ANALOGICAL LEARNING AND TRANSFER IN LANGUAGE-Impaired CHILDREN

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In this study, the trial-by-trial acquisition procedures developed by Gholson, Eymard, Morgan, and Kamhi (1987) were used to examine analogical reasoning processes in school-age language-impaired (LI) children and normal age peers. Subjects were 16 LI and 16 normally developing children between the ages 6:4 and 8:9 years. Half of the subjects heard only verbal presentations of the problems, whereas the other half heard the verbal presentations while simultaneously viewing physical demonstrations of the problems. The LI children who heard only verbal presentations of the problems took significantly longer to acquire the problem solutions than the other LI children and the normal children in both conditions. There were no differences in children's performance on the transfer task. Theoretical and clinical implications of the findings are discussed.

KEY WORDS: language, disorders, problem solving, cognition, analogic reasoning

Within the past few years, there has been increasing interest in the nature and development of analogical reasoning in young children. Analogical reasoning is widely assumed to represent a central mechanism in the processes of learning, transfer, and discovery (Brown, 1989; Brown & Campione, 1984; Gentner, 1983; Holyoak, 1984; Sternberg, 1985). Analogical reasoning involves applying or transferring existing knowledge (a familiar concept) from a known situation to a novel one, even if the two situations are superficially dissimilar (Gick & Holyoak, 1983). An important aspect of analogical reasoning is noticing the correspondence or analogy between the known situation and the novel one (Brown, Kane, & Echols, 1986; Ross, 1987).

Because analogical reasoning is a central mechanism in learning, it is not surprising that it has a rich history in theories of language acquisition (Bloomfield, 1933; 1961; MacWhinney, 1978). Analogy was a central construct during the early periods of linguistic structuralism. Bloomfield (1933; 1961), for example, called a grammatical pattern, such as a sentence type, an analogy. Analogies, he noted, permitted speakers to utter speech forms that they had not heard "on the analogy" of similar forms that they had heard (p. 275). A grammar, according to Bloomfield, is a description of the analogies that hold for a language. MacWhinney has noted, however, that the structuralists never gave linguistic analogy a proper psychological definition. MacWhinney (1978) includes analogy as one of the three central constructs underlying language acquisition and has attempted to identify its role in the acquisition of morphological forms. More recently, there has been some interest in the role that analogical reasoning processes might play in language-learning disorders (Kamhi, 1988; Nippold, Erskine, & Freed, 1988). The present study examines analogical reasoning processes in children with specific language impairments.

Traditionally, analogical reasoning has been examined by having subjects respond to proportional analogies of the form "A is to B as C is to D" (e.g., Nippold & Sullivan, 1987; Sternberg & Nigro, 1980; Sternberg & Rifkin, 1979). An example of a proportional analogy is "Indiana is to basketball as Edmonton is to ?" Performance on proportional analogies, however, does not provide information about the factors that influence analogical reasoning and the actual processes involved in reasoning analogically.

Gholson, Eymard, Morgan, and Kamhi (1987, p. 228) have recently summarized the processes involved in transfer between problems with identical goal structures and problem states. First, the solution to the original problem, referred to as the base, must be learned and represented in terms of a generalizable mental model (Brown et al., 1986; Gentner, 1983; Johnson-Laird, 1980) rather than in terms of specific surface details, such as object attributes. Second, the child must notice the correspondence between the known solution (base) and the target problem (Ross, 1987). Third, the solution to the base problem must be retrieved in terms of its general structure rather than in terms of specific surface detail (Gentner, 1983; Reed, 1977). Finally, the one-to-one correspondence between the base and the target problem must be mapped and appropriate problem-solving activities carried out (Brown et al., 1986; Gholson et al., 1987; Holyoak, 1984).

Gick and Holyoak (1980, 1983) were the first researchers to study systematically the conditions that influence transfer performance in an analogical reasoning task. The task they used was Dunker's (1945) radiation problem. In this problem, subjects have to find a way to destroy a tumor without also destroying surrounding cells. The solution is to use multiple low levels of radiation that converge from different directions. In a typical study (e.g., Gick & Holyoak, 1983), the radiation problem was preceded by one or two analogous problems that also required a "convergence" solution. For example, in order to capture a military target without incurring many casualties, it is necessary to divide the military force into
smaller groups that can converge on the target from different directions.

