VI. RESULTS: KANZI AND ALIA'S PERFORMANCE ON DIFFERENT SENTENCE STRUCTURES

ALL SENTENCE TYPES

Kanzi and Alia's overall scores are presented in Table 5; these are shown broken down by sentence type in Table 6. Overall, Kanzi was correct on 72% of all trials and 74% of the blind ones. Alia was correct on 66% of all trials and 65% of the blind ones. (Table 6 gives the number of trials for each sentence type.) The overall high performance level of both subjects provided strong evidence of their ability to comprehend most sentence types and subtypes. This comprehension ability was independent of the semantic content of any given utterance since subjects responded correctly to all sentence types and subtypes, representing a wide range of novel utterances, on their initial presentation.

PERFORMANCE BY SENTENCE TYPE

The odds that any single sentence would be responded to correctly by chance are extremely low as an error could be made in selecting the appropriate object *A*, the appropriate object *B*, the appropriate action, the appropriate location, and the appropriate recipient, all of which were represented by multiple exemplars. It was also possible to misconstrue the intended relation between the words themselves. Even in object-location sentences, if a mean of seven objects and six locations is assumed, the probability of getting any such sentence correct by chance is 2.4%. The probability of being correct on other sentence types would be less as the potential for error is higher. The possibility that, with each trial represented by different tokens, either subject would be correct on a majority of sentence types by chance approaches zero.

Whenever data consist of counts organized in contingency tables, as is

TABLE 5

OVERALL PROPORTIONS OF DIFFERENT RESPONSE CODES OBTAINED BY KANZI AND ALIA

	KANZI				ALIA			
	All Trials		Blind Trials		All Trials		Blind Trials	
RESPONSE	*N*	%	*N*	%	*N*	%	*N*	%
C	369	57	246	59	319	54	220	54
C1	11	2	10	2	20	3	18	4
C2	36	6	16	4	32	6	16	4
C3	34	5	21	5	13	2	9	2
C4	8	1	7	2	7	1	4	1
C5	9	1	7	2	0	0	0	0
Total correct	467	72	307	74	391	66	267	65
PC	153	23	87	21	124	21	84	21
OE	6	1	5	1	20	3	17	4
I	9	1	8	2	9	2	7	2
W	8	1	4	1	32	6	24	6
NR	10	2	4	1	11	2	8	2
Total wrong	186	28	108	26	196	34	140	35
Overall total	653	100	415	100	587	100	407	100

NOTE.—Kanzi had seven mistrials, and Alia had two mistrials. Percentages are rounded to the nearest whole number.

the case here, log-linear analyses are recommended (Bishop, Fienberg, & Holland, 1975; Fienberg, 1980; Knoke & Burke, 1980; see also Bakeman, Adamson, & Strisik, 1989; Green, 1988; Tabachnick & Fidell, 1989, chap. 7). Similar in some ways to analyses of variance, these techniques are not as familiar to most psychologists (but see Cohn & Tronick, 1987; and Stevenson, Ver Hoeve, Roach, & Leavitt, 1986), so some general comments are in order. The analysis is called asymmetric, instead of symmetric, when independent and dependent variables are distinguished as they are for the present study; in such cases, the analysis of variance analogy is particularly apt (Kennedy, 1983). For the present analyses, the dependent variable is the response categorized as correct versus not correct; this forms one dimension of a contingency table. Other variables, such as condition or sentence type, form the other dimensions. The analysis proceeds hierarchically, beginning with the most complex model and successively removing terms. Terms are identified with the interactive and main effects of the independent on the dependent variables. Each model generates expected frequencies for the cells of the contingency table; thus, the goodness of fit for each model can be assessed, usually with the log-likelihood chi-square statistic or G^2. One goal of the analysis is to find the least complex model that fits the

TABLE 6

PROPORTION OF RESPONSES TO DIFFERENT SENTENCE TYPES CODED CORRECT FOR KANZI AND ALIA

Sentence Type	Kanzi Count	Kanzi % Correct	Kanzi Adjusted Residual[a]	Alia Count	Alia % Correct	Alia Adjusted Residual[a]
All trials:						
1A	80/126	64	−1.4	88/123	72	1.4
1B	36/49	74	.1	31/43	72	−.1
2A	56/69	81	.0	47/58	81	−.0
2B	7/21	33	−1.6	12/21	57	1.6
2C	16/18	89	.2	13/15	87	−.2
2D	61/86	71	1.5	45/75	60	−1.5
3	56/80	70	.6	41/63	65	−.6
4	10/16	63	−1.3	11/13	85	1.3
5A	64/85	75	.9	55/80	69	−.9
5B[b]	40/47	85	3.5	23/45	51	−3.5
5C[b]	27/35	77	2.2	16/31	52	−2.2
6	7/10	70	.5	6/10	60	−.5
7	7/11	64	1.5	3/10	30	−1.5
Blind trials only:						
1A	39/62	63	−1.3	47/64	73	1.3
1B	13/17	77	.4	12/17	71	−.4
2A	36/46	78	−.7	36/43	84	.7
2B	7/19	37	−1.3	12/21	57	1.3
2C	10/11	91	.0	10/11	91	.0
2D	37/49	76	1.6	31/51	61	−1.6
3	40/49	82	2.0	25/40	63	−2.0
4	8/12	67	−.9	10/12	83	.9
5A	45/58	78	.8	42/59	71	−.8
5B[b]	32/39	82	3.4	18/40	45	−3.4
5C[b]	27/35	77	2.2	16/31	52	−2.2
6	6/9	67	.5	5/9	56	−.5
7	7/9	78	1.9	3/9	33	−1.9

[a] The adjusted residuals in the table derive from an analysis of 2 × 2 frequency tables (Alia vs. Kanzi, correct or not, for each sentence type for both all and blind trials only, for a total of 52 tables). For 2 × 2 tables, adjusted residuals (a term used in the log-linear literature) are identical to the square root of the more familiar chi square; thus, for 2 × 2 tables, all four adjusted residuals are identical except for sign. Assuming independence of samples, adjusted residuals greater than 1.96 absolute should occur less than 5% of the time if the percentage correct is truly not different for Kanzi and Alia for a given sentence type.

[b] Kanzi > Alia.

observed data. Interactions and main effects are said to be significant if the terms associated with those effects are required for a model to fit. As for analysis of variance, interpretation focuses on any significant interactions, not on their component parts, because the interaction identifies significant conditional relations among the variables.

The performance of both subjects across the different sentence types is shown in Table 6. Hierarchical log-linear analyses (see Bakeman et al., 1989) were used to determine which sentence types elicited better performance from Kanzi, which did so from Alia, and whether Kanzi performed significantly better than Alia overall. The 2 × 2 × 11 × 2 contingency table included condition (blind vs. nonblind) × subject (Kanzi vs. Alia) × sentence type (11 types) × response (correct vs. not correct). All C codes were counted as "correct"; all others, including "partly correct," were counted as errors. The number of sentence types was reduced to 11: type 6 sentences were not included in this analysis because of the small *N*, and type 7 sentences were dropped since they represented such a variety of different kinds.

The four-way interaction terms involving condition were not significant (i.e., were not required for a fitting model); thus, we conclude that the pattern of results was essentially the same for both blind and nonblind trials (likelihood ratio of $G^2[110]$ of 7.81, $p = .640$). Removing the three-way interaction term resulted in a likelihood ratio of $G^2(31)$ of 42.62, $p = .079$, suggesting that Kanzi and Alia did perform differently. The tests of partial associations revealed a subject × sentence type × response interaction (likelihood ratio of $G^2[10]$ of 17.45, $p = .064$). However, a number of sentence types occurred only or predominantly on blind trials; consequently, differences between the subjects as a function of sentence type are best addressed with the blind data subset. Examination restricted to the blind data indicated that the three-way subject × sentence type × response term was required for a fitting model; that is, removing it resulted in an increase in the likelihood ratio of $G^2(10)$ of 24.35, $p = .006$. Examination of the adjusted residuals for all data and for the blind data subset revealed that Kanzi was more likely than Alia to do well on sentence types 5B and 5C (see Table 6). In addition, removing the subject × response term resulted in a significant increase in $G^2(1)$ of 4.15, $p = .041$; thus, Kanzi made significantly fewer incorrect responses than Alia.

In order to determine whether the trials on which the subjects engaged in a tangential activity, or those on which the experimenter repeated or reworded the sentence, might be contributing significantly to the results and causing one or both subjects to appear more competent than they actually were, all trials with a C1, C2, C3, C4, or C5 code were eliminated from the corpus, and a 2 × 2 × 11 (subject × code × sentence type) analysis was rerun on the blind trials alone. Again, the subject × response terms were required for a fitting model (removing them resulted in $G^2[10]$ of 45.58, $p = .072$). Also, it was again the subject × sentence type × response interaction that was significant (likelihood ratio of $G^2[10]$ of 18.45, $p = .047$), indicating that the same pattern of results held for the data when only those trials with immediate correct responses were considered. Consequently, it is reasonable to conclude that the subjects' intervening behaviors prior to carrying out the sentence appropriately do not account for either their overall performance during this test of language comprehension or the general pattern of the results.

