Journal of Psycholinguistic Research, Vol. 7, No. 6, 1978

Some Psychological Relations Between Action and Language Structure

Patricia Marks Greenfield[1] and Michael A. Westerman[2]

Received March 30, 1976

This study investigated the relationship between complex grammatical structures and complex action sequences. A developmental progression of strategies for combining seriated cups identified in an earlier study (Greenfield et al., *1972) was used to demonstrate some psychological consequences of formal parallels between language and action. The role of grammatical complexity and situational structure in language-action relations was explored. The results have implications for understanding the organization and development of complex action, its control by verbal commands, and the basic processes of speech comprehension.*

INTRODUCTION

This study sought to test the psychological effects of possible homology or congruence between certain grammatical structures and specific manipulative strategies identified in an earlier experiment (Greenfield *et al.*, 1972). Its broader purpose was to elucidate characteristics of the relation between language and action.

Greenfield *et al.* (1972) established the existence in children from 11 to 36 months of age of a developmental sequence of three rulebound or consistent

The research was supported by an NIMH grant to Jerome S. Bruner, Director, Center for Cognitive Studies, and a grant from the Milton Fund, Harvard University, to Patricia Greenfield.

[1]Department of Psychology, University of California, Los Angeles, California 90024.
[2]Department of Psychology, University of Southern California, Los Angeles, California 90007.

0090-6905/78/1100-0453$05.00/0

strategies for combining seriated cups. These three action strategies are formally homologous to certain grammatical constructions, and the manipulative strategies appear to be acquired in the same developmental order as the corresponding grammatical structures. The three manipulative strategies are shown in Fig. 1, numbered according to their order of acquisition.

The distinctive feature of strategy 1 is that it involves pairs of cups, one acting or moving and one the stationary recipient of action. Its grammatical analogue is the simple sentence with a single subject and a single object. This structural analogy between language and action is shown in Fig. 2, in terms of the experimental materials used in the present study.

Grammatical relations presented in Fig. 2 are base-structure relations depicted in terms of Fillmore's (1968) case grammar. (Whenever we refer to the sentences in this figure, we shall be analyzing only the sentential complements on the right side of the figure.) Instrument and Location were the two case concepts which seemed to describe the situation most accurately. According to Fillmore, the Instrumental may be an inanimate object causally involved in a state; the acting or moving cup appears to have just such a causal role in our situation. The Locative, states Fillmore, may identify the location of this state; the stationary cup appears to fulfill just this role. In the sentences of Fig. 2, base structure Instruments are expressed as surface structure subjects, while base structure Locations are expressed as prepositional objects. Whether the analysis is done in terms of surface structure or underlying case relations, the important fact is that the grammar expresses a relationship between acting and acted on.

The defining feature of strategy 2, the pot method, is that there are multiple acting cups and a single recipient. Although strategy 2 is composed of a series of strategy 1 moves, strategies describe certain formal properties of

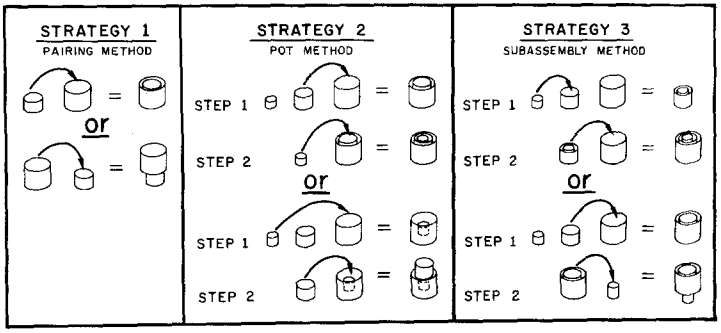

Fig. 1. Developmental sequence of strategies for combining seriated cups.

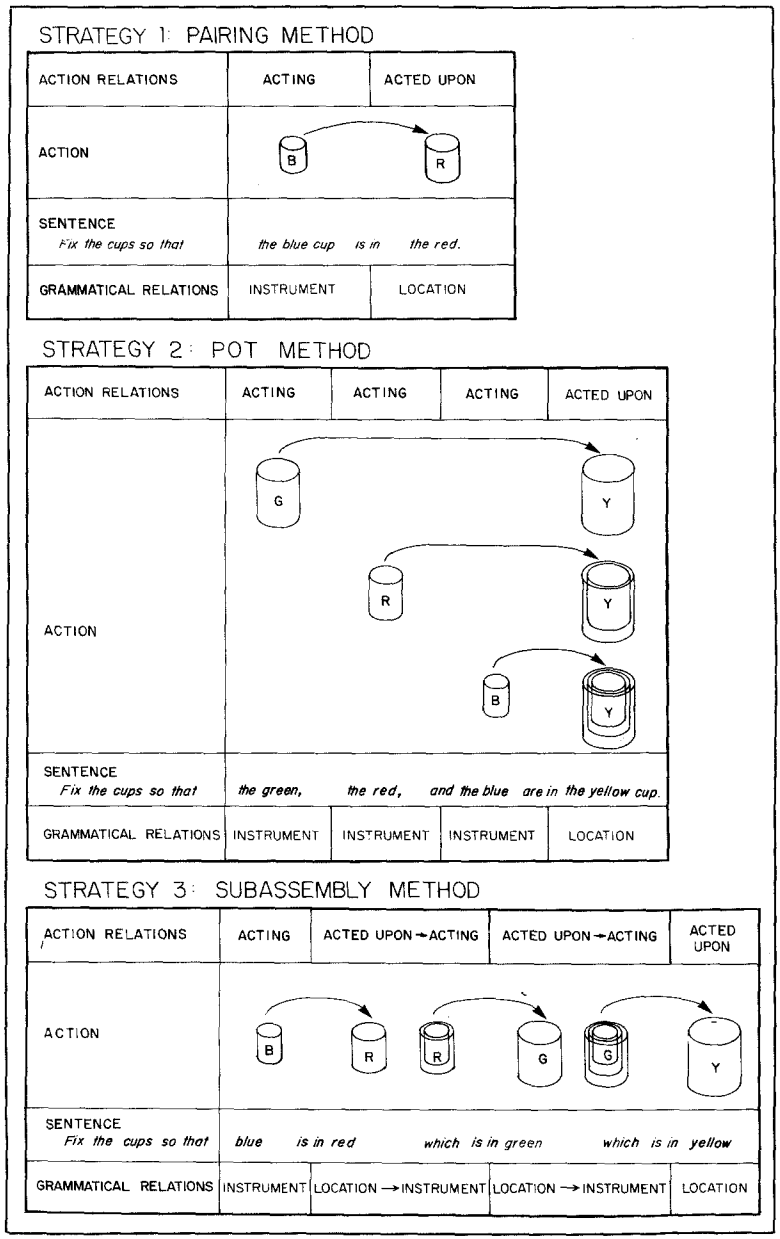

Fig. 2. Parallel structures in action and grammar.