Gick and Holyoak (1983) found that in control conditions, young adults provided convergence solutions no more than about 10% of the time. Receiving one analogue in various combinations with diagrams and instructions produced transfer in about 40% of the subjects. When two analogues preceded transfer, performance increased to 90%. When subjects gave evidence that they understood the common goal structure by indicating how they related two analogues, performance was nearly perfect. These findings were taken as evidence that learning one analogue generally yields fragmentary knowledge that is context specific, whereas learning two analogues encourages subjects to disembed the common goal structure from specific details.

The advantages of learning from two analogues has also been shown in children. Gholson et al. (1987) presented 60 third graders and 60 sixth graders with a problem-solving task, the Farmer's Dilemma (Wickelgren, 1974), that required a specific sequence of seven moves for solution. In this problem, the subject must find a way to get a fox, goose, and corn across a river without anything being eaten. The problem has two basic constraints: First, only one thing can be taken across the river at a time. Second, the fox will eat the goose and the goose will eat the corn if either pair is left alone. The key move in solving the problem is taking the goose back across the river after it has already been taken across. Two analogues of this problem were created for the study: One involving a lion, pony, and oats and the other a wolf, rabbit, and carrots. The constraints and goal structure (i.e., solution to the problem) of these problems were similar to the fox, goose, and corn problem (see Method section and Appendix).

Trial-by-trial acquisition procedures were used to evaluate the processes involved in analogical reasoning. These procedures, which are replicated in the present study, include an acquisition phase and a transfer phase. On each trial during the acquisition phase, the child first heard a list of statements describing the series of moves necessary to solve the problem. The child was then asked to recall the list and solve the problem using physical props. The recall protocols provide an indication of the knowledge represented in memory from trial to trial during the course of acquisition. A trial was terminated and a new one begun when an error was made on the enactment task. Half of the children received one analogue of the problem, and half received two analogues. Criterial performance was defined as correctly acting out the problem solution(s). As soon as this criterion was met, another analogue of the problem was presented. This was the transfer phase. Children were allowed up to 60 moves to solve the transfer problem.

Both third and sixth graders showed significantly better transfer following two analogues than one analogue. Age did not affect transfer performance: However, third graders in the two-analogue condition needed more trials to reach acquisition criteria than the other groups. Grade level also affected recall accuracy, but recall accuracy was not a good predictor of transfer performance. Like Gick and Holyoak, Gholson et al. concluded that exposure to two analogues increases the likelihood that children will disembed the common goal structure from its specific details and generalize it to a new analogue in transfer.

In the present study, we were interested in examining analogical reasoning abilities in children with specific language impairments. Although language-impaired (LI) children perform within normal age limits on nonverbal intelligence tests, a growing body of literature has found that their perceptual and conceptual processing abilities are not totally intact (Johnston & Weismer, 1983; Kamhi, 1981; Nelson, Kamhi, & Apel, 1987, Savich, 1984; Stark & Tallal, 1988; Weismer, 1985). Specific deficiencies have been found, for example, in auditory discrimination, anticipatory imagery, inferencing, and hypothesis testing. Stark and Tallal (1988) have recently suggested that these deficiencies as well as linguistic ones can be explained by a basic deficit in perceiving and producing both verbal and nonverbal information that occur rapidly in time. In light of these points, LI children might show deficient analogical reasoning when the problems are presented verbally because the verbal presentations might not allow sufficient time to create an accurate representation of the problem.

Only one study to date has examined analogical reasoning abilities in LI children. In this study, Nippold et al. (1988) found that 6–8-year-old LI children performed more poorly than age-matched peers on three analogical reasoning tasks. However, when differences in nonverbal intelligence were statistically controlled, the group differences on each of the tasks no longer existed. The tasks used in this study were two proportional analogies and a story problem adapted from Holyoak, Junn, and Billman (1984). As indicated above, proportional analogies provide little information about the processes involved in analogical reasoning. In the story problem task, transfer performance in both groups of children was not good because only one analogue was presented. Only 1 LI child and 2 normal children solved the transfer problem without hints. If differences between normal and LI children exist, they might be found after training on two analogues because training on two analogues has been shown to lead to higher levels of transfer performance.