Although partially correct and incorrect responses were grouped together in the hierarchical log-linear analysis, both subjects generally responded correctly to at least a portion of the sentence; only rarely was either of them completely incorrect (see Table 5). Most of the time both attempted to carry out what they thought was the appropriate action with at least one correct object. Thus, rather than behaving as though they heard only key words, they behaved as though they had heard a sentence. In many cases, they carried out the correct activity with the incorrect object, suggesting that they understood the sentence structure but not all the words. The frequency with which the experimenter needed to repeat or rephrase the utterance did not differ between subjects and was minimal for both (for the frequencies with which repetitions and rephrasing occurred, see Table 5).

The error of bringing multiple objects appeared 20 times in Alia's data but only six times in Kanzi's. When sent to a location to retrieve an object, Alia often returned with two to four objects, one of which was the requested item. A few times she reported to the experimenter about her choice by saying, for example, "Mommy, I got the carrot," even though she also had a number of other things. However, on most trials, it was not possible to determine whether Alia simply enjoyed carrying many items or whether she actually forgot which item she was to retrieve. Both she and Kanzi were encouraged to bring only the requested item, and, if they brought additional items, they were usually asked to identify the one that had been the requested item. However, they were not required to return the additional items or to repeat the trial. Such occurrences were scored as object errors.

Kanzi, like Alia, was able to carry more than one item, and, on trials where multiple copies of the same item were present (such as many cans of Coke or cereal), he often brought as many exemplars of the requested item as he could carry. However, unlike Alia, he rarely made the error of bringing items that were not requested. A review of the videotapes of Alia's error trials suggested that she did not understand the words *just one* when she made an error. When the experimenter attempted to correct her error by asking her to bring "just one," Alia tended to bring all the objects, as though she thought *just one* was the name of an object (i.e., a *duston*). It appeared that, because she did not know which object was a "duston," she brought all the objects she found. In fact, the more the experimenter tried to correct Alia's tendency to bring multiple objects, the more frequently she seemed to do so.

TYPES OF ERRORS IN PERFORMANCE ON DIFFERENT SENTENCE TYPES

Type 1

Type 1A: Put object X *in/on transportable object* Y.—Overall, both subjects evinced high levels of comprehension of this sentence type (see Table 6). Unlike some other sentence types, an important feature of type 1A requests was that the actions they required were readily reversible (i.e., it was as likely that the subjects would put object *Y* in/on object *X* as it was that they would put object *X* in/on *Y*).

One type of error that occurred for both subjects was to respond with a "typical action" rather than the one requested by the sentence. For example, Kanzi put vitamins in the bowl instead of on the shirt, while Alia cut an apple with a knife instead of putting the knife in the hat. However, the rarity of this type of error (Kanzi made it on two trials, Alia on only one) indicated that neither subject generally approached the task simply by looking for key objects on which to perform a routine action.

Other errors appeared to be due to a lack of attention to the task rather than to an inability to understand the sentence. Moments of distraction and negativism characterized the behavior of both subjects from time to time throughout the testing. For example, Kanzi ate one of the food items on four trials instead of carrying out an action with it; Alia did this five times. On a few trials both subjects played with the items instead of attempting to carry out the request, and on two trials both indicated that they did not want to do what they were asked. Both subjects also simply held one or both items on some trials and did nothing more.

The two subjects also evinced similar interpretive stances when asked to place a food that was in a closed container with some other food. For example, when Kanzi was asked to "Put the milk in the water," the milk was, by chance, left in a closed can, and the water was in a bowl. Instead of picking up the can of milk and placing it in the water, Kanzi repeatedly tried to open the milk so that he could pour it into the water. When he did not succeed in getting the milk container open, he stopped attempting to carry out the request. Alia behaved similarly when asked to "Put the peaches in the strawberries." The can of peaches was accidentally left unopened, and the strawberries were in a bowl. Alia tried repeatedly to open the can before she would execute the request. In both cases, the experimenter urged Kanzi and Alia to go ahead and place the unopened can of milk or peaches with the other food, but neither subject would do so.

Kanzi invented a unique way of complying with one of the requests. When asked to "Put some water on the carrot," he responded by tossing the carrot outdoors; since it was raining heavily at the time, his action resulted in water getting on the carrot even though he applied the water indirectly. This method of "putting water on the carrot" appeared to be deliberate on Kanzi's part. At no other time during the test did he toss food or other items outdoors. It is also noteworthy that no one could recall ever demonstrating this behavior to Kanzi as a means of putting water on any item. Moreover, at other times during the test, and when it was not raining, he readily used both the hose and the faucet at the sink as a means of obtaining water if a request required him to do so, indicating that he knew how to obtain water. The novel solution of throwing the carrot into the rain is indicative of the flexibility that characterized the behavior of both subjects throughout the test. Kanzi and Alia's "solutions" were often surprising even to those who had worked with them from infancy.

Type 1B: Put object X *in nontransportable object* Y.—Kanzi and Alia did not differ significantly in their overall level of performance on these sentences. However, whereas Alia's performance on type 1A and 1B requests did not differ, Kanzi performed 10% better on type 1B requests, thus appearing to lend credence to Schusterman and Gisiner's (1988) contention that sentences with one transportable and one nontransportable object are simpler, as the relation to be enacted between the two objects is self-evident. However, an analysis of Kanzi's errors does not support this view because he was as likely to make an error on the item that he could pick up and carry as he was on the item that was too bulky to transport. For example, when asked to "Put the backpack on the Fourtrax," Kanzi went to the Fourtrax and sat on it without the backpack. Kanzi also revealed that "nontransportable" objects could, if needed, be treated as transportable ones. When he heard the sentence "Can you put the rest of the paint in the potty?" he put the clay—which he often confused with paint—in the potty instead. Even after the sentence was repeated, he was so certain that he had responded to it properly that he dragged the supposedly nontransportable potty over to the one-way mirror and pointed to the clay within it, to indicate to the experimenter that he had completed the request correctly. He apparently deduced that the experimenter needed a closer look in the potty to affirm that the "paint" was indeed in the potty.

In every case but one, Alia's errors were due either to selecting the wrong nontransportable object (e.g., when asked to "Put the clay on the vacuum," she put the clay on the window sill) or to a refusal to go to the nontransportable object at all (e.g., when asked to "Put the grapes in the oven," she stood in the middle of the room and swung the grapes around instead of taking them anywhere). Since Alia was correct on 72% of the type 1B items overall, her tendency to err on nontransportable items cannot be attributed to a lack of understanding of the names of the nontransportable objects.

In general, Alia had more difficulty than Kanzi with requests that entailed traveling to another location, although she was clearly capable of doing so. It is possible that these difficulties were simply the result of the fact that she was quite young and consequently more hesitant than Kanzi to travel on her own.

Type 2

Type 2A: Give (or show) object X *to animate* A.—Giving objects to an animate was easy for both Kanzi and Alia. When errors did occur, Kanzi tended to give the wrong item to the correct person, whereas Alia tended to select the correct item but then either do nothing with it or look at the person but refuse to take it to her. Occasionally, Alia played with the items instead of responding, and on one trial she ate the item, as did Kanzi.

A few sentences in this group included the modifiers *toy* and *real.* Both subjects made errors on these sentences, although not of the same sort: Alia tended to give both the toy and the real item, while Kanzi tended to give the real item and ignore the toy item.

Type 2B: Give object X *and object* Y *to animate* A.—This sentence type proved the most difficult for Kanzi (33% correct) and the second most difficult for Alia (57% correct). Alia tended to engage in some action prior to carrying out type 2B requests more often than Kanzi (who did not do so at all). Indeed, it may have been that the extra time that Alia spent prior to carrying out this sentence was used to encode it in some way that aided the integration of both objects and the memory of the needed response.

Because both object names were spoken before the subject selected either, this sentence type required that Alia and Kanzi hold in memory two unrelated objects and perform the same action (giving or showing) on both. Each subject made the error of giving one incorrect and one correct item on one occasion. Additionally, on one occasion, each subject made the error of relating the two items in the array to each other instead of giving them to a person. Alia poured the cereal in the bowl when asked to "Show me the ball and the cereal," apparently confusing the words *ball* and *bowl,* while Kanzi dipped the lighter in the water when asked to "Give the lighter and the water." The fact that this sort of error was made only once by each subject lends additional support to the conclusion that neither was employing a strategy of listening for key words (i.e., object names) and carrying out a common or obvious action without processing the additional information inherent in the sentence structure. Had only "key-word" analysis been occurring, far more errors of this type should have appeared in responding to type 2B requests.

