

# Hierarchical Planning Abilities in Children With Specific Language Impairments

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The present study examined Cromer's (1983) claim that children with language impairments have a hierarchical planning deficit that affects language as well as performance on complex construction tasks. Subjects were 30 boys (ages 5–7 years), 15 with specific language impairments (SLI) and 15 with normally developing language. Children were asked to build four hierarchical structures: a block construction, a puzzle construction, a simple straw construction, and a complex straw construction. Children who failed to complete the complex straw construction were taught how to construct the model using a sequential strategy. The two groups tended to perform comparably on the block and complex straw construction, the easiest and hardest of the four constructions. The two groups performed least comparably on the puzzle, simple straw construction, and the training task. On the basis of these findings and recent work by Greenfield (1991), we concluded that it is time to reject the notion that a central hierarchical planning mechanism underlies language and non-language structures that contain hierarchical components. The possible exception is early in development before language and manual actions become more autonomous and modular in nature.

**KEY WORDS:** child language disorders, cognitive abilities, hierarchical planning

The cognitive strengths and weaknesses of children with specific language impairments (SLI) have become clearer in recent years (Bishop, 1992; Johnston, 1988; Kamhi, 1993; Weismer, 1993). One area that has received little attention, however, is hierarchical planning. Only one study, by Cromer (1983), has examined hierarchical planning ability in children with language impairments. To study hierarchical planning, Cromer used a construction task adapted from Greenfield and Schneider (1977), whose study was part of an ongoing attempt by Greenfield and her colleagues (e.g., Goodson & Greenfield, 1975; Greenfield, Nelson, & Saltzman, 1972) to investigate the use of structural principles from language in the domain of action. A brief discussion of this research is necessary to understand Cromer's subsequent study.

Greenfield and Schneider (1977) began their article by pointing out the long history of the notion of hierarchical organization in linguistics (e.g., Lashley, 1951) and psychology (Piaget & Inhelder, 1956; Sinclair, 1971; Werner, 1948). Werner, for example, stated that "childlike actions exhibit relatively little articulation, not only because of their global character, but also because they are more or less lacking in hierarchic organization" (p. 207). Sinclair (1971), a Piagetian psychologist, wrote about the parallel between embedded structures in language, a type of hierarchical organization, and the embedding of action schemes into one another.

Within these perspectives, Greenfield and Schneider (1977) examined the devel-

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opment of hierarchical complexity and the strategies of construction in 70 children from 3 to 11 years old. Children were instructed to build a mobile just like the one hanging in front of them (see Figure 2, complex straw construction). They were allowed to use any strategy they wanted to construct the initial model. The 6-, 7-, 9-, and 11-year-old children who were able to build an exact or very close replica of the model were asked, "Is there an easier way to build the mobile?" and "Is there a harder way to make the mobile?" The expectation was that the easiest way involved minimal interruption of component parts, branches, and subunits, whereas the hardest way would involve maximum interruption. If a child did not come up with "easier" and "harder" strategies alone, the experimenter modeled them and asked the child to do each one in turn.

Greenfield and Schneider found that children younger than 6 had some difficulty replicating the models. By age 6, only 1 child out of 10 failed to copy the model exactly. All of the older children copied the model perfectly. To measure complexity of the constructions, Greenfield and Schneider used a measure that combined "node" complexity (i.e., how many lines are joined) and number of straws. The analyses of these data revealed that each age group up to 6-year-olds created significantly more complex structures than the next younger one. Children 6 years and older correctly replicated the model, so their final structures showed no new level of hierarchical complexity.

The next series of analyses examined the strategies used for constructing the mobiles. Greenfield and Schneider predicted a developmental progression from strategies involving less interruption of subunits to strategies involving more interruption. The striking feature of the typical 6-year-old strategy was that children started at the bottom of one side, worked sequentially up the figure, across the midline, and down the other side. In contrast, all but 1 of the 29 7-, 9-, and 11-year-olds began their construction at a superordinate connecting level. The use of an interrupted strategy (reflected by the number of shifts across various units and subunits) was taken as evidence that the mobile was conceptually organized as a hierarchy—in terms of the superordinate and subordinate parts. Interestingly, none of the children used any other possible construction strategies (e.g., beginning at the middle of a branch and working in both directions).

In summarizing their findings, Greenfield and Schneider wrote, "In accord with our expectations, we have found systematic growth in the representation of this hierarchical structure [i.e., a double-branched tree structure], just as language development shows systematic growth of hierarchical forms" (p. 312). They proceeded to point out, however, that no exact analogy to the most interrupted strategy could ever occur in language because such a strategy would result in shifting between clauses after every word. They concluded by noting that although common organizational principles may underlie language and action, the application of these organizational principles in different modalities and domains will yield many diverse forms of behavior.

