data revealed a significant difference for group [ $F(1, 28) = 4.92, p < .05$ ] and a significant group-by-task interaction, [ $F(1, 28) = 5.30, p < .05$ ]. The main effect for task was not significant at the .05 level. A Tukey HSD post hoc comparison test indicated that the MA-matched control group used a significantly higher proportion of locally consistent responses than the language-impaired group on the nonexplicit input problems. However, the difference between the language-impaired and MA-matched control groups on the explicit input problems was not significant at the .05 level.

### *Within Group Differences*

The range of performance of the subjects in the two groups is shown in Table 5. The data in this table indicate

TABLE 5. The range of performance tabulated for the language-impaired (LI) and MA-matched (MA) subjects on the explicit input and nonexplicit input problems.

Problems	1	2	3	4	5	6	7	8	9	10
Explicit input		LI	LI	LI	LI	LI	LI	LI		
					LI	LI	LI	LI		
					LI				LI	
					LI					
					LI					
						MA	MA	MA	MA	MA
							MA	MA	MA	MA
								MA	MA	MA
									MA	MA
Nonexplicit input	LI	LI	LI		LI	LI	LI			
		LI	LI		LI	LI	LI			
		LI	LI		LI					
					LI					
						MA	MA	MA	MA	MA
						MA	MA	MA	MA	MA
							MA		MA	
								MA		
									MA	

the number of subjects who solved different numbers of problems. The performance of the children in the language-impaired group varied considerably for both the explicit input and nonexplicit input problems. The range for number of problems solved was 2–8 for the explicit input problems and 1–7 for the nonexplicit input problems. The performance of the children in the MA-matched control group was less variable. The range for this group for number of problems solved was 6–10 for both the explicit input and nonexplicit input problems. On the nonexplicit input problems, the language-impaired group separated into two nearly equal subgroups. Seven of the language-impaired subjects solved 3 or fewer nonexplicit input problems, whereas the other 8 language-impaired subjects solved 5 or more nonexplicit input problems. The performance of the latter subgroup approached that of the MA-matched control group on the nonexplicit input problems.

## DISCUSSION

As expected, the exemplar trials used in the present study made the discrimination-learning problems easier to solve. In an earlier study (Kamhi et al., 1985), normal children solved 19% of the problems, and LI children solved 28%. In the present study, the normal children solved more than 80% of the problems, whereas the LI children solved only about 50%. Clearly, the normal children benefited more from the reduction in processing demands than the LI children. It is important to note that the MA levels of the normal and LI children in the two studies, as measured by the Columbia, were almost identical (range = 67–69.4 months for the four groups). The improved performance of the children in the current

study, therefore, could not be attributed to differences in cognitive level between the two samples.

The comparison involving type of input (explicit vs. nonexplicit) revealed clear differences between the two groups of children. The normal children essentially showed no difference in their performance relative to the type of input provided. They solved approximately the same number of problems, used the same number of simple object hypotheses, and made the same proportion of locally consistent responses on problems with explicit input and problems with nonexplicit input. In contrast, the LI children had considerably more difficulty solving problems with nonexplicit input than problems with explicit input. Seven of the children performed quite poorly, solving three or fewer problems. Interestingly, although the LI children solved significantly fewer explicit input problems than the normal children, there were no group differences in the number of simple object hypotheses and the proportion of locally consistent hypotheses. The latter findings confirm that the explicit input problems were less difficult for the LI children than the nonexplicit problems.

It is possible that providing explicit verbal input reduced the encoding demands of the discrimination learning problems. The explicit verbal descriptors directed children to attend to particular cues, such as size, shape, color, or line position. The explicit verbal input made it unlikely that children would attend to irrelevant cues such as position. The key finding in this study was that only the LI children benefited from the explicit verbal input, whereas the normal children performed well on both explicit input and nonexplicit input problems. This finding suggests that LI children's encoding processes are not as proficient as those of normally developing children.