In the present study, the trial-by-trial acquisition procedures of the Gholson et al. study were used to compare analogical reasoning processes of LI and normal children. With these procedures, it is possible to study acquisition as well as transfer processes. All children received two analogues of the farmer's dilemma problem in the acquisition phase. A different analogue was used to evaluate transfer. Measures obtained with these procedures included (a) the number of trials to reach the acquisition criterion, (b) the number of moves in the transfer task, and (c) trial-by-trial analyses of the propositions represented in the recall protocols. As described above and in the next section, the trial-by-trial acquisition procedures also include recall data. Recall protocols provide an indication of the knowledge represented in memory from trial to trial during the course of acquisition.
In the standard procedure, the story analogs are presented verbally. As indicated earlier, however, verbal presentations might tax LI children’s limited processing capabilities. Interestingly, Gholson, Dattel, Morgan, and Eymard (1989) found that preschool 4- and 5-year-old children could not solve five-move scheduling problems unless physical demonstrations of the problem accompanied the verbal presentation. LI children might also benefit from viewing physical demonstrations of the problems. To address this possibility, half of the LI and half of the normal children viewed physical demonstrations of the problems while they heard the verbal presentations. The remaining children heard only verbal presentations of each problem.

To summarize, the ability of LI and normal children to acquire, recall, and transfer problem solutions was investigated in this study. Specific research questions included:

1. Do LI and normal children need approximately the same number of trials to reach acquisition criterion?
2. Do LI and normal children show comparable transfer performance after training on two analogues?
3. Do LI and normal children show comparable performance on the recall protocols?
4. Does viewing physical enactments of the problem solutions enhance LI children’s analogical reasoning abilities, as measured by the acquisition, recall, and transfer data?

METHOD

Subjects

Subjects were 16 normal children ranging in age from 6:4 to 8:5 years (M = 7:6) and 16 LI children ranging in age from 6:4 to 8:9 years (M = 7:8). All of the children were monolingual native English speakers, and all were enrolled in a small urban school that drew from lower-middle-class homes. Half of the LI and half of the normal children were randomly assigned to the two presentation conditions: the verbal condition and the modeling condition. These conditions are described in the next section.

The LI children were previously diagnosed as language impaired by a certified speech-language pathologist and were currently enrolled in speech-language therapy. The language impairment was not the direct result of global intellectual, sensory, motor, emotional, or physical impairments. All of the LI children performed within normal age limits on the Test of Nonverbal Intelligence (TONI) (Brown, Sherbenou, & Johnsen, 1982). To be included in the study, the LI children also had to perform at least 1 year below age level on at least three of the five language subtests of the Test of Language Development (TOLD) (Newcomer & Hammill, 1982). The mean spoken language quotient (SLQ) for the LI children was 79.1 (range: 64–94). LI children in the verbal condition were found to have significantly higher SLQ scores (M = 84.1) than children in the modeling condition (M = 74.1) [t(7) = 2.29, p < .05]. This difference was not expected given the random assignment of children to the two conditions. The possible effects of these language differences on analogical reasoning abilities will be considered in the Discussion section.

The normal children had no history of speech, language, or hearing problems. They also performed within normal age limits on the TONI. Table 1 presents means and standard deviations for chronological age (CA) and mental age (MA) for the normal and LI children according to condition. There were no significant differences in CA or MA across condition or group at the .05 level.

Materials

The setting information and the story units for one analogue of the farmer’s dilemma (fox, goose, and corn problem) are provided below:

Setting Information
Once a man bought a fox, a goose, and some corn at the market. He wanted to take them to his house, but it was on the other side of a river that he had to cross. He had a boat, but it would only carry the man and one other thing over to his house at a time. He knew that if he left the fox alone with the goose, the fox would eat it. He also knew that if he left the goose alone with the corn, the goose would eat it. So he had to figure out how to get them all across the river to his house without anything being eaten.

Recall Instruction
"Now here is what I want you to try to remember so that you can repeat it back to me."