Cromer (1983) made a couple of significant changes to Greenfield and Schneider's notion of hierarchical organization. First, he changed the word *organization* to *planning*.

Second, and more important, instead of "organizational principles," he proposed the existence of a "central planning mechanism" whose function was to convert thoughts and intentions that are not temporally ordered into events that occur in real time. It is this conversion process that Cromer defines as hierarchical planning ability. Cromer further suggested that hierarchical planning ability may be crucial for the organization of incoming stimuli in perception and for the production of behavior.

To support his claim for the existence of a central hierarchical planning mechanisms, Cromer cites research on SLI children's sense of rhythm. Kracke (1975), for example, found that 12-year-old children with severe receptive aphasia performed significantly worse than NL or deaf peers identifying rhythmic sequences presented through auditory and tactile modalities. In contrast to the NL and deaf children who processed the patterns in a Gestalt holistic manner, the children with receptive aphasia processed the rhythmic sequences element by element. Temporal gestalts, Cromer argues, depend on hierarchical planning ability. Thus, the difficulty children with language impairments had identifying rhythmic sequences may be caused by a more general deficit in hierarchical planning ability.

More substantial support for the existence of a central hierarchical planning mechanism is found in Grossman's (1980) study of adults with aphasia. Grossman predicted that individuals with agrammatic Broca's aphasia would also have difficulty constructing nonlinguistic tree structures. Subjects in the study included 7 adults with Broca's aphasia, 8 individuals with Wernicke's aphasia, 6 individuals with right hemisphere damage, 7 alcoholic Korsakoff patients, and 5 control subjects. Each subject was given two hierarchically organized tree structures to copy using tongue depressors. The results were quite straightforward. Of all the groups, the Broca's subjects were the most successful and closest to the normal adults in matching the number of sticks used in the models. In contrast, they were the least successful in replicating the hierarchical structure of the model when the model was not present. The subjects with Broca's aphasia also used a chain-like (sequential order) strategy in constructing their tree structures rather than the hierarchical (shifting) strategy used by the other subjects. The constructions did not appear to be affected by the use of the nonpreferred left hand; the two Broca's subjects who used their preferred right hand performed similarly to the other Broca's subjects. These findings were taken as evidence that "a central processor for hierarchically-structured material may be compromised in the Broca's aphasic" (Grossman, 1980, p. 306) and that a specific deficit in hierarchical organization is associated with Broca's area in the left hemisphere (Greenfield, 1991, p. 535).

If there is such a thing as a central hierarchical planning ability, then it must be possible to have a central hierarchical planning disability. In Cromer's words, "since a hierarchical planning ability is crucial to a number of superficially sequential activities, observed deficiencies of any of these may in some cases be a manifestation of a more basic impairment of that hierarchical ability" (p. 146). The purpose of Cromer's (1983) study was to determine whether children

with severe expressive and receptive language disorders suffer from a hierarchical planning disability.

To address this question, Cromer used two construction tasks adapted from Greenfield and Schneider (1977). In the first task, children were shown a line drawing of a symmetrical tree structure and asked to copy the figure. In the second task, children were shown a completed 3-dimensional mobile built from plastic straws and asked to duplicate it. After they completed the spontaneous construction, they were instructed to build it again after watching the experimenter use an interrupted strategy. Subjects were 5 severely receptively impaired children (ages 9:6 to 16:4 [years:months]) diagnosed as having "acquired aphasia with convulsive disorder," 7 children diagnosed as having a primary expressive language impairment (ages 8:5 to 12:10), 12 profoundly deaf children, and 12 normal language children matched for chronological age to the disordered children. Little information was provided about the actual language abilities of the children in the study. The five children with acquired aphasia with convulsive disorder were described as follows:

Most of these children could produce and comprehend single words that appeared to be semantically correct in the sense of being appropriate to the situation. These children are bright and interested and give the appearance of being frustrated by their lack of communicative ability. The residential school which they attend has taught them to read and to write, but they are still handicapped in these abilities. (p. 150)

No information about the language abilities of the expressive aphasics or deaf subjects was provided. All of the disordered subjects performed within normal limits on a performance IQ test (Collins Drever, Snijder-Oomen Nonverbal, Hisky Nebraska, or WISC). The normal language children were not administered a performance IQ test. Instead, performance on the Peabody Picture Vocabulary Test was used to determine IQ. In addition to the lack of common test across the groups, the mean IQ for the various groups differed by as much as 20 points:  $M = 99$  (receptive aphasics), 105 (expressive aphasics), 114 (deaf subjects), and 119 (normal-language children).