In order to make even more direct comparisons between sentences in which the relation was that of conjunction and those in which a particular relation was specified, half the type 2B requests utilized the same two objects that occurred in other sentences. For example, the sentence "Show me the milk and the dog" was contrasted with the sentence "Feed the dog some milk." The key object words *dog* and *milk* occurred in both sentences; however, a correct response required the subjects to integrate the information carried by the verb with the objects in different ways in each case. In the case of the conjunction, the single verb *show* applied to both objects; however, in the other case, it was necessary to apply the verb *feed* to the dog and to execute the action of moving the milk toward the dog. Both Alia and Kanzi differentiated between such sentences by showing the items in the first instance and constructing a relation between these objects in the second.

Although Kanzi often selected only one item to show, in so doing he was nonetheless still responding to the appropriate overall sentence format rather than attempting to construct a relation between two objects (i.e., putting *X* in *Y*). These data support the view that both subjects processed the sentence as a unitary relation between verb and objects rather than as key words suggesting some inherent relation between the objects. Moreover, they imply that the verb was understood to control either the relation of the objects to each other or that of an object to a recipient.

Giving only one item accounted for nearly all Kanzi's errors on type 2B requests but for only three of Alia's. On two trials, Alia gave more than two items, something that Kanzi never attempted. When Kanzi gave only one item, his errors were distributed between the first and the last items mentioned in the request, although he was more likely to give the last item mentioned. On these occasions, Kanzi understood that the verb *give* applied to both items, for all that was needed to remind him of the second item was to say "and *Y*." Kanzi would then look around, find *Y*, and hand it to the correct person.

Even though Alia did not perform significantly better than Kanzi on type 2B trials, differences in the two subjects' performances deserve special note. The syntactic structure of these sentences is simple and straightforward—the subject need only select two objects and give them to a person (usually the experimenter). The difference between the subjects' abilities to perform this activity correctly with one versus two objects was striking (for the difference between type 2A and type 2B sentences, see Table 6).

Overall, Alia selected two or more objects on 15 trials, while Kanzi selected two objects on six trials. However, these numbers fail to convey the obvious behavioral differences that could be seen in response to this request. Kanzi either processed the sentence very rapidly and gave two things quickly, or he ignored one item and gave the other. Generally, if he gave two things, he did so one at a time. Alia seemed much more deliberate, as though rehearsing the list. She typically picked up both things before orienting her attention to the recipient, then carrying both objects together to the recipient. Although no delay was artificially introduced by the experimenter, Alia's behavior suggested that she could tolerate fairly long delays before forgetting what she was to do on type 2B sentences, whereas Kanzi could not.

The simplicity of both the semantic and the syntactic components of type 2B sentences suggests that Kanzi's difficulty was perhaps due more to short-term memory limitations on the overall amount of information than to processing limitations on the information that was available to him. Indeed, it seems possible that the semantic and syntactic structure in sentences such as "Feed the doggie some milk" permitted Kanzi to go beyond the typical constraints of his short-term memory system by enabling him to process or chunk the information in a meaningful manner. By contrast, sentences such as "Give the doggie and the milk" do not engage semantic chunking strategies but rather force reliance on short-term memory alone. These data thus suggest that syntactic relations may actually make language easier for Kanzi rather than more difficult, as has been suggested by Terrace (1979).

Type 2C: (Do) action A *on animate* A.—Both subjects made only a few errors on type 2C sentences, and these in general appeared to be due to inattention. It is noteworthy that both made a similar interpretative error with the verb *hide.* When given the sentence "You go hide," both Kanzi and Alia went to some room or area out of the experimenter's sight. However, when asked to "Hide the toy gorilla," both subjects changed the gorilla's location (Kanzi pushed it under the fence, and Alia put it on a chair), but neither actually moved the object out of sight. They seemed to understand *hide* in the typical sense of moving out of sight when it applied to themselves, but, when it applied to the toy gorilla, they moved the pretend animate partially out of their own immediate sight, not out of that of the experimenter. Thus, the verb *hide* seemed to have one meaning when applied to themselves and another when it applied to an object that they were to act on, perhaps because they both had difficulty with assuming the experimenter's perspective.

Type 2D: (Do) action A *on animate* A *with object* X.—Interestingly, acting on a person with an object proved more difficult for both subjects than giving an object to a person. (For the comparison between type 2D and type 2A sentences, see Table 6.) All the type 2A sentences entailed the verb *give,* but the verb varied in the type 2D requests. Consequently, it might be anticipated that Kanzi and Alia's errors would center on the verbs; this, however, was not the case. Both Alia's and Kanzi's errors were distributed among all three categories: the verb, the object, and the recipient, although the recipient category had the largest number of errors.

Both subjects at times confused recipients in type 2D sentences (which they did not do in type 2A sentences); presumably, this occurred in part because the recipient class was larger in type 2D sentences, including pretend animates as well as the subjects themselves. For example, when asked, "Can you tickle me with the stick?" Alia tickled the dog instead. When Kanzi was asked to tickle Laura with the dog, he tickled the dog instead of Laura. Both Kanzi and Alia also made the error of directing activities to themselves instead of to another party. For example, when asked to "Put the hat on person *X*," both Alia and Kanzi put it on their own heads.

Some of the recipient errors were clearly prompted by the hesitancy of both subjects to act directly on another person with an object. This hesitancy increased when the recipient of the intended action was blinded (by holding a hand in front of the eyes) and could not give nonverbal acknowledgment when approached.

Type 3

(Do) action A *on object* X *(with object* Y*).*—The sentences in this group covered a wider variety of verbs than those in any other group and were more diverse in the types of actions required of the subjects. Both Kanzi and Alia did well on these sentences, and both subjects distributed their errors across all verbs with no particular verb—except *hide*—causing difficulty in all sentences where it occurred. As we have already noted in an earlier context, both Kanzi and Alia understood *hide* when it applied to themselves or to games of hide and seek; however, when asked to hide an object, they tended to do something with the object (such as pick it up and put it down, move it aside, play with it, etc.) but did not visually obscure it.

The remaining errors on type 3 sentences do not fall into any recognizable pattern. Instead, they seem to arise because the subjects found it difficult to respond to many of the decidedly "odd" sentences in this group. For example, "Hammer the vacuum" puzzled Kanzi, "Wash your watch" befuddled Alia, and "Bite the picture of the oil" stymied both. However, these errors should not be taken to mean that the subjects were completely unable to respond to highly novel and unusual sentences. Both correctly carried out such odd sentences as "Hammer your ball," "Knife the toothpaste," "Stab your ball with the sparklers," and "Give the sweet potato a shot."

Type 4

Announce information.—These sentences entailed announcements of impending events rather than requests. Overall, Alia made somewhat fewer errors on these trials than Kanzi, although the number of trials was too small to warrant a test of significance.

Alia often responded to the statements by vocally announcing her own intent instead of behaving in accordance with what the experimenter had announced. Since she did not do this with other sentence types, the fact that she viewed these trials as an opportunity to announce her own intentions suggests that she recognized the different pragmatic function of this sentence type. For example, when the sentence "Alia is going to chase Mommy" was uttered, Alia responded by saying, "Chase me, chase me." Although in this case she was scored as having erred because she did not follow the implications of the original statement, it is nonetheless possible that she did understand it. On other trials, such as "Nathaniel is going to chase Alia," Alia also announced to Nathaniel, "Chase me, chase me." Kanzi made no such announcements on type 4 trials, although he did so in between trials.

Alia also hesitated at times when announcements such as "Alia is going to chase Linda" were made. In this particular case, she walked past Linda and returned to say, "Chase Linda," as though to announce that she had already completed the action.

Type 5

Type 5A: Take object X *to location* Y.—All type 5 requests involved transporting an object to, or retrieving it from, a fixed location. At first, Kanzi and Alia were asked only to take an object to a location (type 5A). It was thought that this would be the easiest of the object transport requests for them because they could act on the object in front of them as soon as the sentence was completed: once they had picked up the object, they needed to remember only the name of the location. By contrast, if they were asked to retrieve an object in a distal location, they had to remember the object while traveling to that location.

Virtually all type 5A sentences employed the verb *take.* Kanzi and Alia's error patterns differed in that Kanzi's errors were more equally divided between objects and locations: on eight occasions he took the incorrect object to the correct location, while on five he selected the proper object but took it to the wrong place. Alia's errors typically consisted of taking the correct object to the wrong location; she also made three errors in which she selected both an incorrect object and an incorrect location, which Kanzi did once. Both Alia and Kanzi occasionally refused to respond or did nothing. In Kanzi's case, the sentence that elicited no response was "Take the can opener to the bedroom." The word *can* was used in a number of ways throughout this study (*can of Coke, can you, can opener,* etc.) and appeared to cause Kanzi difficulty in most instances, as he apparently had not yet resolved the different understandings of *can* that were required. On the remaining "no response" trials, it was concluded that the subjects either were not listening, did not want to carry out the request, or felt unable to do so.