1. First the man took the goose across the river to his house.
2. Then he went back across the river.
3. Next he took the fox across the river to his house.
4. Then he took the goose back across the river with him.
5. Next he took the corn across the river to his house.
6. Then he went back across the river.
7. Finally, he took the goose across the river to his house.

TABLE 1. Group means (M) and standard deviations (SD) for chronological age (CA), mental (MA), and language according to condition.

<table>
<thead>
<tr>
<th>Group</th>
<th>CA (months)</th>
<th>MA (months)</th>
<th>TOLD* SLQ</th>
</tr>
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<tbody>
<tr>
<td>Language impaired Verbal</td>
<td>M 93.0</td>
<td>89.2</td>
<td>84.1</td>
</tr>
<tr>
<td></td>
<td>SD 9.1</td>
<td>8.3</td>
<td>7.3</td>
</tr>
<tr>
<td>Modeling</td>
<td>M 90.6</td>
<td>87.2</td>
<td>74.1</td>
</tr>
<tr>
<td></td>
<td>SD 8.9</td>
<td>10.1</td>
<td>10.0</td>
</tr>
<tr>
<td>Normal Verbal</td>
<td>M 91.0</td>
<td>90.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SD 8.3</td>
<td>10.9</td>
<td></td>
</tr>
<tr>
<td>Modeling</td>
<td>M 89.8</td>
<td>92.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SD 7.1</td>
<td>11.6</td>
<td></td>
</tr>
</tbody>
</table>

*Test of Language Development (Newcomer & Hammill, 1982) Spoken Language Quotient.
Procedures

All of the children were trained to acquisition criterion (defined below) on the fox, goose, and corn problem and the wolf, rabbit, and carrots problem. Children in the verbal condition received only verbal descriptions of the problem solutions, whereas children in the modeling condition heard the verbal description as they simultaneously viewed a physical demonstration of the problem solution. That is, the experimenter enacted each move while reading the story to the child.

The acquisition criterion was defined as two consecutive trials in which the child correctly acted out both seven-move problem solutions using the appropriate props. An acquisition trial consisted of the following: (a) the child was read the setting and constraint information for the particular problem, (b) a recall instruction was given followed by the seven story units representing the exact series of moves necessary to solve the problem, (c) recall protocols were obtained and tape-recorded, and (d) the child was given the appropriate props and asked to demonstrate the problem solution. Each move the child made on the physical demonstration was recorded.

At the beginning of the first two acquisition trials, the experimenter read the complete background-setting information (see the Appendix). On subsequent trials, only the constraints (e.g., the fox cannot be left alone with the goose, the goose cannot be left alone with the corn) and requirements of the task were presented. This information was always followed by the recall instruction, the seven story units, recall, and the physical task (i.e., the child physically demonstrating the problem solution). A trial was terminated when the child either made an error on the physical task that would result in something being eaten or successfully completed the moves to solve the problem. When the child made an error the experimenter said, for example, “Whoops, the fox and goose are alone, the fox ate the goose.” A new trial was begun immediately. When the problem-solving moves were carried out correctly, the child was told “very good” and either a new trial was begun or the transfer task was presented.

A maximum of 30 trials were permitted on the acquisition task. A maximum of 15 trials were presented per session. All children tested reached criterion within 30 trials. The transfer task (lion, pony, and oats problem) was presented immediately after acquisition criterion was met. In this task, only the background (setting) information was provided; neither the recall instructions nor the story units that contained the problems-solving information was presented to the children (see the Appendix). After the setting information was presented, the child was given the physical task materials and asked to show how the man could get everything across the canyon without anything being eaten. The experimenter recorded each move the child made in the transfer task and provided immediate corrective feedback following all errors that would have led to something being eaten. The maximum number of moves allowed was 60. If the child did not solve the problem in 60 moves, hints were provided that led to solution, and a score of 60 was recorded. One LI child did not solve the problem in 60 moves.

RESULTS

Several sets of analyses were performed on the data. These analyses included (a) the number of trials to reach the acquisition criterion, (b) the number of moves in the transfer task, and (c) trial-by-trial analyses of the propositions represented in the recall protocols. Trial was a within-subject variable in all trial-by-trial analyses.