The two groups of aphasic children were treated as one group in the various analyses because they performed comparably on the construction tasks. The measure of hierarchical planning was the number of shifts in construction from one subunit to another. Shifts that involved crossing from one side of the figure to the other were given a double weighting. A chain or sequential strategy resulted in a zero score. A maximally interrupted strategy (i.e., shifting every time across midline) resulted in a score of 25. On both tasks, the children with aphasia obtained significantly lower scores than both their deaf and normal language peers. Five of the children with aphasia were never able to copy or build the figures using an interrupted construction strategy, though they were able to complete the same tasks in a serial manner. In contrast, all 12 normal language children and 11 of the 12 deaf children were able to do at least one task using the interrupted construction strategy.

Although Cromer was careful to make no claims about a direct parallel between language and action, he did argue

that it is difficult to imagine how a severe deficit in hierarchical planning could fail to affect language. More specifically, he stated that "a primary hierarchical planning disability in some aphasic children can account for some aspects of their linguistic disabilities and for disabilities on other non-language and nonauditory tasks" (p. 156). Cromer was careful to point out that it would be incorrect to conclude that all children with language impairments suffer from a hierarchical planning deficit. In support of this point, he gave the example of one child with receptive aphasia who drew and constructed the model using a hierarchical strategy and obtained the second highest score of all 36 children.

Cromer appears to have developed a compelling case for the existence of a central hierarchical planning mechanism. Some recent studies, however, argue against the existence of such a mechanism. For example, a series of case studies by Curtiss and Yamada (Curtiss, Yamada, & Fromkin, 1979; Yamada, 1990) found dissociations between language and hierarchical planning abilities. In the earlier study, Curtiss et al. found that some retarded individuals (age 6–20) performed well on the construction tasks but had difficulty producing hierarchically complex grammatical structures, whereas other individuals performed poorly on the construction tasks but had no difficulty producing hierarchically complex grammatical structures. In the later study, Yamada (1990) provided a detailed case study of a young retarded woman with an IQ of 40 whose language contained many examples of hierarchically complex linguistic structures. In contrast to this woman's linguistic strengths, she could not copy anything more complex than a simple three-block bridge and could not even copy a simple three-stick bridge. This pattern of results led Yamada to the conclusion that there is no underlying mechanism, central processor, or neural substrate for hierarchical organization.

Greenfield (1991), in a provocative article, attempted to resolve the conflicting views on the existence of a central hierarchical planning mechanism by suggesting that two neural circuits are involved in hierarchical tasks: a circuit for the hierarchical organization of manual sequences (anterior superior prefrontal cortex) and one for the hierarchical organization of grammar (prefrontal cortex just superior and anterior to Broca's area). Citing research on brain development, Greenfield proceeded to argue that early in development, Broca's area is an undifferentiated neural region that programs both manual action and language production. With maturation, Broca's region develops differentiated circuits, causing the structure of manual action and language to become more divergent, autonomous, and complex. In the remainder of the article, Greenfield provided evidence for the close link between the hierarchical organization of language and manual object combination early in development and the increasing differentiation of language and object combination after age 2.

If Greenfield is correct, then we would expect to find dissociations between language abilities and performance on hierarchical construction tasks in older children, as Curtiss and Yamada have found, rather than close links between language abilities and performance on construction tasks, as Cromer has reported. In the present study we questioned whether young school-age children with moder-

ate language impairment (i.e., a typical group of children with specific language impairment) showed evidence of a hierarchical planning disability. It may be that only children with very severe language impairments, like the ones in Cromer's study, evidence such a disability. Differences in general cognitive abilities also may have contributed to Cromer's findings. As indicated earlier, the different groups in Cromer's study were matched for chronological age rather than mental age. In the present study, children were matched for mental age. In addition, four construction tasks were administered rather than one. Children who were unable to replicate the complex straw model were trained to construct the model, thus providing a measure of learning ability.

## Method

### Subjects

Subjects were 30 boys (ages 5–7 years), 15 with a specific language impairment and 15 with normally developing language. The subjects were matched for mental age on the basis of their performance on the Test of Nonverbal Intelligence (TONI) (Brown, Sherbenou, & Johnsen, 1982). The two groups of children had a mean mental age of approximately 6 years (see Table 1). All the children were monolingual native English speakers. Both groups of children were drawn from a school system in a small Arkansas city close to Memphis. The normal language (NL) children had no history of speech, language, or hearing problems, and all performed within normal age limits on the TONI and the PPVT-R.

The children with SLI were previously diagnosed as language-impaired by a certified speech-language pathologist and were currently enrolled in speech-language treatment. The language impairment was not the direct result of global intellectual, sensory, motor, emotional, or physical impairments. All of the children with SLI performed within normal age limits on the Test of Nonverbal Intelligence (TONI) (Brown, Sherbenou, & Johnsen, 1982). Note, however, that the children with SLI did have significantly lower TONI quotients than the NL children,  $t(28) = 2.97, p < .01$ . To achieve a mental age match between the two groups, the SLI group averaged 6 months older than the NL group, a difference that also was significant,  $t(28) = 3.16, p < .01$ .