complete sequences of cup combinations rather than individual moves. The grammatical structure corresponding to the pot method includes a sequence of subject-object (or *Instrument-Location*)[3] combinations which share a common object *(Location)*. There are a number of possible sentences which have this characteristic. One is shown at the right side of the middle panel of Fig. 2.

The third strategy is distinguished by the fact that a previously constructed structure consisting of two or more cups is moved *as a unit* into or onto another cup or cup structure. In terms of individual cups, the distinctive feature of this strategy is that the stationary cup that is acted on in the first move becomes acting cup in the third move. In terms of the multi-cup units or subassemblies, the defining feature is that each multi-cup unit functions as a single moving or acting cup. In terms of grammatical analogy, the object *(Location)* of the first clause also functions as the subject *(Instrument)* of the second clause of the sentence complement (last panel of Fig. 2).

But the preceding analysis of the manipulative strategies is nothing more than an analogy unless some direct psychological relation between action strategies and grammatical structures can be demonstrated. This was the motivating problem of the present study.

Two studies by Huttenlocher and her colleagues were critical in the development of our line of experimentation (Huttenlocher and Strauss, 1968; Huttenlocher *et al.*, 1968). These studies were the first to suggest the possibility that the manipulation of concrete objects involves a relation between acting and acted on, that is, active and passive elements, and that the active-passive relation among these real-world objects may be psychologically related to both deep and surface subject-object relations in language. This notion was basic to the language-action homology conceptualized in our earlier study of the development of manipulative strategies. More important for the present experiment, the Huttenlocher work suggested an experimental approach for demonstrating the psychological reality of the hypothesized action-grammar parallels. Huttenlocher and Strauss (1968) demonstrated that correspondence between the grammatical subject in a verbal instruction and the moving element in a concrete manipulation facilitated the action, that is, made reaction times faster. Thus the same manipulation was more difficult under conditions where the moving or "acting" element appeared as object in the command sentence. In this study, the effects of deep- and surface-structure relations were confounded. The second study (Huttenlocher *et al.*, 1968) separated the effects of base and surface grammatical structure and showed that each has an effect on the action. This experiment also showed

[3]The corresponding underlying case relations are presented parenthetically in italics.

that the relation between a subject and the object of a locative preposition in an intransitive sentence yielded the same results as the relation between subject and object in a transitive sentence. The important feature common to both grammatical relationships appears to be a distinction between moving and fixed objects, active and passive roles. When the moving element in the action is encoded by the deep- and surface-structure subject and the fixed element by the deep- and surface-structure object, verbal instructions are carried out faster than when this is not the case. (Note that Huttenlocher's deep subject, a Chomskyan term, would be an Instrument in our case terminology, while her deep object would be a Location.) The implication is that there is a perceived connection between the subject of a sentence and the acting element in a situation, between the object of a sentence and the passive element in a situation. Hence these two studies by Huttenlocher and her colleagues establish the basic correspondences between grammatical roles and action roles demanded by the analysis of strategy 1 portrayed in Fig. 2. The findings of Huttenlocher and her colleagues are evidence for the claim that one type of comprehension response—responding to a command by carrying out a concrete task—is affected by parallels between the structure of the sentence and the structure of the activity.

Although Huttenlocher and her colleagues were working in a Chomskyan grammatical framework, their analysis relates semantic notions to grammar, a recent trend in both linguistics (e.g., Fillmore, 1968; Lakoff, 1968; McCawley, 1968; Ross, 1969) and developmental psycholinguistics (e.g., Schlesinger, 1971; Bowerman, 1973; Brown, 1973; Greenfield and Smith, 1976). We have preferred Fillmore's (1968) case terminology precisely because its semantic basis permits it to describe the action situation in a rather precise way. Semantic notions in grammar introduce the possibility that the basic processes of sentence comprehension depend on real world relationships.

As in these studies, we used the strategy of comparing the action response to instructions varying in their grammatical form. We used instructions of varying grammatical structure to see if each would elicit an action pattern corresponding to one of the two later-developing manipulative strategies identified in the earlier study, the pot method (strategy 2) and the subassembly method (strategy 3). Thus our study extended the investigation of language-action parallels to relationships between *complex* grammatical structures and *sequences* of related actions. The second aspect of our experimental strategy was to vary the structure of the manipulative task while holding constant the grammatical structure of the instructional sentences. We were interested in the role of the task structure in comprehending and responding to a given type of instructional sentence.

We sought to demonstrate that the parallels between complex action

sequences and language structures posited in the developmental study of cup manipulation (Greenfield *et al.*, 1972) were more than an analogy. Our objective was to show that the comprehension of verbal commands to carry out sequential action on objects involves specific interrelations among linguistic structure, action structure, and the structure of the object array. At the level of psycholinguistic theory, the study sought to develop some specific psychological ramifications of generative semantics, a view which sees an intrinsic connection between the linguistic realm and the rest of the speaker's world.

METHOD

Hypotheses and Experimental Materials

A principal hypothesis of the present study was the existence of psychologically real connections between the pot strategy and its corresponding conjoined sentence complement (strategy 2, Fig. 2) and between the subassembly strategy and its corresponding embedded sentence complement (strategy 3, Fig. 2).