Even though the locations in this category were designated "nontransportable," one of them, a portable potty, was in fact movable, although cumbersome. In all but one sentence, the word *potty* was employed as a nontransportable. In "Take the potty outdoors," however, it was suddenly treated as a transportable object, which the subjects were asked to move for the first time, something they did not generally do with the potty otherwise. Kanzi succeeded with this sentence, but Alia failed. However, she did attempt to pick up the potty, but could not do so because she was standing on it. After several attempts, she gave up, not realizing she could not move it unless she stepped off it first. The fact that Kanzi did take the potty outdoors and that Alia attempted to do so indicated that the verbal input they received via this unusual novel sentence exerted more influence over their behavior than did their previous experience with the potty. Both were able to apply at once the verb *take* to the word *potty*, an object that had always served before as a recipient and one that they did not normally transport.

Type 5B: Go to location Y *and get object* X.—Surprisingly, both subjects were able to go to a distal location, remember the object they had been asked to retrieve, and return with it. Kanzi was significantly better than Alia at doing so, although he needed to be reminded to return more often than did Alia as he was generally interested in staying to play at locations.

In the subgroup of 20 blind control trials, the item to be retrieved from location *Y* was also present in the array immediately in front of the subjects, requiring them to ignore the immediately available item and travel to another location for its duplicate. As noted earlier, however, these sentences were syntactically ambiguous because they could be interpreted as two sets of independent things to do: (*a*) go to a location and (*b*) get an object. The type 5B sentence structure did not clearly indicate that the item to be retrieved was to be obtained from another location.

Kanzi acted on the object in the immediate display on 50% of these trials and Alia on 25%. Kanzi required more explicit instructions to ignore the object in the immediate display and often could not be persuaded to put it down by any means other than direct intervention.

Both subjects' responses on these control trials indicated that, from their perspective, type 5B sentences were indeed ambiguous. However, neither subject invariably selected the object in the immediate array. Often their response was simply to touch the object in the immediate array and then go to retrieve the distal object. If they attempted to give the experimenter the immediate object rather than getting it from the specified location, they were asked not to do so. If they then properly retrieved the distal object, they were scored as having correctly carried out the sentence. Consequently, their overall scores were not deflated on type 5B sentences as a result of the ambiguity generated by the sentence structure.

Type 5C: Go get object X *that's in location* Y.—Both type 5B and type 5C sentences required that the subjects travel to a distal location to retrieve an object, and in both cases the requested object was also present in the array in front of them on control trials. Type 5B sentences presented the request in a linear construction that mapped the sequence of activities to be carried out, whereas type 5C sentences employed a phrasal modifier that inverted the linear sequence by mentioning the object first and the location last: "Go get object *Y* that's in location *X*." To be correct on both types, the subjects had to demonstrate an ability to process the same sort of information presented in two different formats, one that inverted the linear order and one that did not.

It could be argued that, in both types of requests, the subjects were simply responding to the verb, the location term, and the object term and that the order of these terms was irrelevant. The control trials address this issue since the embedded phrasal structure of type 5C sentences removed the semantic ambiguity inherent in type 5B sentences. The central question was whether the subjects performed better on these trials (i.e., with objects duplicated in the immediate and distal arrays) when presented with type 5B or with type 5C requests. Better performance on type 5C control trials would indicate that they processed the phrasal modifier appropriately and that the syntactic structure of type 5C sentences indeed functioned to eliminate the ambiguity inherent in type 5B control trials.

Kanzi's data provide strong support for the view that he comprehended the syntactic relation expressed in type 5C sentences. Kanzi acted on the object in the near array on only 9% of these trials, as contrasted with 50% of the type 5B control trials. (One of his two errors occurred because Kanzi looked for, but failed to see, the object in the distal location; thus, his interpretation of the sentence structure was in fact syntactically correct. His other error occurred when both the object of the modifier and its duplicate were in the array immediately in front of him. That is, in the sentence "Take the potato that's in the water outdoors," the two potatoes were side by side, but one was in a bowl of water; Kanzi took both potatoes outdoors. Since Kanzi's performance on type 1A sentences indicated that he did *not* differentiate *in* from *next to,* it seems reasonable to attribute this error to a lack of understanding of the word *in* rather than to a misreading of the syntactic structure of the sentence.)

The manner in which Kanzi responded to the type 5C sentence format was most impressive. Unlike his behavior in response to the ambiguous type 5B sentences, on hearing type 5C sentences Kanzi typically did not even glance at the array in front of him. Instead, he headed directly for the specified location, suggesting that he had deduced from the structure of the sentence itself that there was no need to search for the object in the array in front of him.

Alia's data followed a similar pattern. She was correct on 25% of the type 5B control trials and on 63% of the type 5C control trials, suggesting that the syntactic structure of type 5C sentences functioned to clarify ambiguity for her as well. Indeed, the only type 5C trial that elicited a response to the incorrect similar item from Alia was "Drink the chocolate that's hot": she drank both cups of chocolate, the cold one first. Alia appeared to relish the chocolate thoroughly (she was not often permitted to have chocolate), and her error here may well have been intentional.

Thus, both Alia and Kanzi responded appropriately to the phrasal modifier *that's* when it was used to distinguish between a distal object and one present in the immediate field of vision. However, both made an error when it was used to differentiate two objects that were both in the immediate array.

The overall performance of both subjects on type 5A, 5B, and 5C sentences, regardless of whether the object to be retrieved was present in the near array, indicated that they were able to comprehend the syntactic relations among word units, not just the units themselves. The ability to respond correctly to a set of sentences such as "Take the tomato to the microwave," "Go to the microwave and get the tomato," and "Go get the tomato that's in the microwave" demonstrated an understanding of the fact that such sentences reflect an intended relation between all words (the verb, the object, and the location). Most important was the finding that a phrasal modifier functioned to clarify the object of reference, which indicates that both subjects were capable of interpreting the syntactic device of recursion appropriately, at least within the context of type 5C sentences.

Type 6

Make pretend animate A *do action* A *on recipient* Y.—These sentences proved difficult for both subjects. They required that the subjects distinguish between agent and recipient and make the two act out different roles. Additionally, they involved an element of "pretend" not always present in other categories. For example, to "make the doggie bite the snake," one must pretend that both are animates.

It is of interest that neither subject was correct on any sentence that named a toy bug as either agent or recipient (as in "Can you make the bug bite the doggie?"). Even though both knew the word *bug* and could point out live bugs and photographs of bugs when asked, both seemed puzzled by the idea of treating a plastic bug as an animate. However, both were able to treat the toy dog, bunny, and snake as agents and recipients and to carry out some sentences correctly with these pretend "agents." Both subjects also confused the word *orang* (for *orangutan*) with *orange* on some trials.

Type 7

All other sentence types.—As noted earlier, 11 sentences that did not fit any of the other categories were grouped together into a "leftover" type. Most of these sentences required two separate actions—for example, "Open the Jello and pour it in the juice" or "Take the potato outdoors and get the apple." (Interestingly, on the latter request, both subjects took the potato outdoors, picked up the apple, and returned with both foods.)

These sentences were intended as "probes" to determine whether it would be feasible to test additional sentence types in the future. Our general impression was that the subjects might have had the potential to process sentences in which multiple actions were linked in a functional sense. For example, in order to pour the Jello into the juice, it is necessary to open it first, and this request was completed correctly by both subjects. However, sentences requiring actions that were not functionally linked from the subjects' point of view proved difficult. Kanzi did considerably better than Alia on type 7 requests (Kanzi responded correctly on seven trials, Alia on three); however, the small number of sentences and their diversity render conclusions about possible differences between the two subjects on this sentence type premature.

WORD ORDER

Although Kanzi and Alia's ability to respond to many different sentence types indicates that they are processing syntactic relations, these data do not address the issue of word order directly. To do that, it is necessary to regroup the sentences on the dimension of word order per se rather than sentence type. The data base afforded several different means of manipulating word order, some of which were meaningful (e.g., "Put the noodles in the hotdogs" vs. "Put the hotdogs in the noodles") and some not (e.g., "Wash your collar" vs. "Collar your wash"). In order to address the ability of the subjects to comprehend reversal of word order directly, we compared their performance on pairs of sentences that were presented with both possible word orderings (summary statistics are presented in Table 7). Paired instances of the three classes of word-order manipulations that occurred in the data base are presented in Table 8.