To further document the nature and extent of children's language impairment, the following language tests and subtests were administered: the Peabody Picture Vocabulary

Test-Revised (Dunn & Dunn, 1981), the Grammatical Understanding Subtest of the Test of Language Development-2 (Newcomer & Hammill, 1988), Subtests IV and V from the Token Test for Children (DiSimoni, 1978), and the Structured Photographic Expressive Language Test-II (SPELT, Werner & Kresheck, 1983). Five children were also given the Miller-Yoder Language Comprehension Test (Miller & Yoder, 1984). Thirteen of the children with SLI performed at least one standard deviation below the mean on at least 3 of the 5 measures of language. One child with SLI performed more than one standard deviation below the mean on the SPELT and the Miller-Yoder Language Comprehension Test. The other child with SLI performed two standard deviations below the mean on the SPELT and at the 37th percentile on the Grammatical Understanding subtest on the TOLD. Table 1 presents subject data for the two groups.

Samples of expressive language also were obtained from each child. All children were asked to tell a story from a picture book (spontaneous story) and to retell a story after hearing it (story recall). In addition, a 5-minute spontaneous language sample was obtained from the children with SLI. These samples were analyzed for the presence of multiple clause structures (see Lund & Duchan, 1988, p. 186).

### Procedures

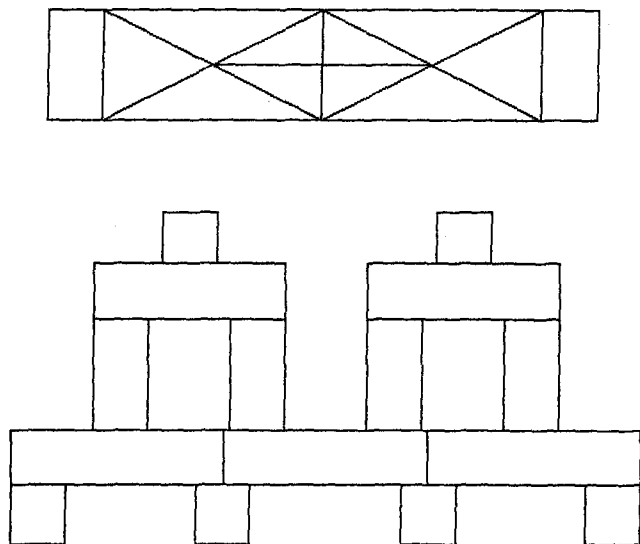
Testing was conducted in 2 or 3 sessions. In the first session, children were administered the TONI and the battery of language tests. Samples of expressive language also were obtained during this session. In subsequent sessions, children were asked to build four hierarchical structures: a puzzle construction, a block construction, a simple straw construction, and a complex straw construction. Children who failed to complete the complex straw construction task were taught how to construct the model using a sequential strategy. Eleven of the NL children and 13 of the children with SLI participated in this phase of the study.

The puzzle construction task consisted of 12 separate pieces. Ten of the pieces were triangles and two were rectangles. The puzzle was symmetrical, with each half containing 6 pieces (see top of Figure 1). The block construction task was adapted from the "bench model" construction task described in Goodson and Greenfield (1975). The block design was a three-tiered two-tower model consisting of 15 wooden, colored blocks of three different sizes.

**TABLE 1.** Group means (*M*) and standard deviations (*SD*) for chronological age (CA), mental age (MA), IQ, and language measures.

Group	CA (in months)	MA (in months)	TONI (quotient)	PPVT (SS)*	TOLD (%ile)	SPELT-2 (%ile)	TOKEN IV (SS)	TOKEN V (SS)
NL								
<i>M</i>	70.5	74.1	105.3	105.6	•	•	•	•
<i>SD</i>	4.2	10.0	12.8	13.2	•	•	•	•
SLI								
<i>M</i>	77.6	73.5	94.8	77.5	22.8	5.0	492.4	493.6
<i>SD</i>	7.6	7.8	4.8	12.1	20.1	4.1	3.8	4.0

\*SS = Standard Score



**FIGURE 1.** Illustrations of the puzzle (top) and block (bottom) models.

Each tower contained 7 blocks; 1 block linked the two towers (see bottom of Figure 1).