Acquisition

The number of trials to criterion was treated in a 2 (Group: LI vs. normal) x 2 (Condition: verbal vs. modeling) analysis of variance. Significant main effects were found for Group [F(1, 28) = 8.68, p < .01] and Condition [F(1, 28) = 10.87, p < .01]. The interaction between group and condition was also significant, F(1, 28) = 7.48, p < .01. The significant main effects were the result of the relatively poor performance of the LI children on the verbal condition. As can be seen in the left half of Table 2, the LI children in the verbal condition needed an average of 15 trials to reach criterion compared to approximately 4 trials for the normal children in the same condition. In contrast, both groups of children reached criterion in less than 5 trials in the modeling condition.

Individual subject data revealed a bimodal distribution for LI children in the verbal condition (see Table 3). Half of the children needed at least 20 trials to reach criterion (range = 20–27). Two of the children performed like their normal counterparts, solving the problems in 3 and 4 trials, respectively. The other 2 children reach criterion in 9 and 13 trials. No normal child required more than 9 trials to reach criterion in the verbal condition. One normal child took 11 trials to reach criterion in the modeling condition. No LI children in the modeling condition needed more than 8 trials.
Transfer

The number of moves children needed on the transfer task was analyzed in a 2 (Group) x 2 (Condition) analysis of variance. This analysis uncovered no significant differences between groups or conditions. In looking at the transfer data in Table 2, LI children in the modeling condition appeared to need considerably more moves to solve the transfer problem. One should be struck, however, by the especially large standard deviation. The relatively large mean and standard deviation was caused by 1 LI child who did not solve the problem in 60 moves and hence obtained a score of 60. Another LI child needed 25 moves, but the remaining 6 children required fewer than 10 moves (see Table 4). Means and standard deviations calculated without the 1 LI child's scores appear in the last column in Table 2. These recalculated scores were essentially comparable with the other transfer scores.

Recall Data

The recall protocols were first transcribed independently by one of the authors. Eight protocols were then transcribed independently by an author not involved in the original transcription. Word-for-word transcription agreement was 100%. Following Stein and Nezworkski (1978), the recall protocols were scored for semantic agreement with the original seven story units (see the Appendix). All protocols were scored independently by two judges, and disagreements (about 12%) were resolved by discussion. Four measures were obtained from the recall data: (a) the amount of extraneous information produced, (b) recall accuracy, (c) the order of the propositions recalled, and (d) the presence of a key detour (backup) move proposition (#4, see the Appendix).

Extraneous information. Five different types of extraneous information were identified: (a) intrusions from other stories, (b) intrusions from setting information, (c) consecutive repetitions, (d) nonconsecutive repetitions, and (e) irrelevant propositions. A 2 (Group) x 2 (Condition) analysis of variance was conducted on the variables of number of intrusions, number of consecutive repetitions, and number of nonconsecutive repetitions. No significant differences were found between groups or conditions on any of the extraneous information measures.

Accuracy. The percentage of correct recall of the seven story units was calculated for each child. A 2 (Group) x 2 (Condition) analysis of variance was conducted on the accuracy measure. This analysis uncovered no significant differences between groups or conditions.

Order of the propositions. The order of the propositions recalled was scored as correct or incorrect. A 2 (Group) x 2 (Condition) analysis of variance was conducted on the order of the propositions. This analysis uncovered no significant differences between groups or conditions.

Key detour (backup) move proposition. The presence or absence of a key detour (backup) move proposition was scored for each protocol. A 2 (Group) x 2 (Condition) analysis of variance was conducted on the key detour (backup) move proposition measure. This analysis uncovered no significant differences between groups or conditions.
tion) \times 5 \text{ (Types of Extrinsic Information) multivariate analysis of variance revealed no significant main effects or interactions. LI children in the verbal condition did have a tendency, however, to produce more intrusions, consecutive repetitions, and irrelevant propositions than LI children in the modeling condition and all of the normal children. For example, LI children in the verbal condition averaged four setting intrusions compared to two or fewer for the other children.}

**Recall accuracy:** A series of 2 (Group) \times 2 (Condition) \times 5 (Trial (5, 4, 3, 2)) univariate analyses of variance were used to analyze the number of relevant propositions included in the two solution trials and the three trials preceding these trials. Recall that acquisition criterion was defined as two consecutive trials in which the solution was demonstrated. It is important to note if a child solved the problem in 5 or fewer trials, all of the recall protocols were analyzed. In contrast, if a child needed 15 or more trials to solve the problem, only the last 5 trials were analyzed.