The instructional sentences shown in Fig. 2 could also be represented in terms transformationally closer to their underlying structure—as a series of simple sentences whose base structures constitute the sentential components of the conjoined or embedded sentence. Every conjoined or embedded sentence in our experiment was matched with another sentence of this sort, labeled simplex. The more complex members of each pair, such as those presented in Fig. 2, were labeled complex. Figure 3 lays out the six pairs of instructional sentences actually used in the experiment. Each one calls for an action sequence corresponding to either the pot or the subassembly method. Each sequence involves the four distinctly colored nesting cups shown in the figure. Thus our first hypothesis led to the prediction that subjects would in fact respond to the embedded sentences shown in Fig. 3 with the subassembly strategy, whereas they would respond to the conjoined sentences shown in the same figure with the pot strategy.

In the original experiment with seriated cups (Greenfield *et al.*, 1972), it was proposed that the complex version of each type of instructional sentence would bear a closer relation to a sequence of related acts than the simpler sentences, because the transformation of discrete grammatical units into a conjoined or embedded sentence relates separate grammatical elements to each other just as the pot or subassembly method of combining cups relates separate manipulative elements into a structured whole.

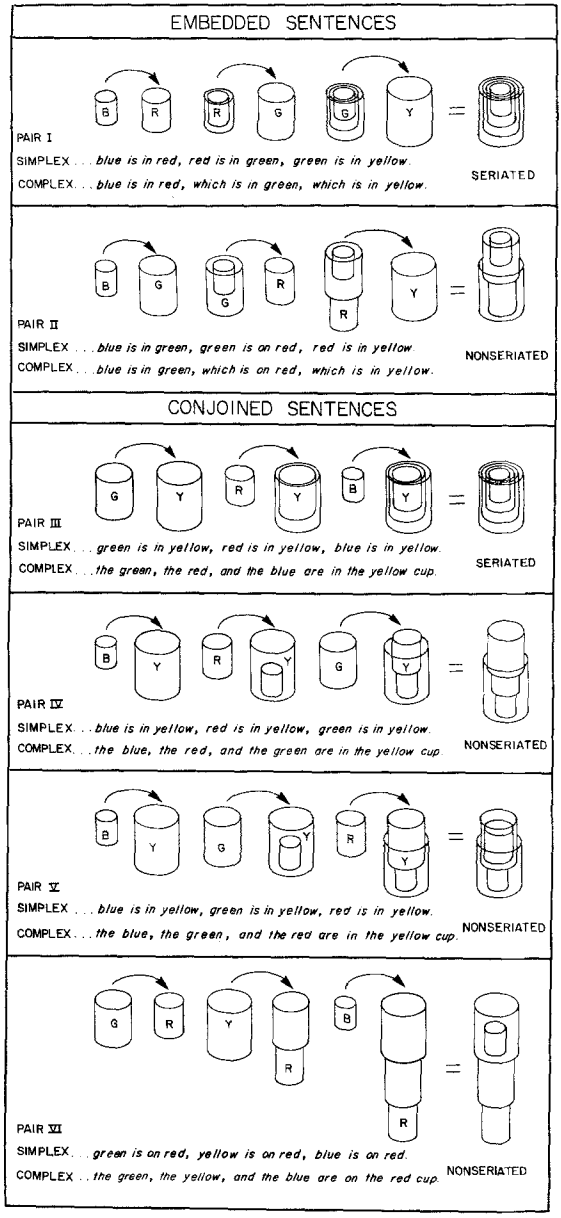

Fig. 3. Instructional sentences and expected manipulative responses.

Let us begin our analysis with the most clear-cut case first—the subassembly strategy—and compare two instructions for using it to build a seriated cup structure. (The identifying numerals and letters correspond to those used in Fig. 3. S, Simplex; C, Complex.)

I-S Fix the cups so that *blue is in red, red is in green, green is in yellow.*

I-C Fix the cups so that *blue is in red, which is in green, which is in yellow.*

In terms of psychological or semantic function, the second version explicitly connects the three discrete acts referred to in the first sentence. In terms of the specific surface-structure differences between the two forms, *which* replaces the second of two identical substantives wherever possible (the color names used to identify the cups). This replacement indicates that the intended referents are the same. This fact of identical referents is called *coreference* and is a condition of the relativization transformation by which relative-clause sentences are formed (Chomsky, 1965; Klima, 1969; McCawley, 1968; Smith, 1969). If we look at the above sentences in isolation from the practical content, we can see that in I-S the second *red* might be a different cup; the relative pronoun *which* in I-C removes this possibility.

A better way of looking at the difference is in terms of our manipulative strategies. The essence of carrying out the subassembly is the double role of the cups—a cup that is acted on becomes the actor in the next move. In the embedded instruction (I-C), this double role of a single cup—red, for example—is linguistically explicit. In the string of simplex sentences (I-S), it is not, for one needs to look to the cup array to know that there is but a single red cup. *Therefore, the hypothesis was that the complex embedded sentences would be more congruent with the subassembly strategy than their simplex counterparts and that they would therefore be easier to process.* Note that this prediction runs counter to the theoretical rationale behind experiments carried out by Miller and his colleagues in the 1960s (e.g., Miller and McKean, 1964); their hypothesis was that processing time is a function of derivational complexity. In a comprehension task, derivational complexity would be the number of transformational steps necessary to recover base structure from superficial structure. In this framework, instructions in the form of simple sentences ought to be more easily processed than a complex version, exactly the opposite of our prediction. Ours was based, in contrast, on the notion that complexity can facilitate comprehension if the grammatical structure in question is congruent with the structure of the referential situation.

Our prediction with respect to the pot strategy was the same. *It was*

hypothesized that complex conjoined sentences would be more congruent with the pot strategy than their simplex counterparts and therefore easier to process. We will use pair III to explain the rationale for this prediction:

III-S Fix the cups so that *green is in yellow, red is in yellow, blue is in yellow.*

III-C Fix the cups so that *the green, the red, and the blue are in the yellow cup.*

(The words *the* and *cup* were added so that III-C would have the same number of words as III-S.) It was hypothesized that III-C would be easier to process than III-S. As in the case of the relative-clause sentence, the complex transformed version explicitly connects the three discrete acts referred to in III-S, presumably facilitating a connected sequence of acts. In terms of specific surface-structure features, the conjoining of subjects results in the deletion of repetitive predicate phrases, thus making the many-to-one relationship between subjects and objects more obvious. This deletion indicates that not only words but also the referents of these predicates are identical. In the simplex version, III-S, there *might* be three yellow cups; one needs to look to the cup array to know. Deletion of the second and third repetitions of *yellow* removes this possibility. Relating this analysis of surface-structure features to the manipulative strategy, we see that the many-to-one relation obtaining between actors and acted-on is the essence of the pot method. The conjoined instructional sentence, III-C, makes this relation linguistically explicit; the string of simplex sentences in III-S does not. Hence it was thought that the complex conjoined sentences would be easier to process than the simplex versions. The basic argument is the same as for the embedded sentences: when coreference is explicit, instructions to use single objects in multiple moves are easier to comprehend.