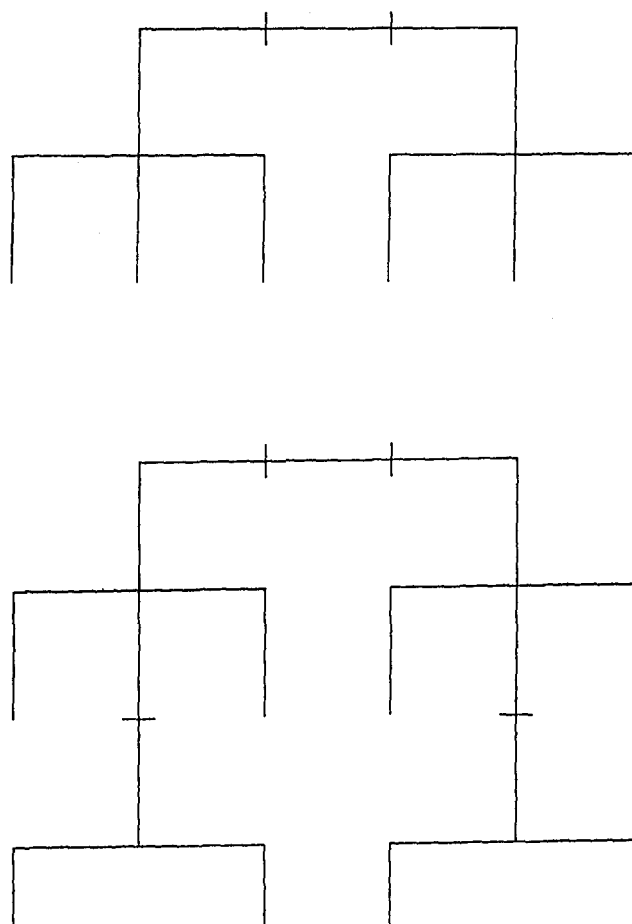
The straw construction tasks were adapted from Greenfield and Schneider (1977). The simple design was a double-branched, one-level structure containing 15 straws and 10 connectors (see top of Figure 2). The complex design was a double-branched, two-level structure containing 25 straws and 18 connectors (see bottom of Figure 2).

For each of the construction tasks, there were two conditions: nondirected and directed. In the studies by Greenfield and Cromer, these conditions were referred to as "spontaneous construction" and "modeled construction." In the nondirected condition, the children were asked to build a replica of the model structures. The model structures were constructed by the examiner before each session; children did not see the initial models being constructed. With the model in full view, children were instructed to put their blocks, puzzle pieces, or straws together so that they looked just like the model. Children were allowed to modify completed replicas if they felt that their constructions did not resemble the model.

In the directed condition, children were shown how to make the model using a "maximally interrupted strategy." By pointing to specific pieces or straws on a fully constructed model, the examiner showed children how to build the model by continually shifting from one side of the structure to the other until the entire structure was completed. Children were able to look at the models during the construction of their replicas.

The nondirected condition for each task was always administered before the directed condition, and the simple straw construction task was always administered before the complex straw construction task. With these constraints, the administration of the block, puzzle, and straw construction tasks was counterbalanced across the two groups. The training task, which followed the administration of all four construction tasks, is described below.

Children who failed to construct a replica of the complex



**FIGURE 2.** Illustrations of the simple (top) and complex (bottom) straw models.

straw structure were taught how to construct the structure using a sequential strategy. A trial-by-trial learning paradigm was used to train the children. For each trial, children (a) watched the examiner build the model using a sequential strategy, (b) verbalized how they would build the structure, (c) drew a picture of the completed structure, and (d) constructed the structure. Children were stopped immediately after they made a construction error and were given corrective verbal and nonverbal feedback (i.e., the examiner pointed to the error location). The structure was then dismantled and a new trial was begun. All of the children were able to replicate the model within 10 trials. After the children correctly constructed the model using a sequential strategy, they watched the examiner build the model using a maximally interrupted strategy and were asked to build the model in the same way.

### **Scoring and Reliability**

For each task, the examiner recorded the sequence of items (i.e., blocks, puzzle pieces, straws) used in constructing the various designs. All constructions were evaluated first for whether or not they matched the model. Constructions were judged as correct or incorrect replicas of the

model. Only exact replicas were considered correct. The extent to which children used a maximally interrupted strategy to construct the replicas was determined next by calculating a construction score for each of the correctly replicated models. Each construction shift across the midline received a score of 1. Construction scores for the puzzle, block, and simple straw tasks were determined by adding all of the construction shifts children made in building the structures. For these tasks, the total number of possible shifts was 11 (puzzle), 13 (block), and 12 (simple straw). Greenfield and Schneider's (1977) double-weighted scoring procedure was used to calculate construction scores for the complex straw task. Shifts in construction from one subunit to another received a score of 1, whereas shifts that involved crossing from one side of the figure to the other received a score of 2. The maximum construction score possible was 46.

To provide additional information about hierarchical complexity, several other measures were calculated for the two straw construction tasks: (a) the number of straws used to build the structures, (b) whether or not children built double-branched structures (as opposed to a single-branched structure, such as a square), and (c) whether or not children built structures that contained extraneous elements (i.e., subunits in the wrong places).

Performance on the training task was reflected in the number of instructional trials needed to build the complex straw replica using a sequential strategy. For the next phase, children's ability to replicate the model using a maximally interrupted strategy was recorded and construction scores were calculated for the correct replications.