Although the data point to encoding deficiencies in LI children, they do not totally rule out the possibility that LI children have difficulty storing information, acting on this information, and retrieving it. Some of the discrepancy in the performance levels of LI and normal children in this study can probably be attributed to difficulties in these areas.

Consider, for example, that although it is not possible to solve discrimination-learning problems consistently with inaccurate representations of the stimulus cues, it is also not possible to consistently solve these problems without doing the right things with the information encoded. This information must be actively maintained in short-term memory so that the various problem solutions can be evaluated and incorrect ones systematically ruled out. There is, in fact, some recent evidence that LI children are less able to actively maintain and regenerate word-list items in short-term memory than normal controls (Kirchner & Klatzky, 1985). LI children might also have more difficulty than normal children evaluating and systematically ruling out problem solutions. Although these deficiencies necessarily would result from difficulty in encoding information, they can occur independently of encoding problems.

Although it is necessary to acknowledge the possible contribution of other processing deficits in LI children,

the ability of these children to perform within normal limits on nonverbal intelligence tests provides some independent evidence of the intactness of these children's general problem-solving abilities. For example, in order for LI children to perform at age level on the Columbia they must have age-appropriate knowledge of perceptual features, such as size, shape, and color, as well as knowledge of various conceptual categories. Children must also be able to rule out alternatives in some systematic way. The question often raised is why LI children perform as well as normal children on nonverbal performance tests and significantly poorer than normal children on other cognitive tasks, such as discrimination learning, anticipatory imagery, and selected short-term memory and perceptual tasks?

Although there are clearly many differences in these tasks (e.g., conceptual difficulty and response requirements), the most important difference appears to be the memory demands of the tasks, particularly the encoding and storage demands. The encoding and storage demands for the Columbia and other nonverbal performance tests are minimized by allowing children to view the stimulus cues until a response is made. In contrast, in order to solve discrimination-learning problems, children must encode the stimulus cues accurately and remember and act on information presented across a series of trials. Similarly, performance on anticipatory imagery tasks depends on children's ability to encode, store, manipulate, and interpret symbolic representations of stimulus input (Johnston & Weismer, 1983). An empirical test of this interpretation would be to increase the memory demands of nonverbal performance test and then compare the performance of LI and normal children. LI children should show a significantly greater decrease in performance than the normal children if our interpretation is correct.

### *Linguistic and Cognitive Deficits: A Common Source or Not?*

It is perhaps no coincidence that the type of problem-solving abilities tapped in this study resemble the kinds of abilities that play an important role in the acquisition of language. To construct a grammar, a child must be able to form representations of physical and social world knowledge (e.g., Bates, Benigni, Bretherton, Camaioni, & Voltera, 1979). In order to form accurate representations and generate grammatical rules, a child must be able to encode, store, organize, and evaluate (rule out alternatives) information. Current conceptualizations of language learning also contend that children are active problem solvers who must discover (induce) language rules and patterns (Clark, 1983; Karmiloff-Smith, 1978; Slobin, 1979). The difficulty LI children have in solving the discrimination-learning problems in this study might not be so different than the difficulty they have in acquiring and using linguistic rules.

Kirchner and Klatzky (1985, p. 563) recently suggested that LI children's linguistic and memory difficulties stem

from a common source—less capacity for processing verbal information. Our claim is somewhat broader while at the same time more specific. We believe that LI children's linguistic and cognitive difficulties are caused by less capacity and efficiency in processing verbal as well as nonverbal information. As exemplified in the present study, LI children have considerable difficulty solving visually presented discrimination-learning problems. Other studies that have documented deficits in anticipatory imagery abilities offer additional evidence that the processing difficulty is not limited to verbal information (e.g., Johnston & Weismer, 1983; Savich, 1985).

The more specific claim made in this study is that LI children have particular difficulty encoding information as opposed to storing and retrieving it. This difficulty can be attributed to the limited resources these children have in perceptual, attentional, and/or representational abilities for it is these abilities that determine how well information is encoded. Although it was not possible to rule out the possibility that other processing deficits affected LI children's performance, the data clearly indicated that these children do not encode information as well as normally developing children.

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