The meaning of designating the structurally simple member of a pair as conjoined or embedded should be made clear. Not only does each one contain the same underlying sentences as the more complex member of the pair, but also, in terms of the identity relations obtaining among its referents in the experimental situation, these sentences have the potential for entering into a conjoined or embedded structure eligible for the same transformation as their complex pairs. Thus, in III-S above, the fact that *yellow* in the simplex sentence refers to the very same cup in each sentence, because of the constitution of the actual cup array, means that the three propositions could be conjoined and subject to an identical conjunct reduction transformation, yielding the complex member of the pair. That is, *yellow* in fact has the same referent *in this particular situation* even though this state of affairs is not

formally required by the simplex sentence structure. Similarly, in pair I shown above, the fact that *red* refers to the very same cup both times it occurs, as does *green* both times it occurs, means that the three propositions could, *in this particular situation,* be embedded and subjected to a nonrestrictive clause transformation. Again, however, these common referents are not required by the sentence structure itself.

We were interested in the effect of the structure of the materials on action patterns, as well as the effect of the structure of the instructions. The inclusion of nonseriated pairs II, IV, V, and VI (Fig. 3) allowed us further to assess the effect of this variable, although no specific predictions were made. We expected that these sentences would be incongruent with the perceived structure of the materials and that subjects would tend to respond by seriating anyway. We were interested in seeing how this tendency would interact with different types of sentence structure, but made no specific predictions about these interactions. A second reason for including instructions to make nonseriated pairs was to make sure that any relation between sentence structure and action pattern that appeared in the results would have some generality and would not be restricted to the situation where the command was intended to lead to a seriated result.

Subjects

There were 48 subjects (24 men, 24 women), native English-speaking college students. Although the original nesting cup experiment (Greenfield *et al.*, 1972) revealed manipulative strategies in a developmental context, pilot work showed that our experimental paradigm for looking at the relation of these strategies to grammar was not suitable for subjects younger than teenagers. Hence it was decided to study the language-action relations in mature adults.

Procedure

The subjects participated individually in the experiment, seated at a table to the left of the experimenter. The cups of different sizes and colors were on the table, laid out in a square pattern: blue (smallest, outside bottom diameter 27 mm) and yellow (largest, outside bottom diameter 66 mm) formed a row closest to the subject, with green (second largest, outside bottom diameter 57 mm) behind blue, and red (second smallest, outside bottom diameter 42 mm) behind yellow. This layout was as far away from the seriated structure of the cups as possible.

The experimenter told the subject that tape-recorded instructions would explain what to do with the four cups. The subject was also told to follow the instructions as quickly as possible, starting any time after the onset of the command and using only one hand. The experimenter demonstrated six possible ways of combining the cups and told the subject that each way was a correct response to certain sentences he or she would hear. The nonverbal demonstrations served to provide a common set of alternative manipulative methods and cup structures for every sentence heard by every subject in every order. The demonstrations were given in the following order (Roman numerals refer to Fig. 3): IV, II, III, VI, V, I. Following these demonstrations, the subject heard a tape recording of the first of 12 instructional sentences. The onset of each recorded sentence automatically started a Cramer electric timer (1/100 sec) connected to the recorder via a Gerbrands electronic voice key. The timer, hidden from the subject's view, was stopped manually by the experimenter when the subject completed the task. The experimenter then stopped the tape and recorded the time from the onset of the instructions to task completion. The following measures were also recorded: final structure of cups (seriated or nonseriated), method of cup construction (pot or subassembly), any errors in following instructions, and cup orientation. (Method and structure could then be scored for correctness in accord with the norms presented in Fig. 3.) Because the subassembly method turned out to be the prepotent response to the cups, the source of any deviation away from the subassembly in the direction of the pot strategy was of interest, and all such deviations were classified together. Thus, for purposes of analysis, mixed strategies were classified with the pot method. The task was set up so that subjects could begin carrying out the instructions at any point after their onset because this procedure simulates the reality of following verbal directions. It was thought that the structure of some sentences might give subjects enough information to start working with the cups before the sentence was finished, and that the resultant variability in action starting point might be an important manifestation of processing differences for different types of instructional sentences. Task time rather than reaction time was used as a measure of cognitive processing, because processing could continue during the task itself.

The experimenter replaced the cups in their original position and repeated the procedure, playing a second instructional sentence. Each sentence began "Fix the cups so that . . . ." The grammatically subordinate part of the sentence was what varied. Every subject heard the 12 different instructions for manipulating the cups depicted in Fig. 3. As can be seen from the figure, each sentence contained the same number of syllables as every other. Each sentence was also recorded to last the same length of time (within 1/10 sec).

Experimental Design and Statistical Analysis

Each subject heard all the simplex sentences in one block of six and all the complex sentences in another block of six. Half the subjects (24) heard simplex sentences first and half the subjects (24) heard complex sentences first. The use of blocks prevented the change *per se* from simplex to complex (or *vice versa*) from confounding the results in an indeterminate way.

The blocks were arranged in 12 different orders, constructed by taking one basic order—pairs IV, II, III, VI, V, I (the numbering corresponds to Fig. 3)—and its reverse—pairs I, V, VI, III, II, IV—and generating a Latin square from each. A given subject heard both simplex and complex sentences in the same order. In this way, each block of six sentences (simplex or complex) was balanced not only for ordinal position but also for sentence context, because each sentence was preceded and followed by each of the five other sentences an equal number of times.

Each order was heard by four subjects, two hearing the simplex sentences first, two hearing the complex sentences first. One of the two was always male, the other always female.