No significant differences were found in the 5-trial or 4-trial analyses. Table 5 presents the data for the pre criterion trial and the 2 solution trials. A significant main effect for condition was found in the analysis involving 3 trials (the criterion trial and the 2 solution trials), $F(1, 21) = 4.44, p < .05$. Children in the modeling condition included more relevant propositions than children in the verbal condition. Although the interaction between group and condition was not significant, the LI children in the modeling condition performed slightly better than LI children in the verbal condition across trials.

In the analysis involving the 2 solution trials, the group effect was significant, $F(1, 28) = 4.03, p < .05$. The interaction between group and trial was also significant, however, $F(1, 28) = 6.22, p < .05$. As can be seen in Table 5, the normal children recalled significantly more propositions than the LI children on the second solution trial. The condition effect, which was significant in the previous analysis, was not significant when only the 2 solution trials were considered.

**Temporal ordering:** In order to explore the children's acquisition of the structure of the problem during acquisition, trial-by-trial analyses were performed on the recall-order data. Kendall's rank-order correlation coefficients, collapsed across group and condition, were used to compare recall order with the order in which the propositions were presented. The coefficients for the two solution trials and the three previous trials were .62, .68, .79, .93, and 1.00. The coefficients were submitted to a series of 2 (Group) \times 2 (Condition) \times Trials (5, 4, 3, 2) univariate analyses of variance. No significant main effects or interactions were found. The internal structure of the stories as reflected by how the propositions were ordered was thus similar for LI and normal children and was not affected by condition.

**Presence of key proposition.** In order to solve the seven-move detour problems, children had to realize that one of the objects had to be taken back across the barrier (e.g., river) after it had been taken across in an earlier move. This move, which was always the fourth proposition in the story, was crucial for solving the problem. Ghoshal et al. (1987) reported that although children tended to include this proposition in their recall protocols, it was rarely positioned properly in the recall sequence prior to the first criterion trial, usually occurring as either the second or third in the sequence.

As can be seen in Table 5, children produced three to five propositions on the pre criterion trial and four to five propositions on the first solution trial. An analysis of the propositions most likely to be produced on the two solution trials indicated that Propositions 2 and 6 ("He went back across the river.") were the least likely to be produced (Tukey HSD, $p < .05$). Proposition 7 ("He took the goose across the river.") was the most likely proposition to be left out, followed by Proposition 4. The three remaining propositions (1, 3, 5) were consistently produced by all of the children in both solution trials. The key proposition (4) was the fourth most likely proposition to be included. It was produced 1.72 times (maximum = 2.0). Thus, most of the children produced this proposition in their recall protocols for both of the solution trials.

A 2 (Group) \times 2 (Condition) analysis of variance was used to examine whether there were differences in the use of Proposition 4 as a function of group or condition. The Group \times Condition interaction was significant, $F(1, 28) = 5.44, p < .05$. LI children in the verbal condition were less likely to include the key proposition in their recall protocols than other LI and normal children. Only half of the LI children in the verbal condition produced the key proposition in both solution trials. In comparison, all 8 LI children in the modeling condition, 7 normal children in the verbal condition, and 6 normal children in the modeling condition produced the key proposition in both solution trials.

**DISCUSSION**

Taken together, the findings in this study indicate that LI children are not very different from normal children in acquiring problem solutions, transferring the solutions to an analogous problem, and recalling the story problems. The group differences that were found were a function of the way in which the problems were presented. Compared to all of the normal children and the LI children in the modeling condition, the LI children in the verbal condition (a) took significantly longer to acquire the

### Table 5. Mean number of relevant propositions by group and condition for the pre criterion trial and the two solution trials.