TABLE 7

COMPARISON OF KANZI AND ALIA'S PERFORMANCE ON REVERSED SENTENCES OVER THREE SUBTYPES OF REVERSALS: SUMMARY STATISTICS

	KANZI		ALIA	
	C/N	%	*C/N*	%
Subtype A:				
Sentences	38/46	83	26/44	59
Pairs	17/23	74	8/21	38
Subtype B:				
Sentences	22/28	79	18/27	67
Pairs	8/14	57	5/13	38
Subtype C:				
Sentences	33/42	79	27/39	69
Pairs	12/21	57	7/18	39

NOTE.—C = number of correct responses (C, C1–C5). N = total number of sentences or sentence pairs given to the subject. Subtype A = verb plus word order changes, and appropriate response differs. Subtype B = word order remains constant, but appropriate response differs. Subtype C = word order changes, and appropriate response changes.

The first group includes those sentences that afforded two signals for a differential response, both word order and verb ("Could you take the pine needles outdoors?"/"Go outdoors and get the pine needles"). Consequently, the best performance would be expected on these sentences. This occurred for Kanzi but not for Alia. The second group includes those sentences in which the order of the key words remained constant but the nature of the appropriate response did not ("Take the rock outdoors"/"Go get the rock that's outdoors"). The final group reflects all sentences in which the order of the key words was reversed while maintaining the same verb ("Put the juice in the egg"/"Put the egg in the juice"; see Fig. 15).

Kanzi's performance across these three word-order manipulations did not differ significantly, nor did Alia's. However, Kanzi performed significantly better than Alia on the type A reversal (word-order manipulations in which there was a reversal of the key words with a different verb, such as *get* vs. *take*), $\chi^2(1, N = 90) = 7.12, p < .01$. Alia and Kanzi were not significantly different on type B and C reversals. Alia's difficulty with type A reversals reflected her tendency to return from various locations with more than one object.

Taken together, these sentences presented the subjects with a difficult challenge. On the one hand, some sentences required that the order of X and Y be treated as a signal about the sequence that their ensuing actions should follow. In other cases, the order of X and Y was to be ignored. Word order was to be attended to when it was the only cue or when it occurred with the verbs *get* and *take* following the command "Go. . . ." However, the

TABLE 8

COMPARISON OF KANZI AND ALIA'S PERFORMANCE ON REVERSED SENTENCES OVER THREE SUBTYPES OF REVERSALS: SUBJECTS' PERFORMANCE ON EACH SENTENCE

A. SUBTYPE A

	Kanzi	Alia	Sentence
1	PC	C	Take the carrots outdoors.
2	C5	C	Go outdoors and find the carrot.
3	C	NG	Could you take the pine needles outdoors?
4	C	C2	Go outdoors and get the pine needles.
5	C	C	Put the sparklers in the potty.
6	PC	OE	Go to the potty and get the sparklers.
7	C	C	Take the orange outdoors.
8	C3	OE	Go outdoors and get an orange.
9	C	C	Take the umbrella [box] outdoors.
10	C	C	Go outdoors and get the umbrella [box].
11	C	C	Take the pineapple [apple] outdoors.
12	C5	W	Go outdoors and get the pineapple [apple].
13	C	C	Go to the refrigerator and get some ice.
14	C	C4	Take the ice back to the refrigerator.
15	OE	PC	Take the stick to the bedroom.
16	C5	NR	Go to the bedroom and get the stick.
17	C	C	Take the potato to the bedroom.
18	C3	C	Go to the bedroom and get the potato.
19	C	C	Take the potato outdoors.
20	C3	C	Go outdoors and get the potato.
21	C	OE	Bring the raisins to the bedroom.
22	C5	PC	Go to the bedroom and get the raisins.
23	C	C	Take the orange to the colony room [Karen's room].
24	C5	PC	Go to the colony room [Karen's room] and get the orange.
25	C	C	Take the lighter [matches] outdoors.
26	C1	NR	Go outdoors and get the lighter [matches].
27	C	W	Go to the refrigerator and get an orange.
28	C2	C	Take the orange to the refrigerator.
29	C	C	Go to the microwave [oven] and get the tomato.
30	C	W	Take the tomato to the microwave [oven].
31	C	PC	Take the tomato to the bedroom.
32	C5	PC	Go to the bedroom and get the tomato.
33	C	C	Put the raisins in the refrigerator.
34	C	C	Go to the refrigerator and get the [some] raisins.
35	C	C2	Take your collar [watch] to the bedroom.
36	C2	NR	Go to the bedroom and get the collar [watch].
37	C	PC	Go to the refrigerator and get the melon [peaches].

TABLE 8A (*Continued*)

	Kanzi	Alia	Sentence
38	W	NG	Take the melon to the refrigerator.
39	PC	C	Take the doggie to the T-room [bathroom].
40	W	PC	Go to the T-room [bathroom] and get the doggie.
41	C	C	Take the banana outdoors.
42	C	C	Go outdoors and get the banana.
43	PC	PC	Can you make the bug bite the doggie?
44	PC	PC	Can you make the doggie chase the bug?
45	C	C	See if you can make your doggie bite your ball.
46	C	C	Can you put the ball on the doggie?

B. Subtype B

	Kanzi	Alia	Sentence
1	PC	OE	Take the rock outdoors.
2	C	C	Go get the rock that's outdoors.
3	C	C	Take the stick outdoors.
4	OE	C	Go get the stick that's outdoors.
5	C	C	Take the snake [bug] outdoors.
6	C	C	Go get the snake [bug] that's outdoors.
7	C	C	Take the banana outdoors.
8	C	C3	Go get the banana that's outdoors.
9	C	W	Take the tomato to the microwave [oven].
10	C	PC	Go get the tomato that's in the microwave [oven].
11	C	C	Put the raisins in the refrigerator.
12	C	OE	Go get the raisins that are in the refrigerator.
13	C	C	Put your collar (watch) in the refrigerator.
14	C	C	Go get your collar (watch) that's in the refrigerator.
15	C	C	Put your apple in the microwave [oven].
16	C	OE	Go get the apple that's in the microwave [oven].
17	C3	C	Put the melon [peaches] in the potty.
18	C	M	Get the melon [peaches] that's in the potty.
19	C	C2	Put the doggie in the refrigerator.
20	W	W	Go get the dog that's in the refrigerator. [Go to the refrigerator and get the dog.]
21	NR	C2	Take the can opener [fork] to the bedroom.
22	C	W	Go get the can opener [fork] that's in the bedroom.
23	C	C	Take the umbrella [box] to the colony room [Karen's room].
24	PC	OE	Go get the umbrella [box] that's in the colony room [Karen's room].

TABLE 8B (*Continued*)

	Kanzi	Alia	Sentence
25	C	C	Take the lighter [matches] outdoors.
26	C	C	Go get the lighter [matches] that's outdoors.
27	C	C	Take the doggie out of the pillow.
28	PC	PC	Hide the doggie in the pillow.

C. Subtype C

	Kanzi	Alia	Sentence
1	C	NG	Can you put some oil on your ball?
2	C	C1	Put the ball in the oil.
3	PC	C	Put the hat on your ball.
4	I	I	Put the ball on the hat.
5	C	C	Put the ball on the rock.
6	C	NG	Can you put the rock on your ball?
7	C	C3	Put the pine needles in your ball.
8	C	W	Can you put the ball on the pine needles?
9	C	C2	Put some water on the carrot.
10	C1	C2	Put the carrot in the water.
11	PC	C	Pour the milk in the cereal.
12	C	I	Pour the cereal in the milk.
13	C	PC	Pour the Coke in the lemonade.
14	C	PC	Pour the lemonade in the Coke.
15	C3	C	Pour the juice in the egg.
16	C	C	Put the egg in the juice.
17	C	C1	Put the rock in the water.
18	PC	PC	Pour the water on the rock.
19	C	C	Put the raisins in the water.
20	C2	I	Pour some water on the raisins.
21	PC	C3	Put the melon [peaches] in the tomatoes.
22	C3	NG	Put the tomatoes in the melon.
23	C	C2	Put the milk in the water.
	C2	C	Put the milk in the water.[a]
24	C	PC	Pour the Perrier water in the milk.
25	C	C	Put the tomato in the oil.
26	C	C	Put some [the] oil in the tomato.
27	I	I	Put the shoe in the raisins.
28	C2	C	Put the raisins in the shoe.
29	C	PC	Pour the juice in the Jello.
30	C	C	Open the Jello and pour it in the juice.
31	C	C	Rose/Nathaniel is gonna chase Kanzi/Alia.
32	PC	I	Kanzi/Alia is going to chase Rose/Mom.
33	C	C2	Liz/Linda is going to tickle Kanzi/Alia.
34	PC	C	Kanzi/Alia is gonna tickle Liz/Nathaniel.