The basic statistical analysis was an analysis of variance with two between-subject variables and three within-subject variables. The analysis used a fixed-effects model with random sampling of subjects. Unweighted means were used to adjust for unequal cells. The between-subject variables were order of blocks and order of sentences within each block. The effect of these variables was of no particular theoretical interest. The within-subject variables constituted a description of the 12 sentences in terms of three dichotomous variables:

1. Conjoined vs. embedded sentence structure.
2. Simplex vs. complex sentence structure.
3. Seriated vs. nonseriated description of cup structure.

This classification is shown graphically in Fig. 3. These three variables constituted the theoretical center of the experiment. An analysis of variance was done for each of the dependent measures already described. Subsequent to the analyses of variance, the response to every sentence was compared with the response to every other sentence by means of matched-pairs t tests. All analyses were carried out by computer using the Datatext program.

RESULTS

Conjoined vs. Embedded Sentence Structure

Our first hypothesis was tested by seeing whether conjoined instructional sentences elicited the pot strategy while embedded sentences elicited the subassembly strategy. The results show that pairs I and II (Fig. 3), the sentences with embedded complements, elicited the subassembly strategy with great regularity. There was no similar uniformity for sentences with conjoined complements. The pot and subassembly methods both appear with at least some degree of frequency as responses to each of the eight sentences (pairs III-VI, Fig. 3). In addition, mixed strategies employing both pot and subassembly elements were observed. Still, the results of an analysis of variance on data from all six sentence pairs showed that the conjoined base structures (both simplex and complex) elicited the pot method (including mixed strategies) significantly more often (58.0%) than the embedded structures (5.7%). (For purposes of analysis, mixed strategies were classified with the pot method unless otherwise noted.) This main effect was significant below the 0.001 level ($F = 169.98$, df = 1, 24). Thus embedded sentence structure has a specific psychological relationship to the subassembly strategy in manipulative behavior, while conjoined sentence structure has a definite, if weaker, psychological relationship to the pot strategy.

The association of conjoined sentence structure with the pot strategy and embedded sentence structure with the subassembly strategy confirms our most basic hypothesis concerning the psychological reality of formal parallels between action and grammar. Our adult data indicate that the pot and subassembly action strategies identified in children by Greenfield *et al.* (1972) are psychologically, as well as formally, connected to conjoined and embedded grammatical structures, respectively. Although the hypothesis is basically confirmed, there are moderating factors which elucidate the nature of the relationship. These will be taken up in the next sections.

Simplex vs. Complex Sentence Structure: Embedded Sentences

Time required to carry out instructions was investigated by an analysis of variance for the two simplex and two complex embedded sentences (pairs I and II, Fig. 3). Complexity of sentence structure did not produce a statistically significant main effect on task time for these sentences. The interaction between complexity of sentence structure and described cup structure was, however, significant ($F = 5.59$, df = 1, 24, $p < 0.027$). Table I shows the

Table I. Mean Number of Seconds to Construct Seriated and Nonseriated Cup Structures Under Verbal Instructions Differing in Grammatical Form

	Complexity of sentence complement	
Cup structure required	Simplex	Complex
Nonseriated	7.90	7.57 $p < 0.037$
Seriated	6.87	7.01 n.s.

nature of this interaction. We see that, among the instructions calling for nonseriated cup structures (pair II, Fig. 3), the complex sentence produced significantly faster cup manipulation than its simplex counterpart, as predicted. A t test for matched pairs indicated that this time difference (mean = 0.33 sec) was statistically significant ($t = 2.16$, df = 47, $p < 0.037$). The time difference (in the opposite direction) for seriated structures was not statistically significant, so we interpret the times as equivalent. It seems justified to conclude from these results that relative-clause structure facilitates the manipulative sequence when the instructions violate the "natural" or obvious (in this case, seriated) structure of the materials. Under these circumstances, the surface-structure cues to cup identity (contained in the coreferential property of *which*) appear to help the subject follow the instructions quickly. When the instructions conform to the "natural" structure of the materials by calling for a seriated construction, however, relative-clause embedding has no discernible effect. Apparently, when the instructions call for a seriated structure, the cues from the cups themselves make explicit verbal cues to cup identity superfluous, as shown by the greater speed with which instructions to seriate the cups are followed no matter what the grammatical form ($F = 49.61$, df = 1, 24, $p < 0.001$). Although we did not predict this differential effect of the relative-clause structure according to whether instructions called for a seriated cup structure or not, it fits well with the rationale behind the basic prediction. That was that the replacement of the redundant substantives in a sentence like "Fix the cups so that blue is in red, red is in green, green is in yellow" with the relative pronouns *which* should facilitate the required action sequence by making explicit the identity relationship obtaining between the referents of each pair of substantives. That is, in the instructions *Fix the cups so that blue is in red, which is in green, which is in yellow,* the coreferential property of the relative pronouns *which* makes it linguistically explicit that the very same red cup that has just been acted on is to become the acting cup in the next move. It might well be that such cues would make

a contribution to action only under circumstances where the required sequence of action was uncertain. We can hypothesize that such uncertainty is introduced when instructions call for a construction that violates the seriated structure of the cups. Only under these conditions, therefore, would we expect a transformed relative-clause structure to facilitate the subassembly strategy, and this is exactly what our results show to be the case. Thus the effect of the grammatical form of instructions on object manipulation depends not only on the structure of the action but also on the structure of the objects. With this qualification, the results confirm our second hypothesis: that, because of greater congruence with the subassembly method, complex embedded instructions will be processed more easily than simplex.

Simplex vs. Complex Sentence Structure: Conjoined Sentences

Because conjoined sentences elicited subassembly responses as well as pot strategy responses, data on task time could not be used to test our hypothesis that congruence with the pot method would be greater for complex conjoined sentences than for their simplex counterparts. The qualitative data on type of strategy were therefore used to test this hypothesis. In fact, the results were contrary to our hypothesis: the simplex sentences usually elicited the pot strategy (74.7% of the time), whereas the complex did not (41.3% of the time). This difference comes out in the analysis of variance as a significant interaction between type of sentence structure (conjoined vs. embedded) and sentence complexity ($F = 33.65$, df = 1, 24, $p < 0.001$). Thus simplex conjoined sentences are more closely associated with the pot strategy than their complex counterparts, a fact which disconfirms our third hypothesis.