The recorded construction sequence for each task was used to calculate the various construction measures. Each of the measures was independently scored by the second and third authors. Interjudge reliability for these measures ranged from 86% to 100%. Disagreements were resolved through discussion. To evaluate intrajudge reliability, both the second and third authors rescored each of the measures for three children in each group. Agreement ranged from 92% to 100%.

The language and story samples for each child were transcribed by two research assistants. The samples were combined for the subsequent analyses that examined whether or not children used multiple clause structures. One of the research assistants identified all of the multiple clause sentences in each sample (e.g., compound clauses, adverbial clauses, relative clauses, complex verb phrases, and subject clauses—see Lund & Duchan, 1988, p. 186). The first author independently coded the multiple clauses in each sample. Agreement was 100%.

## Results

The first set of analyses compared the ability of the two groups to construct replicas of the model. These data are presented in Table 2, which shows that all but one child from the NL group and a few children from the SLI group successfully replicated the block construction in both conditions. In contrast, children in both groups had the most

TABLE 2. Number of subjects replicating models.

Group	Construction tasks			
	Block	Puzzle	Simple Straw	Complex Straw
NL				
Nondirected	14	11	9	4
Directed	15	11	11	7
SLI				
Nondirected	11	4	6	2
Directed	13	5	4	3

difficulty replicating the complex straw construction. Only 2 of the children with SLI and 4 of the NL children could replicate this structure in the nondirected condition. Chi square analyses were used to compare group performance across the four tasks. Significantly more NL children correctly replicated the puzzle and simple straw structures than did children with SLI [ $\chi^2 = 6.53, p < .01$  (puzzle, nondirected);  $\chi^2 = 4.82, p < .02$  (puzzle, directed);  $\chi^2 = 6.53, p < .01$  (simple straw task, directed)]. None of the other group comparisons were significant.

The second set of analyses compared the ability of the two groups to use a maximally interrupted strategy in constructing replicas of the models. The use of a maximally interrupted strategy is reflected in the construction scores presented in Table 3. Recall that construction scores were calculated only on correctly replicated models, so the mean construction scores in Table 3 reflect different numbers of children in each condition (refer to Table 2 for the actual subjects in each group). None of the group differences were significant ( $p > .10$ , Mann Whitney U Test). The children with SLI obtained comparable construction scores for the directed and nondirected conditions. In contrast, the NL children's construction scores were significantly higher for the directed condition than they were for the nondirected condition on three of the four construction tasks (block, Wilcoxon  $T = 2, p < .01$ ; puzzle, Wilcoxon  $T = 0, p < .01$ ; simple straw, Wilcoxon  $T = 3, p < .05$ ).

TABLE 3. Construction scores of exact replicas.

Group	Construction tasks			
	Block (13) <sup>a</sup>	Puzzle (11) <sup>a</sup>	Simple Straw (12) <sup>a</sup>	Complex Straw (46) <sup>a</sup>
NL				
Nondirected				
<i>M</i>	5.0	2.8	2.4	15.5
<i>SD</i>	2.0	1.8	3.2	2.5
Directed				
<i>M</i>	8.9	6.3	6.6	30.9
<i>SD</i>	3.5	3.5	4.1	14.3
SLI				
Nondirected				
<i>M</i>	5.5	2.0	4.2	18.5
<i>SD</i>	1.9	1.2	4.4	9.1
Directed				
<i>M</i>	6.7	2.6	5.8	19.6
<i>SD</i>	2.8	0.9	2.1	6.3

<sup>a</sup>Maximum construction score

The next set of analyses further examined the structural complexity of the simple and complex straw structures. Children in both groups used the same number of straws in constructing the simple (14-15) and complex structures (20-23). Some differences were found, however, in the number of children in the two groups who constructed double-branching structures and added extraneous elements to their structures. All but one NL child constructed a double-branching structure. In contrast, several children in the SLI group, particularly in the directed condition of the simple straw task, did not construct a double-branching structure. In this condition, only half of the SLI group (8/15, 53.3%) were able to construct a double-branching structure. This difference was significant ( $\chi^2 = 6.13, p < .01$ ). Similarly, only 1 NL (not the same one as above) added an extraneous element to his structure, once in the simple straw task and once in the complex straw task. In contrast, 5 of the children in the SLI group added extraneous elements in one of the tasks; 2 of the children did so in each condition of the two tasks.

Data from the learning task were examined next. Recall that children who failed to construct a replica of the complex straw structure were taught how to construct the structure using a sequential strategy. After correctly constructing the model using a sequential strategy, children viewed the examiner building the model using a maximally interrupted strategy and were asked to build the model in the same way. The data for these tasks are presented in Table 4.