TABLE 8C (*Continued*)

	Kanzi	Alia	Sentence
35	C	C	Kanzi/Alia is going to chase Liz/Nathaniel.
36	C	C	Liz/Nathaniel is going to chase Kanzi/Alia.
37	C	C	Kanzi/Alia is going to tickle Liz/Nathaniel with the bunny.
38	PC	C	Liz/Nathaniel is going to tickle Kanzi/Alia with the bunny.
39	C	PC	Make the doggie bite the snake.
40	C	C	Make the snake bite the doggie.
41	PC	PC	Hide the ball under the blanket.
42	C	C	Can you put the blanket on your ball?

NOTE.—For code definitions, see Table 3. Words in square brackets reflect changes in the sentences given to Alia since she did not know some of the words in the sentences given to Kanzi. The code "NG" indicates that the sentence was not given to Alia at all.

[a] This sentence was administered with the milk can open, instead of closed. It is counted only once for purposes of the analysis.

occurrence of the verb was not a totally reliable cue since word order was to be ignored if the same verbs were paired with the phrasal modifier *that's*.

Overall, Kanzi was correct on 71 of 88 (81%) of all sentences in which the key words were presented in both orders, while Alia was correct on 53 of 83 (64%) of these sentences. With regard to their performance on specific pairs (i.e., subjects were correct on *both orders* for a given pair), Kanzi successfully responded to 29 of 44 pairs (66%), while Alia successfully responded to 15 of 39 (38%).

It is important to note that the number of inversion errors (occasions on which the subjects performed the actions in inverse order from the request) was small (Kanzi made two inversion errors and Alia five). Consequently, even when the subjects did not carry out both sentences in a pair correctly, it was rare that their difficulties reflected a misunderstanding of the word-order cue. Semantic errors predominated. For example, when Kanzi heard "Put the melon in the tomatoes," he put the melon in the water, thus acting on the water rather than the cereal. Similarly, when Alia was asked to "Pour the lemonade in the Coke," she tried to pour the lemonade (from the can) into the bowl of lemonade. Like Kanzi, she treated the first item mentioned as the one to be moved, but placed this item in the wrong position.

A clear determination of what they failed to understand on these trials awaits future data collection, as their current errors provide only hints. For example, when asked to "Put the knife in the hat," Kanzi tried to cut the soap with the knife, while Alia tried to cut the apple with the knife. Both

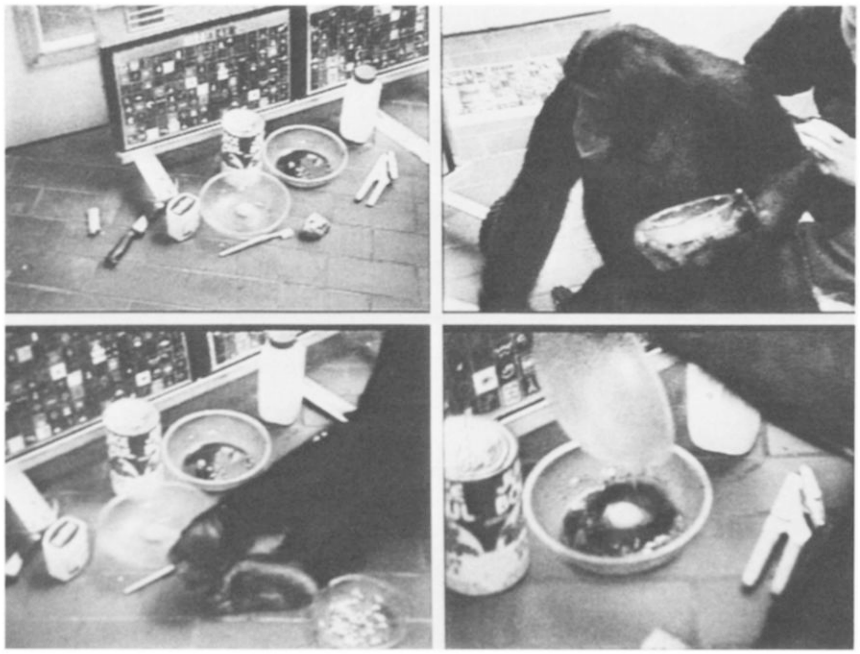

FIG. 15.—This figure illustrates the array in front of Kanzi (top left) as he hears the sentence "Put the egg in the juice" (top right). It is possible for Kanzi either to put the juice in the egg, to put the egg in the juice, or to do something else entirely. Kanzi responds to this sentence by picking up the bowl containing the egg (bottom left) and tilting it until the egg falls into the juice (bottom right).

seemed compelled to use the knife to cut a small firm object in the display rather than to put it in the hat. Perhaps the idea of placing a knife in a hat is too unusual, or perhaps they enjoyed trying to cut other things. There appear to be inherent properties within some objects that caused the subjects to feel compelled to interact with them in specific ways, and the speech input from the experimenter may simply have been insufficient to override their own inclinations in such cases. Semantic errors and errors of inattention dominated the cognitive processes of both subjects at this level of language comprehension.

These data support the view that both Kanzi and Alia were sensitive to word order as well as to the semantic and syntactic cues that signaled when to ignore word order and when to attend to it. Overall, Kanzi appeared to be slightly more sensitive to word order than Alia at the time of this test, although neither was able to respond to this cue in an unfailing manner.

VII. DISCUSSION: WHY NOT GRANT SYNTACTIC COMPETENCE TO A SIBLING SPECIES?

SIMILARITIES IN KANZI AND ALIA'S PERFORMANCE

The clear outcome from the present study is that two normal individuals of different ages and different genera (*Homo* and *Pan*) were remarkably closely matched in their ability to understand spoken language. A 2-year-old human female and an 8-year-old bonobo male demonstrated that, under relatively similar rearing circumstances and virtually identical test conditions, they could comprehend both the semantics and the syntactic structure of quite unusual English sentences. The similarity between the two subjects is all the more remarkable in that, while able to comprehend sentences, neither subject was as yet a fluent speaker. The child was not fluent because she was too young, while the structure of Kanzi's laryngeal tract made it impossible for him to produce comprehensible speech. Near the completion of this test, Alia began to produce complex multiword utterances, and, across the next 6 months, her productive capacity leapt dramatically ahead of that of Kanzi, who failed to improve noticeably.

The lack of contingent reward, the novel nature of the requests, the absence of previous training to perform these specific requests, and the unique nature of each trial countermand simple explanations that depend on the conditioning of responses independently of semantic and syntactic comprehension. Both subjects clearly demonstrated a capacity to process the semantic and syntactic information in the sentences presented to them. Moreover, the manner in which they did so revealed that they did not interpret the words contained in sentences as randomly juxtaposed events, to be acted on independently. Instead, they invariably attempted to carry out a complex set of related actions that reflected their interpretation of the semantic and syntactic features of each novel utterance. Thus, for example, Kanzi's solution to "Put the water on the carrot" was to toss it out into the rain. Such innovative actions revealed a sophisticated processing of the

FIG. 16.—This figure illustrates Kanzi listening to the sentence "Feed your ball some tomato" (top left), selecting the tomato (top right), bringing a soft sponge ball with a "pumpkin" face embedded within it into his lap (bottom left), and then placing the tomato into the mouth on the face embedded in the ball (bottom right).

speaker's intent (in this case, to get the carrot wet) rather than a rote, unthinking solution. Even when the subjects failed, they virtually never did so in a way that would suggest that they were assigning key words randomly.

Both subjects appeared to process the experimenter's words at the sentence level. The meaning that they assigned to a word was based on its role in the sentence rather than on a dictionary-like set of referents. For example, both responded appropriately to "Give the knife to [person]" as well as to "Can you knife the sweet potatoes?" even though the word *knife* indicates an object in the first case and an action with an object in the second. It was the sentence context itself that made the difference, and this context was appropriately evaluated by both subjects.

Both subjects also responded appropriately to very unusual sentences. For example, Kanzi correctly responded to the sentence "Feed your ball some tomato" (see Fig. 16). Since in Kanzi's prior experience the word *feed* had never been juxtaposed with the word *ball,* his appropriate response can only be interpreted as indicating that he understood that the action encoded in the verb *feed* was to be directed toward the unusual recipient *ball,* regardless of whether the act appeared plausible. Kanzi also responded appropriately to the difference in sentences such as "Give the shot to Liz" and "Give Liz a shot"—by handing Liz the syringe in the first case and taking off the needle covering and touching the needle to her arm in the second case.

When the proper response to a request was not obvious from the array in front of the subjects, both proved innovative in their solutions. For example, when we asked them to "Wash the hotdogs," we assumed that, were the subjects to respond correctly, they would carry the hotdogs to the kitchen sink since that was where they had always observed food being washed. In fact, neither subject traveled to the sink; rather, each searched for closer means to wash the hotdogs. Looking around, Kanzi noticed the hose that was usually used to spray the floor and proceeded to use it for spraying water on the hotdogs, utilizing the plastic wrapping as a container for the water, even though he had not seen anyone do this before. After a moment of puzzlement, Alia selected a small sponge ball from the array and began wiping the hotdogs with it.