Although this difference in type of strategy according to complexity of form runs counter to our prediction, it makes sense in the total context of the results. Given the fact that the subassembly method was the dominant strategy overall, it seems reasonable to take it as the prepotent manipulative response to the cups in the absence of any verbal instructions (and despite the four initial demonstrations of the pot method). If this is the case, then insofar as conjoined instructions implicate the pot strategy, the subject is faced with an ambiguous situation, a conflict between the pot and subassembly methods. The more easily the conjoined instructions can be reconciled with the subassembly strategy, the less likely the ambiguity will be resolved by using the pot strategy. Our argument is that, relative to the simplex conjoined instructions, the complex conjoined sentences can be more easily reconciled with the prepotent subassembly strategy. Hence the ambiguity concerning

method is more frequently decided in favor of the subassembly strategy when the conjoined instructions are complex in form than when they are simplex in form. Let us look at a pair of conjoined sentences (V) to understand why this is so. Comparing the two sentences–*Fix the cups so that blue is in yellow, green is in yellow, red is in yellow* vs. *Fix the cups so that the blue, the red, and the green are in the yellow cup*–we see that the conjunction transformation results in less explicit information about method. Gone is the complete description of every manipulative step, because references to the recipients of the first two acting cups have been deleted. While, on the one hand, it is possible to interpret this conjoined instruction as requiring the same series of steps as its simplex counterpart, it is also possible to interpret it as requiring the simultaneous or grouped placement of the three smaller cups in the largest without specifying *how* this will be done. This interpretation is consonant with the prepotent manipulative strategy, the subassembly method, the last step of which involves placing three cups *as a group* in a fourth cup. Thus one of two possible interpretations of the complex conjoined instructions would be consonant with using the prepotent subassembly method, and the subassembly strategy is in fact used more than half of the time (58.7%). The cues for using the pot strategy as a means are relatively stronger in the simplex form of the conjoined instructions: the sentence *Fix the cups so that blue is in yellow, green is in yellow, and red is in yellow* implies that the blue, the green, and the red cups are to be placed in the yellow cup one at a time because the recipient cup–yellow–is repeated three separate times. Hence it is not surprising that the pot method is used in response to these sentences 74.7% of the time. This result reflects the influence of the homology that we have referred to as the pairing method (strategy 1, Fig. 2): subjects tend to act in such a way as to make each acting-acted on relationship among the cups correspond to a subject-object (or Instrument-Location) relationship in the instructional sentence. Thus this basic language-action congruence holds for a squence of acts as well as for a single move. The fact that the pot strategy is not used 100% of the time must relate to the ambiguity as to action introduced by the prepotence of the subassembly method as a way of manipulating seriated cups.

Conformity of conjoined instructions to the structure of the materials seemed to affect the language-action relations by altering the ambiguity of the instructions. Sometimes an interpretation of conjoined instructions as calling for the pot strategy produces a seriated structure (pair III, Fig. 3), and is thus in harmony with the prepotent structure or end state of the cups. Sometimes the pot strategy interpretation produces a nonseriated structure (pairs IV, V,

and VI, Fig 3) and is thus in conflict with the structure of the materials. Thus to interpret these pairs of conjoined instructions as calling for the pot strategy creates an ambiguous or conflictive situation. One possible resolution is to take the interpretation of conjoined sentences as describing nothing more than an unordered group of acting cups and a particular recipient and use the subassembly method to produce seriated structures. If this reasoning is correct, then we would expect those conjoined sentences intended to produce seriated structures (pair III) to elicit the pot strategy more frequently than those intended to elicit nonseriated structures (pairs IV, V, VI). Our results are in accord with this *post hoc* expectation: the two sentences of pair III triggered the pot method an average of 67.7% of the time, whereas the sentences of pairs IV, V, and VI triggered the pot method only 48.3% of the time. (This effect emerges from the analysis of variance of strategy responses as a significant interaction between type of sentence structure and described cup structure, $F = 28.37$, df = 1, 24, $p < 0.001$.) This effect demonstrates the influence of the materials on the way a sentence is interpreted. Thus perceived structure of materials, as well as prepotent action strategy, can generate alternative interpretations of a sentence, reducing the effect on performance of the language-action homology.

The structure described by pair VI is unique. Analysis of the responses to this pair of sentences in comparison with IV and V gives important information about the action implications of conjoined sentence structure. We have hypothesized that conjoined sentence structure basically specifies an unordered group of acting cups and a particular recipient, and this basic feature becomes more pronounced after the conjunct deletion transformation. As long as the large yellow cup is specified as the common recipient, this basic psychological aspect of conjoined sentences would be compatible with the creation of seriated cup structures. Pair VI is the only one in which the recipient cup is not the largest (yellow) cup. If conjoined sentence structure expresses a relationship between acting and acted on, while not specifying the relationship among the acting elements themselves, then we would expect this pair of sentences to result in nonseriated structures more often than IV and V, stemming from placement of the smaller red cup as the common recipient. This is precisely what our results show. Matched-pairs t tests show that VI-S results in significantly more nonseriated structures (97.9%) than IV-S (58.3%) or V-S (52.1%), while VI-C results in significantly more (100%) than IV-C (6.2%) or V-C (35.4%). The probability of each of these differences occurring by chance is less than 0.001 ($t = 5.55$, 6.31, 26.55, and 9.26, respectively; df = 47). What is more, the modal structure for VI-C is a seriated nest of cups placed on top of the middle-sized red one. This modal structure reflects the influence of the seriated structure of the materials while maintaining the

contrast between moving and stationary cups, an expression of the many-to-one relationship inherent in conjoined subjects and a single object.

Finally, the influence of the seriated structure of the materials (and the dominant subassembly strategy) is clearly stronger than the brute serial order in which cups are mentioned. Our results show that order of mention is often disregarded in the conjoined pairs of sentences, as when pairs IV and V (Fig. 3) are seriated by the subassembly method. Indeed, the majority of subjects adopt this approach, thus picking up the moving cups in an order different from order of mention in the instructional sentences.

DISCUSSION

Our results show a homologous relationship between two grammatical structures and two strategies of sequential action. A conjoined series of subject-object (or *Instrument-Location*) relations with different subjects (or *Instruments*) and a single object (or *Location*) corresponds to the pot strategy: multiple moving cups and a single stationary one. A relative-clause structure in which the Location of the first clause becomes the Instrument of the next corresponds to the subassembly method, where the Location of one manipulation becomes the Instrument in the next.