<table>
<thead>
<tr>
<th>Group/Condition</th>
<th>Precriterion</th>
<th>Solution Trial 1</th>
<th>Solution Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language impaired</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal</td>
<td>3.6</td>
<td>4.4</td>
<td>4.3</td>
</tr>
<tr>
<td>Modeling</td>
<td>5.0</td>
<td>5.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal</td>
<td>3.7</td>
<td>4.9</td>
<td>5.4</td>
</tr>
<tr>
<td>Modeling</td>
<td>4.6</td>
<td>5.0</td>
<td>5.4</td>
</tr>
</tbody>
</table>
problem solutions, (b) were less likely to include the key backup proposition in their recall protocols, and (c) had a nonsignificant tendency to produce more extraneous information in their recall protocols and include fewer overall propositions in the two solution trials.

At first glance, the recall data do not seem to reflect any facilitating effects of the modeling condition. These effects, however, have been obscured by the way in which these data were analyzed. Recall that the analyses of the recall data considered only the two solution trials and the three trials prior to solution. Because many of the normal children and LI children in the modeling condition reached acquisition criterion in no more than 5 trials, most of the recall protocols produced by these children were analyzed. For a child who solved the problem in 5 trials, the second solution trial was #5 and the -3 trial was the first trial. In contrast to these children, the LI children in the verbal condition needed an average of 15 trials to reach criterion. Four children needed more than 20 trials. For the child who needed 20 trials, the first 15 recall trials thus were not analyzed. The solution trial for this child was Trial 20 and the -3 trial was Trial 15.

In light of these points, it is impressive that even after hearing the story an average of 10 more times, the LI children in the verbal condition still did not produce more relevant propositions than the LI children in the modeling condition. In fact, the LI children in the verbal condition never did as well in their recall as LI children in the modeling condition. This finding is perhaps even more impressive given the significantly higher language abilities (as measured by the TOLD) of the LI children in the verbal condition.

Despite the difficulty LI children in the verbal condition had in acquiring problem solutions, they performed as well as the other children in the transfer task and in their temporal ordering of the recall propositions. The lack of differences on the transfer task was expected. Previous studies (Gholson et al., 1987; Holyoak, 1984) have shown that training with two analogues leads to the development of an accurate, high-quality problem representation. The LI children in the verbal condition took longer to acquire such a representation, but once acquired they had no difficulty applying it to solve an analogous problem.

The lack of group differences involving the temporal-order data requires an explanation. In previous studies, Gholson et al. (1989) have found differences in the temporal-order data produced by preschool and school-age children. For school-age children, correlations between recall order and order of presentation of the propositions showed a dramatic increase on the first solution trial, with little or no increase prior to this trial. Performance on the solution trials was nearly perfect. Preschool children, in contrast, showed little or no increase on the solution trial and very poor performance throughout, including the solution trials (r ~ .58). Gholson et al. attributed these differences to preschoolers not having the reversible thought processes needed to verbalize the correct alternating move sequence. Thus, cognitive level rather than language level may determine a child's ability to verbalize the propositions in order. This hypothesis was supported by the findings in the present study. The LI and normal children, who had comparable cognitive levels as reflected by their scores on the TONI, showed the same pattern of correlations for the temporal-order data.

Theoretical and Clinical Implications

The findings from this study are consistent with previous research that has found conceptual deficiencies in LI children. However, only LI children in the verbal condition exhibited such deficiencies, not LI children in the modeling condition. The simplest explanation for these findings is that the linguistic content of the problems exceeded the linguistic competencies of LI children. This seems unlikely, however. Although the setting information for each problem contained a series of complex sentences with subordinating or coordinating conjunctions, the age-level performance of LI children in the modeling condition suggests that they had no difficulty understanding this information. The recall instructions, which consisted of simple sentences with prepositional phrases, were well within the linguistic competencies of young school-age LI children.

Another possible explanation for the findings in this study is that LI children's processing problems are restricted to information presented verbally. This claim is consistent with Kirchner and Klitzky's (1985) conclusion that LI children have less capacity for processing verbal information. Although this conclusion can account for the present data, it cannot account for existing evidence that LI children exhibit perceptual and conceptual deficiencies when information is presented nonverbally (Kamhi, 1981; Nelson et al., 1987; Stark & Tallal, 1988). This evidence suggests that it is not the nature of the input (e.g., verbal or nonverbal) that determines performance level, but the extent to which input places demands on LI children's information-processing system. Input that occurs rapidly in time, such as speech, places particularly high demands on these children's processing resources (Stark & Tallal, 1988), resulting in a decrease in the quality of memory codes and the likelihood that these codes will decay rapidly over time.