The ability of both subjects—and particularly the strong tendency exhibited by Kanzi—to interpret the phrasal modifier *that's* as a syntactic morpheme used to clarify which of two objects to retrieve revealed that the syntactic device of recursion was mastered for at least this sentence type. In addition, Kanzi was more likely to be correct when ambiguity was dispelled by a recursive structure. His general performance and demeanor on such trials also implied that he processed the sentence as a complete unit. For example, when asked to "Take the tomato to the microwave," Kanzi hesitated and began visually to search the items in front of him. However, when he heard "Get the tomato that's in the microwave," he did not even pause to glance at the immediate array but wheeled quickly around and proceeded to retrieve the tomato from the microwave. It is important to note that the present study was not initially designed to determine whether the subjects could process sentences that utilized a recursive structure. Rather, our tests of this capacity evolved when it became apparent that the subjects were having difficulty with an ambiguous linear structure—only then was the recursive structure introduced to resolve this ambiguity.

In addition to providing evidence for his understanding of recursion, Kanzi's data also indicate that he parsed word order appropriately in the majority of sentence reversals. Alia's data were not as strong, although she also appeared to be responding to word order. Additionally, it is important to note that, when errors were made, they tended to reflect a lack of attention or an incorrect semantic comprehension on the part of both subjects rather than difficulty in comprehending the syntax of the sentence.

Word order surely guided Kanzi's response in sentence contrasts such as "Can you put the ball on the pine needles?" and "Can you put the pine needles in your ball?" Kanzi had never encountered requests to put objects

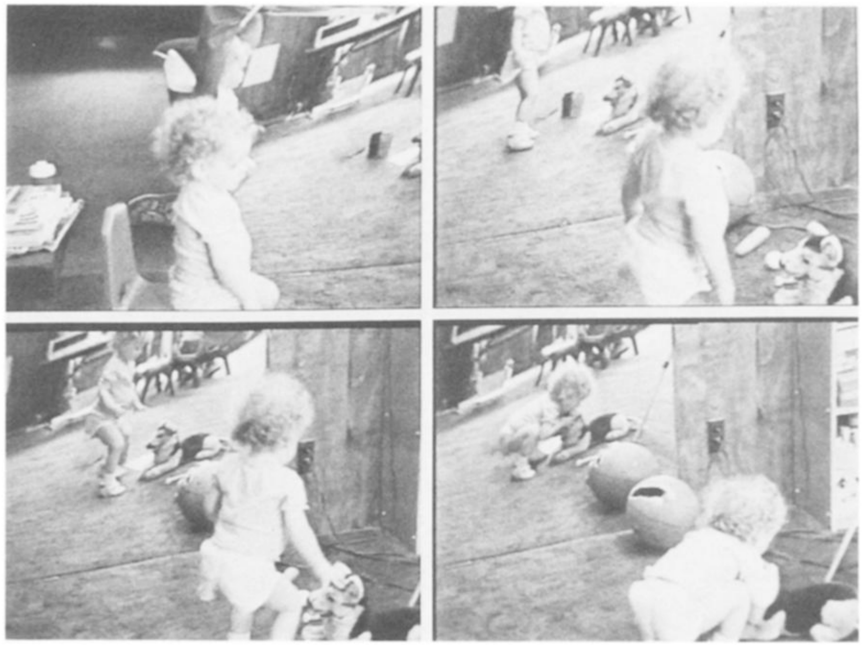

FIG. 17.—This figure illustrates Alia listening to the sentence "Make the doggie bite the snake" (top left). Alia approaches the array and bites the doggie herself.

in balls, although he frequently opened balls. Only by listening to the sentence and decoding the word order could he have responded to both requests appropriately. Even more unusual were the opposing requests "Make the doggie bite the snake" and "Make the snake bite the doggie." In both instances, Kanzi picked up the agent first and moved the agent toward the recipient. Alia misinterpreted the agent in this sentence and bit the doggie herself (see Fig. 17). Since Kanzi's previous experience had been with real snakes and dogs, and since he had never before encountered dogs and snakes together, his ability to enact such a truly novel sentence with toy exemplars supports the view that he understood the nature of language as a representational device and that he was able to respond to important structural rules.

The range of capabilities demonstrated by these subjects becomes apparent when their performance on a given word is seen in the context of all the different sentences presented with that word. For example, the word *ball* occurred in 76 different sentences, including such different requests as "Put the leaves in your ball," "Show me the ball that's on TV," "Vacuum your ball," and "Go do ball slapping with Liz." Overall, 144 different content words, many of which were presented in ways that required syntactic parsing for a proper response (such as "Knife your ball" vs. "Put the knife in the hat"), were utilized in this study. Neither subject could have performed at the levels of correctness that we found without comprehending the basic components of syntactic relations among words in a string.

RECEPTIVE VERSUS PRODUCTIVE CAPACITIES

The abilities of Kanzi and Alia to comprehend language clearly exceeded their productive abilities to a considerable degree. The discrepancy was even greater for Kanzi than for Alia, presumably because Kanzi's output was limited to lexigrams, whereas Alia could speak. Her mean length of utterance (MLU) increased from 1.91 to 3.19 during the study period, and toward its end she was able to construct syntactically appropriate sentences such as "Monster's grabbing bunny's hand," "Mommy gonna hide the M&M's," and "The snake bit you." Maintaining his MLU at 1.15 throughout the study period, Kanzi was able to form two-symbol combinations that displayed order and to construct simple ordering rules (Greenfield & Savage-Rumbaugh, 1990). However, neither subject produced sentences with embedded phrases or employed constructions with phrasal modifiers such as *that's*, even though both evinced comprehension of such structures.

Alia and Kanzi's comprehension of novel constructions differs from that reported for dolphins (Herman, 1987) and sea lions (Schusterman & Krieger, 1986) in a number of ways. The most important is the manner in which this comprehension is acquired. Both Alia and Kanzi observed competent speaking models and began to decode the speech signal into its components as well as to assign meaning to those components on their own. By contrast, the dolphins and sea lions were taught to perform specific actions on specific objects and were rewarded with fish for so doing. The "sentences" to be comprehended were broken down into word units, and the dolphin was repeatedly rewarded for carrying out individual commands such as "peck-touch frisbee" and "tail-touch hoop" until it could perform them without error. Training was then extended to three-symbol combinations, such as "window fetch hoop" and "gate fetch frisbee." After these commands were also performed without error, test combinations that contained a minor variation, such as "peck-touch hoop" or "window fetch frisbee," were given; the dolphins were able to respond correctly about 60% of the time.

The restricted nature of the input and the training format used with dolphins make it difficult to draw meaningful comparisons between their skills and those of Kanzi and Alia. Nonetheless, it can be said that all three species apparently respond to ordering rules that indicate relations among objects, although the dolphin's ability to do so appears limited to tightly controlled training settings that permit almost no structural flexibility. However, the structural knowledge that they do exhibit is the sort of skill that an intelligent creature could build on to construct a complex language were this skill utilized to *deduce* structure and to relate structured sound units to real-world events, as Kanzi and Alia did with spoken English.

While the data indicate that Kanzi was slightly more advanced than Alia with regard to comprehension of the syntactic devices of word order and recursion, Alia was able to use her capacities for speech in ways that Kanzi could not. For example, she often attempted to repeat the sentence after she heard it, as though encoding it herself helped her store the sentence in memory for action. Also, Alia used her vocal ability to refuse to perform on some trials and to indicate her preference for a specific alteration of the request on other trials. Kanzi may have attempted similar actions as he vocalized in similar circumstances. However, the human experimenters could not decode these vocalizations as readily and did not respond to them as they did with Alia.

ARE APES WASTING THEIR INTELLIGENCE IN THE WILD?

How did Kanzi come to understand the complexities and nuances of human speech when apes generally do not? We propose that the answer is to be found in how the neural networks of a highly complex and relatively plastic brain, such as is found in the order primates (Jerison, 1985; Stephen, Bauchot, & Andy, 1970), become organized in response to recurring and complex patterns of stimulation during infancy and early development. Not only is early environmental stimulation advantageous for the development of the nervous system (Bennett, Rosenzweig, Morimoto, & Herbert, 1979), but the primate brain is also responsive to the structure and function of recurring patterns of stimulation, be those afforded by light or by motor/activity patterns (Riesen, 1982; Stell & Riesen, 1987). Also, early environmental deprivation (e.g., in the first 2 years of life) can produce long-term, probably irreversible deficits in the ape's capacity for complex learning and proficient transfer of learning (Davenport, Rogers, & Rumbaugh, 1973; Rumbaugh & Pate, 1984).