It is of theoretical importance that the grammatical homologies to the pot and subassembly strategies are not merely a linear series of grammatical relations, just as the action strategies are not merely a series of discrete moves. More importantly, the linguistic parallels also derive from the structured way in which individual Instrument-Location relations are unified into a single grammatical structure.

In terms of the comprehension process, however, both how a given command is comprehended and how long this process takes are affected by the interrelations of one's perception of the reference situation, the grammatical representation of action, and the set of action strategies at the subject's disposal. For seriated materials, the basic congruity is between embedded sentences and the subassembly method. Because of its unsuitability to the physical structure of the materials and the subject's derived plan of action, conjoined instructions were acted on with greater variability than a relative-clause description—even though both the pot strategy and conjoined grammatical structures occur first in development (Greenfield *et al.*, 1972). Conjoined sentences are, moreover, simpler than relative-clause sentences in terms of derivational history. Thus the transformationally more complex form is psychologically simpler in this situation. Our explanation for this paradox is

that relative-clause sentences were processed with the greatest uniformity because of their suitability for manipulating these particular materials. It seems likely that appropriate materials to demonstrate an action strategy congruent with the complex conjoined structure would have a many-to-one structure–for instance, three small beads and a large cup. The beads could then be gathered up as an unordered group and placed in the cup in response to a sentence like *Fix it so that the blue, red, and green beads are in the yellow cup.* The seriated structure of the cups, of course, precluded this response to the complex conjoined sentences in the present study.

Other results show that the effect of transformational complexity depends on its interaction with the structure of the situation in action and perception. More specifically, the psychological effect of linguistic transformation depends on the specific information that is added to or subtracted from the surface structure–the surface-base relationship–and whether that information is needed in the situation at hand. Thus an embedding transformation facilitated the subassembly strategy, but only when instructions required a structure contrary to the intrinsic structure of the cups. The conjunction transformation had quite a different psychological effect. It changed the dominant interpretation of the instructions from pot to subassembly strategy. It appears that, for simplex forms having a repeated predicate, conjunction is interpreted in terms of a group of individual Instrument-Location acts, resulting in the pot strategy. For complex forms, in contrast, it appears that conjunction is interpreted in terms of Instrument grouping, actualized in the last step of the subassembly where three cups are placed as a group in or on a fourth cup.

These contrasting interpretations of the two forms of conjoined sentence constitute evidence that the transformation of conjunction-reduction changes meaning. In her article, "On the requirement that transformations preserve meaning," Partee (1971) states that this particular transformation does preserve meaning unless quantifiers are involved. Our results show that this is not necessarily the case even where, as in our situation, there is no quantifier. The difference between our findings and the examples of Partee and others reflects a difference in the referential or semantic/pragmatic context of the sentences. The implication of this discrepancy is that linguistic rules about a particular type of sentence must be defined relative to the structure of specific semantic/pragmatic contexts in which the sentence type may occur.

Our results add evidence of a new sort to the growing body of fact and theory that states that sentences are understood in reference to a context, either linguistic or nonlinguistic (e.g., Bever, 1970; Carswell and Rommetveit, 1971; Clark, 1974; Wason, 1971). In our experiments, there was evidence that

instructions are always comprehended or interpreted relative to a *prior perceptual encoding* of the cups as containers having a *seriated size structure.* Derived from this encoding is a *plan for ordering* acts such that the cups end up one inside the other in serial order. In our experiment, this plan for the serial ordering of action seemed to be to start with the smallest and proceed in order of size, using the subassembly method (Fig. 1).

When instructions are *congruent* with this plan (pair I, Fig. 3), comprehension and action are speedy and uniform, and the particular syntactic form in which the instructions are put makes no difference (I-S vs. I-C). This latter result suggests that at least some syntactic cues are being bypassed and that the sentences are, to a considerable extent, being comprehended on the basis of the person's prior structuring of the extralinguistic situation—in this case, his or her plan for the sequential manipulations of the cups. This effect of the situational structure on the comprehension process has been identified as a general comprehension strategy by Bever (1970). Smith (1970) and Huttenlocher and Wiener (1972) have made similar suggestions. The fact that the same sentence structure (conjoined) was interpreted differently (pot or subassembly strategy) depending on whether it called for a seriated cup structure or not indicates that context does not just influence language use after comprehension has taken place; it is part of the comprehension process itself. This conclusion is in line with the generative semantic view that the presuppositional or contextual structure is part of the base grammatical structure of sentences.

It seems possible that prior situational context can cause an alternative grammatical interpretation of an ambiguous sentence to be bypassed in similar fashion (Carey *et al.,* 1970). In fact, our study extends the notion of ambiguity to the processing of ordinary sentences by defining nonverbal sources of ambiguity; it finds systematic effects of such ambiguity on the interpretation of ordinary sentences. We thus have positive evidence supporting Garrett's (1970) assertion that "normal sentence processing routines must deal routinely with ambiguity" (p. 49).

When instructions demand action incongruent with a prior or presumed perceptual structure or its derived plan of action, for example, when embedded sentences call for a nonseriated cup structure (pair II), subjects must act in a way congruent with the instructions but incongruent with their plan of action. This idea is closely related to Clark's (1974) application of the congruence notion in a wide variety of comprehension situations. The more explicit the linguistic cues available, the faster is this process of achieving congruence and carrying out the unexpected action—in this case, constructing a nonseriated edifice, even if such clues are provided by a sentence having a

longer transformational history in linguistic terms. Thus the identity cues provided by the relative pronoun *which* facilitated complying with instructions to construct a nonseriated edifice by the subassembly method (sentence II-C, Fig. 3) relative to its pair consisting of the same basic sentences arranged in a simple string (II-S, Fig. 3). The relative pronouns link one move to the next; hence they seem to provide a mechanism by which a syntactic device can transform separate acts into a unified sequence. This hypothesized process of hierarchical integration looks like an important way in which language can perform an organizing role in the sphere of nonverbal action.

Order of mention cannot perform this unifying function, for order of mention expresses only a linear chaining relationship among parts. Subjects completely ignored order of mention in responding to some of the conjoined pairs. This finding shows empirically that order of mention in a sentence does not necessarily control order of action for adults, although it may for young children (Clark, 1971).