In light of these points, it does not seem correct to conclude that LI children had difficulty understanding the linguistic content of the problems, nor is it correct to conclude that these children have a processing deficit that is restricted to verbal information. LI children performed better in the modeling condition because the processing demands were reduced by viewing the physical enactments. This reduction in processing demands led to a more rapid formulation of high-quality memory codes of the problem solutions. If the physical enactments were performed in a way that more closely approximated the temporal qualities of speech, LI children would probably perform more like they did when the problems were presented verbally.

The nature of LI children's learning problems is also clarified by the findings in this study. A widely held view...
is that LI children have difficulty generalizing knowledge from one domain to another (e.g., Warren & Rogers-Warren, 1985). An alternative view is that generalization problems represent a failure to flexibly apply existing knowledge (Brown et al., 1986; Kamhi, 1988). The transfer data in the present study convincingly show that LI children, like other children and adults, have no difficulty applying existing knowledge when the transfer situation is analogous (i.e., isomorphic) to the original learning situation. LI children thus do not have a faulty transfer mechanism. They do, however, sometimes take longer to acquire certain kinds of information. For example, LI children do not seem to be very good at inducing language rules that involve grammatical morphemes (Johnston & Kamhi, 1984; Johnston & Schery, 1976). They also may be less flexible in modifying or discarding existing rules that are immature (e.g., agent + action) but of relatively broad scope (Kamhi, 1988).

The findings also have some clinical and educational implications. It seems clear that LI children will be at a disadvantage whenever a learning task is presented verbally or, more generally, when information approximates the discrete, temporal qualities of speech. All things being equal, learning will be facilitated by reducing the demands placed on information-processing resources. Providing visual support in the form of written text, pictures, physical enactments, or gestures are some ways to facilitate performance (Kamhi, 1982; Nelson & Weber-Olson, 1980). Repetition is another way to reduce processing demands. As exemplified in this study, LI children in the verbal condition needed 15 repetitions of the story solutions to solve the problems, but once acquired, they successfully transferred the problem solution to an analogous problem. Reducing the rate at which information is presented should also facilitate learning. We are currently investigating how rate of presentation affects LI children’s analogical reasoning abilities.

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REFERENCES


ROSS, B. (1987). This is like that: The use of earlier problems and


APPENDIX

Pet Wolf, Rabbit, and Carrots Problem

Once a man got a wolf, a rabbit, and some carrots from a friend. He wanted to take them to his farm, but it was on the other side of a mountain that he had to cross. He had a wagon, but it would only carry the man and one other thing over to his farm at a time. He knew that if he left the wolf alone with the rabbit, the wolf would eat it. He also knew that if he left the rabbit alone with the carrots, the rabbit would eat them. So he had to figure out how to get them all over the mountain to his farm without anything being eaten.

NOW HERE IS WHAT I WANT YOU TO TRY TO REMEMBER SO THAT YOU CAN REPEAT IT BACK TO ME:

1. The man took the rabbit over the mountain to his farm.
2. Then he went back across the mountain.
3. Next he took the wolf over the mountain to his farm.
4. Then he took the rabbit back across the mountain with him.
5. Next he took the carrots over the mountain to his farm.
6. Then he went back across the mountain.
7. Finally, he took the rabbit over the mountain to his farm.

Lion, Pony, and Oats Problem (transfer problem)

Once an explorer was given a lion, a pony, and a basket of oats. He wanted to take them to his camp, but it was on the other side of a canyon he had to cross. There was an old walking bridge but it would only allow the man to take one thing across to his camp at a time. He knew that if he left the lion alone with the pony, the lion would eat it. He also knew that if he left the pony alone with the oats, the pony would eat them. So he had to figure out how to get them all across the canyon to his camp without anything being eaten.

NOW I WANT YOU TO SHOW ME HOW HE CAN GET EVERYTHING ACROSS THE CANYON WITHOUT ANYTHING BEING EATEN.