The NL children needed significantly fewer trials than the children with SLI to construct the complex straw model using a sequential strategy,  $t(22) = 2.23, p < .05$ . About half (5/11, 46%) of the NL children and a third (4/13, 31%) of the children with SLI were able to replicate the model after viewing the examiner construct the model using a maximally interrupted strategy. The 5 NL children who constructed the model correctly had significantly higher construction scores than the 4 children with SLI who constructed the model correctly (Mann Whitney  $U = 0, p < .01$ ). Two of the 4 SLI children had minimal construction scores, indicating that they used a sequential construction strategy to construct the model.

The next series of analyses considered the relationship between the SLI group's hierarchical construction abilities and their language abilities as reflected by scores on the PPVT, TOLD, and SPELT II. Hierarchical construction abilities were rank-ordered on the basis of children's perfor-

mance on the four tasks. Four considerations figured in the rankings: (a) the ability to replicate the models in each of the conditions (range = 0-7), (b) the sum of construction scores from each of the tasks (range = 0-76), (c) the number of trials needed to succeed on the learning task (range = 1-10), and (d) the ability to use a maximally interrupted strategy (yes/no). In all cases, the more models correctly replicated, the higher the ranking. The other three measures (b, c, d) were used to differentiate among children who replicated the same number of models. The variable performance of the SLI group across the four measures made the rank-ordering relatively easy. For example, the child who ranked first successfully replicated seven of the eight models and had a total construction score of 76. In contrast, the child who ranked last replicated none of the models and had a total construction score of 0. Spearman rank-order correlation coefficients were calculated between children's ranking on the hierarchical construction tasks and the three measures of language. None of the coefficients were significant at the .05 level. Nonverbal intelligence was also not significantly related to performance on the construction tasks.

The final analysis considered the use of multiple-clause sentences in the language samples obtained from both groups of children. All the children in the study used at least one multiple-clause sentence. Two of the children with SLI used only compound sentences. One of these children had the highest overall ranking on the hierarchical construction tasks; the other child had the fourth highest ranking. All of the other children used complex verb phrases, adverbial clauses, or relative clauses.

## Discussion

The purpose of the present study was to examine the association between language and hierarchical construction tasks in young school-age children with moderate language disorders. A previous study by Cromer (1983) found that children with severe language disorders performed significantly worse than deaf and normal-language peers in replicating hierarchically organized structures. Other research, however, has found dissociations between language abilities and hierarchical construction tasks (Curtiss et al., 1979; Yamada, 1990). To resolve these discrepant findings, Greenfield (1991) has proposed that there is a close association between the hierarchical organization of language and manual object combination early in development and increasing differentiation of language and object combination after age 2.

The data in the present study seem at first glance to provide some support for both Greenfield's and Cromer's claims. The two groups tended to perform comparably on the block and complex straw tasks, the easiest and hardest of the four tasks. No significant group differences were found in the number of children who could replicate the block and complex straw models or in the construction scores. However, the differences that did exist favored the NL children, most noticeably in the directed conditions on both tasks. Recall that on the block task, the NL children's construction scores were significantly higher in the directed

**TABLE 4.** Learning paradigm data

	NL (n = 11)	SLI (n = 13)
Training task		
M # of trials	3.2	5.8
SD	2.4	3.3
Transfer task		
# of subjects who replicated model	5	4
Construction score		
M	26.8	8.8
SD	7.4	9.6

condition than in the nondirected condition. The NL children thus were able to increase the number of shifts they used in replicating the block structure after watching the examiner model a maximally interrupted shifting strategy. In contrast, children with SLI showed no comparable increase in construction score in the directed condition.

The two groups performed least comparably on the puzzle, simple straw task, and learning tasks. Significantly more NL children replicated the puzzle models in both conditions. For the directed condition, the mean construction score of the NL group more than doubled the mean construction score of the SLI group, but this difference did not reach significance. The puzzle task has not been used in previous studies as a measure of hierarchical planning. The children with SLI seemed to have particular difficulty with the spatial orientation of the puzzle pieces, suggesting that this task might be measuring something other than hierarchical planning.

On the directed condition for the simple straw task, 11 of the NL children replicated the model, compared to only 4 of the children with SLI. Only half of the SLI group (8 children) were able to construct a double-branching straw structure, compared with 14 of the 15 NL children. The remaining children with SLI constructed box-like structures. No differences were found in the construction scores of the children who replicated the model. In other words, the four children with SLI who replicated the model exhibited the same degree of shifting strategy as the 11 NL children who replicated the model.

On the learning task, the NL children needed significantly fewer trials to construct the model using a sequential strategy than the children with SLI. Recall that the learning task was added because so few children were able to replicate the complex straw model. Children were trained initially to make the structure using a sequential strategy. After correctly constructing the model using a sequential strategy, children were shown how to construct the model using a maximally interrupted strategy. The construction scores of the 5 NL children who were able to reconstruct the model were significantly higher than the scores obtained by the 4 children with SLI who constructed the model. Two of these 4 children obtained minimal construction scores.