In conclusion, the existence of psychological connections between language structures and sequential action patterns has been demonstrated for one situation—the manipulation of seriated cups. Whether or not these homologies are best represented by simple or complex grammatical forms depends on the fit between a particular action/situational structure and a particular grammatical form; the structure of the referential situation affects the psychological function of a given grammatical form. Although more complicated than anticipated, our results suggest that structural parallels between language and complex action sequences are not just analogies but have a firm psychological basis. Thus it seems that understanding the structured cognitive capacities common to both language and action may provide insight not only into the organization and development of complex action but also into basic processes of speech comprehension.

ACKNOWLEDGMENTS

The authors would like to thank the following people for their invaluable help: Eric Wanner, Department of Psychology, Harvard University, who played an important role in the experimental design and statistical analysis; Eve Clark, Committee on Linguistics and Herbert Clark, Department of Psychology, Stanford University, who criticized an earlier draft of this article; Paul Holland, Department of Statistics, Harvard University, who gave valuable advice concerning the treatment of binary data in analysis of variance; David Eaglesfield, who made the translation from our experimental

design to the capabilities and requirements of the Datatext computer program; Bernice Laufer, who skillfully ran the subjects; and Marcia Nelson and Sandra Sullaway, who typed the manuscript with insight and good humor.

REFERENCES

Bever, T. G. (1970). The cognitive basis for linguistic structures. In Hayes, J. R. (ed.), *Cognition and the Development of Language,* Wiley, New York, pp. 279-372.

Bowerman, M. F. (1973). *Early Syntactic Development: A Cross-Linguistic Study of Early Syntactic Development with Special Reference to Finnish,* Cambridge University Press, Cambridge.

Brown, R. (1973). *A First Language: The Early Stages,* Harvard University, Cambridge, Mass.

Carey, P. W., Mehler, J., and Bever, T. G. (1970). When do we compute all the interpretations of an ambiguous sentence? In Flores d'Arcais, G. B., and Levelt, W. J. M. (eds.), *Advances in Psycholinguistics,* North-Holland, Amsterdam, pp. 61-75.

Carswell, E. A., and Rommetveit, R. (eds.) (1971). *Social Contexts of Messages,* Academic Press, New York.

Chomsky, N. (1965). *Aspects of the Theory of Syntax,* MIT Press, Cambridge, Mass.

Clark, E. V. (1971). On the acquisition of the meaning of *before* and *after. J. Verb. Learn. Verb. Behav.* **10**:266-275.

Clark, H. H. (1974). Semantics and comprehension. In Sebeok, T. A. (ed.), *Current Trends in Linguistics,* Vol. 12: *Linguistics and Adjacent Arts and Sciences,* Mouton, The Hague.

Fillmore, C. J. (1968). The case for case. In Bach, E., and Harms, R. T. (eds.), *Universals in Linguistic Theory,* Holt, Rinehart and Winston, New York, pp. 1-90.

Garrett, M. F. (1970). Does ambiguity complicate the perception of sentences? In Flores d'Arcais, G. B., and Levelt, W. J. M. (eds.), *Advances in Psycholinguistics,* North-Holland, Amsterdam, pp. 48-60.

Greenfield, P. M., and Smith, J. (1976). *The Structure of Communication in Early Language Development,* Academic Press, New York.

Greenfield, P. M., Nelson, K., and Saltzman, E. (1972). The development of rule bound strategies for manipulating seriated cups: A parallel between action and grammar. *Cogn. Psychol.* 3:291-310.

Huttenlocher, J., and Strauss, S. (1968). Comprehension and a statement's relation to the situation it describes. *J. Verb. Learn. Verb. Behav.* 7:300-304.

Huttenlocher, J., and Weiner, S. L. (1972). Comprehension of instructions in varying contexts. *Cogn. Psychol.* 2:369-385.

Huttenlocher, J., Eisenberg, K., and Strauss, S. (1968). Comprehension relation between perceived actor and logical subject. *J. Verb. Learn. Verb. Behav.* 7:527-530.

Huttenlocher, J., Higgins, E. T., Milligan, C., and Kaufman, B. (1970). The mystery of the "negative equative" construction. *J. Verb. Learn. Verb. Behav.* 9:334-341.

Klima, E. S. (1969). Relatedness between grammatical systems. In Reibel, D. A., and Shane, S. A. (eds.), *Modern Studies in English: Readings in Transformational Grammar,* Prentice-Hall, Englewood Cliffs, N.J., pp. 227-246.

Lakoff, G. (1968). Instrumental adverbs. *Found. Lang.* 4:4-29.

McCawley, J. D. (1968). The role of semantics in grammar. In Bach, E., and Harms, R. T. (eds.), *Universals in Linguistic Theory,* Holt, Rinehart and Winston, New York.

Miller, G. A., and McKean, K. O. (1964). A chronometric study of some relations between sentences. *Quart. J. Exp. Psychol.* **16**:297-308.

Partee, B. H. (1971). On the requirement that transformations preserve meaning. In Fillmore, C. J., and Langendoen, D. T. (eds.), *Studies in Linguistic Semantics,* Holt, Rinehart and Winston, New York.

Ross, J. R. (1969). Adjectives as noun phrases. In Reibel, D. A., and Shane, S. A. (eds.), *Modern Studies in English: Readings in Transformational Grammer,* Prentice-Hall, Englewood Cliffs, N.J., pp. 352-360.

Schlesinger, I. M. (1971). Learning of grammar: From pivot to realization rule. In Huxley, R., and Ingram, E. (eds.), *Studies in Language Acquisition: Methods and Models,* Academic Press, London, pp. 79-89.

Smith, C. S. (1969). Determiners and relative clauses in a generative grammar of English. In Reibel, D. A., and Shane, S. A. (eds.), *Modern Studies in English: Readings in Transformational Grammar,* Prentice-Hall, Englewood Cliffs, N. J., pp. 247-263.

Smith, C. S. (1970). An experimental approach to children's linguistic competance. In Hayes, J. R., (ed.), *Cognition and the Development of Language,* Wiley, New York, pp. 10-135.

Wason, P. (1971). In real life negatives are false. *Commun. Cogn.* **4**:239-253.