Taken together, the data indicate that as a group, children with SLI had some difficulty replicating hierarchical structures using a sequential strategy but, with the exception of the learning task, did not differ from NL children in their use of an interrupted strategy. The findings in the present study are thus inconsistent with those reported by Cromer (1983). Recall that in Cromer's study all of the children with language disorders were able to use a serial construction strategy to replicate the models. Five of 12 children with language disorders, however, could not use an interrupted strategy to copy or build the straw construction. In contrast, all of the NL children and 11 of the deaf children were able to "do at least one task hierarchically" (i.e., using an interrupted strategy). In the present study, only 4 of the 15 children with SLI could replicate the simple straw construction using a serial construction strategy, and there was no difference between SLI and NL groups in their construction scores. In other words, NL children were no more likely to

use a hierarchical, interrupted strategy than children with SLI.

The different levels of performance across the two studies can no doubt be attributed to the 6-year age difference between the subjects in each study. The children with language disorders in Cromer's study had a mean age of 12:6 years, whereas the children with SLI in the present study had a mean age of 6:6 years. The findings in the present study were actually quite consistent with those of Greenfield and Schneider (1977), who found that the typical 6-year-old child was able to replicate the model using a sequential strategy but could not use an interrupted strategy.

Importantly, some NL and SLI children in the present study did use a hierarchical, interrupted strategy. If there is some validity to Cromer's notion of a central hierarchical planning mechanism, one would expect that these children and not others would be able to use hierarchical language structures. Recall, however, that Cromer was careful to make no claims about a direct parallel between language and action. However, he found it difficult to imagine how a severe deficit in hierarchical planning could fail to affect language. In the present study, no significant relationship was found between children's use of multiple clause structures and their performance on the construction tasks. All of the children in the study produced multiple-clause sentences in their samples of expressive language. The children with SLI as well as the NL children who performed the poorest on the construction tasks all used embedded clauses. The one child with SLI who could not replicate even one of the models in any condition produced several examples of clausal embedding in his language sample. In contrast, the two children with SLI who did not produce any examples of clausal embedding in their samples both demonstrated the use of a hierarchical construction strategy. One of these children had the highest overall ranking on the hierarchical construction tasks; the other child had the fourth highest ranking.

Perhaps the children with SLI in the present study did not have a "severe" deficit in hierarchical planning. Given that hierarchical construction strategies first begin to be used by 7 years of age, it would be difficult to find a severe hierarchical planning deficit in 5–7-year-old children. But one should expect to find some relationship between language and performance on the hierarchical construction tasks if a central hierarchical planning mechanism underlies language and nonlanguage structures that contain hierarchical components. No such relationship was found in the present study.

The discrepant findings in the two studies probably are best explained by differences in the severity of the language impairment. Based on the limited information provided about the language abilities of Cromer's subjects, it appears that few if any of them were using multiple-clause structures. In contrast, despite being 6 years younger than Cromer's subjects, all of the children with SLI in the present study had examples of multiple-clause structures. Cromer's subjects thus had a much more severe language impairment than the subjects in the present study.

Given the severity of the language impairment of Cromer's

subjects, it should not be surprising that these children also had significant deficits in other areas as well. The associated perceptual and cognitive limitations of children with SLI have been well documented in the literature (e.g., Johnston, 1988; Kamhi, 1993). That is, children with SLI perform poorly on a wide range of tasks that have some relationship to language. It has also become clear in recent years (Locke, 1994; Powell & Bishop, 1992) that children with SLI also perform poorly on many tasks that are completely unrelated to language learning. For example, Powell and Bishop (1992) found that children with SLI were clumsier than NL peers and performed more poorly than their NL peers on a measure of visual discrimination. Strong correlates of language delay thus exist that do not resemble causes. Locke (1994) argues that "these performance deficits will look like the causes of whatever is running late at the moment, but they are indices of a brain whose development is behind schedule. Red herrings thus coexist with, and may be taken for, contributing factors" (p. 612).

It seems clear there are many problems with the notion that a central hierarchical planning mechanism underlies language and nonlanguage structures that contain hierarchical components and Cromer's more specific claim that children with language disorders suffer from a hierarchical planning disability. At best, a central hierarchical planning mechanism is a macro-level factor that may underlie language and nonlanguage structures early in a child's life before the development of differentiated neural circuits that cause the structure of manual action and language to become more divergent, autonomous, and complex. At worst, the difficulty some children with SLI have performing hierarchical construction tasks is a red herring that some of us have spent much too much time thinking about and periodically chasing over the last 15 years. In either case, the notion of a central hierarchical planning disability is not a useful construct in explaining the various correlates of language disorders or the nature of the developmental language disorder itself.

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