In light of these documented findings, we propose that the basic neural structures for language learning are laid down during the first year of a child's life via recurring observations and visual-auditory patterns experienced in the social contexts of communication and behavioral coordination within which the infant receives care and nurturing. Notwithstanding the fact that psychologists historically have emphasized the role of reinforcement as regards learning, we suspect that observation and perceptual learning processes are far more important to the infant for the learning of complex systems—such as a language (Hopkins & Savage-Rumbaugh, 1991; Rumbaugh et al., 1991). This perspective is compatible with arguments advanced by Mandler (1990) to the effect that the human infant's percepts can produce conceptual representations of its world. The infant is capable of perceptually parsing objects within a complex visual field well before she can manipulate those objects, a capacity held by Piaget (1954) to be requisite for the most basic form of learning (i.e., sensorimotor learning) to occur. Such perceptions can be integrated and can serve to form concepts that Mandler terms *image schemas*—even in the first year of life.

Our thesis is that, as a function of its openness/plasticity, the infant brain, be it human or ape, is uniquely responsive to structured patterns of stimulation that are focal points of life. The brain is responsive both to the patterns and to the specifics of stimulation and assumes a neural organization that is consonant to its recurring themes. Also, it defines the constancies of its constituent relations (e.g., the correlations between words and their interactive use, on the one hand, and their attendant consequences, on the other) and becomes selectively responsive to new experiences that might be incorporated so as to elaborate the emerging structure. Experiences that "fit" are keenly attended and responded to; challenges that are antithetical to the structure and function of the primary developmental format are either resisted or experienced without the accrual of any specific benefit.

We suggest that, as Kanzi grew up hearing others speak and observing the consequences/sequelae thereof, enduring changes occurred in the neurological networks of his brain that most closely approximate those that were basic to the evolution of language in humans. Such networks might serve to integrate and extend Mandler's image schemas into a developing framework for language.

We propose that human competence for language—and also Kanzi's—is a reflection of genetically defined possible modes of development that are responsive to environmental complexity. It is both the plasticity and the inherent similarity between ape and human brains that permits them to lay down the structures of complex systems, such as language, during infant development, even though the manifestation of behaviors that reflect the operations of those systems might be deferred for several months. Early environment serves not only to foster relatively specific competencies but also to preclude the possible development of other dimensions of competence, and it does so increasingly over time.

The ease with which a bonobo such as Kanzi came to understand and use a form of language not characteristic of his species suggests that the communication capacities of wild bonobos may be underestimated. Bonobos employ a wide variety of vocalizations; however, no evidence of anything like a linguistic system of bonobo communication has been suggested (de

Waal, 1987; Kano, 1980; Kuroda, 1980; Mori, 1984). Is this because a linguistic communication system is not there, or might it be that a simple "language" of sorts does exist but that we have been unable to decipher it? By what sort of criteria can we judge whether another species possesses language? While it is generally accepted that only humans possess language, there is no standard set of criteria by which it can be determined that a nonhuman lacks it. The most thoughtful analysis of the problem is still the one provided by Altmann (1967), who concludes, "Many structural properties that are universal in human language are known to occur in various species of nonhuman primates, some of which combine several of these properties. Inadequacies in the available data on social communication among nonhuman primates make it impossible to say whether any species of primate other than man combines all of these properties. Consequently, it is not yet possible to test Charles Darwin's contention . . . that the behavior of man differs from the behavior of other animals in degree, not in kind" (p. 358). This statement remains equally valid 26 years after it was made. The social communication systems of more nonhuman primates have been described in greater detail, but new functional knowledge of these systems has remained elusive. What is needed is a knowledgeable "informant."

Anthropologists face a similar problem when they look back through time to discover the emergence of patterns characteristic of human behavior. Is it possible to determine when language appeared on the scene? It surely occurred before writing, as some cultures lack a system of writing even today, but beyond this the clues to its emergence are vague. By contrast, the earliest stone tools are known to have appeared in the archaeological record some 2–3 million years before *Homo sapiens* roamed the globe. Stone tools leave a residue that language does not; thus, language could have predated the appearance of stone tools without leaving an identifiable trace of its existence.

WHEN DID LANGUAGE EVOLVE?

The widely held view that nonhuman primates lack even simple language skills has been coupled with the Chomskian position that emphasizes the complexity of formal grammar and assumes that language is distinct from other cognitive skills. The coupling of these concepts has led to wide acceptance of the proposition that language must have evolved recently, a view that has been further bolstered by a reinterpretation of the archaeological record that has led to the conclusion that language appeared only 40,000 years ago, or some 160,000 years after *Homo sapiens* came on the scene (Davidson, 1991). The evidence for this interpretation arises from a virtual explosion of the diversity of artifacts that took place 40,000 years ago, including the first documented appearance of art.

In our view, and contrary to this position, Kanzi's ability to understand complex speech and to use written symbols spontaneously suggests that present-day apes possess the capacity for a simple language system and thus that our common ancestor was capable of some sort of symbolic communication. Had Kanzi's skills been systematically shaped with rewards, his accomplishments would have little relevance in speaking to the skills of our common ancestor. However, the fact that he acquired speech comprehension and lexigram usage from exposure to input similar to that received by a child indicates that these cognitive capacities are available to bonobos to use for language or for other skills.

As it is currently employed by human adults, language may not have existed when the first *Homo sapiens* appeared; nonetheless, it is evolutionarily untenable to insist that it appeared full blown and with all the grammatical complexity that it currently manifests unless the cognitive substrate to support it was already in place. Possibly this substrate had evolved for other purposes, such as tool construction or social negotiation. Virtually all observers of nonhuman primate groups have been impressed with the complexity of their social behavior (Humphrey, 1983), and those who have watched apes repeatedly stress the similarities to human social interactions across a wide range of behaviors (Goodall, 1986). Indeed, it is puzzling that the social networks of apes can be as complex as they are without language, for similar social networks in our own species are inevitably mediated by what we call language.

It is unfortunate that the techniques available for assessing vocal communication among wild bonobos are not adequate to uncover symbolic language, if such indeed exists. Symbolic communications regarding activities not currently taking place or objects not immediately present do not lend themselves to the current stochastic coding schemes. For example, if a bonobo were to produce a vocalization that compatriots could interpret as "I am heading toward bananas," how would we decipher the meaning of the vocalization?

Even if all his compatriots understood him, their responses could vary widely. Some might accompany him, others might meet him at the banana site, or any of a number of other equally plausible possibilities might occur. Coding the compatriots' behaviors *immediately* following the vocalization would indicate nothing about their interpretation of the sound. Nor could one design a properly lagged coding system since there would be no consistent temporal relation between the announcement of the intent and the different individuals' arrival at the banana site.

Field researchers have yet to discover whether or how apes plan their daily activities and travel patterns. Yet it is unlikely that apes wander randomly around the forest hoping to come on food. It is more probable that they set out with a specific destination in mind and, in addition, that they are able to communicate that destination to others in some way. Nothing is known about how apes determine where to travel next or indeed about how far in advance they plan their travel route. Yet, being large animals who require a great deal of concentrated food, they cannot afford to expend considerable effort traveling to a location that will contain little sustenance. Their survival depends on determining when and where they will be able to find significant food resources.

Fig trees, the preferred food source among chimpanzees, are rare and do not ripen seasonally. The trees must be checked regularly, or the ripened fruit will be otherwise quickly consumed by monkeys (Ghiglieri, 1984). Arriving at a food source at precisely the right time is difficult, and any information that one could glean from other apes, monkeys, birds, or one's own memory would be of considerable help in making travel plans. All such information would yield only inferential data regarding the probable ripeness of such a tree, and it would be more helpful if the various sources could be aggregated in some manner so as to arrive at a more informed probability judgment.

Thus, the ape is faced each day with the quintessential "traveling-salesman" problem, and his solutions to the problem will depend on his memory, information received from other animals, and his ability to plan ahead. His plans may take into account nothing more than the next stop, but it is likely that they include much more. Even by the age of 5 years, Kanzi was able to specify in advance travel routes that included two and three stops. If apes in the wild are doing anything similar, it is certain that planning skills are the ones that would also serve them well should they decide to design a language system.

Regardless of whether or not apes use some simple form of symbolic communication in the wild, it is clear that they cannot produce anything like the continuous stream of highly discriminable sounds that characterizes human speech. Any communication system that may exist is necessarily limited to relatively short staccato sounds that intergrade into each other with fuzzy boundaries. Nonetheless, Kanzi's ability to understand human speech suggests that, if apes could produce human-like sounds, they might well invent and utilize a language that would be similar to our own, although probably considerably simpler.

Arguments from Tool Use

However, the currently popular evolutionary view of language—that it was a very late adaptation, occurring approximately 40,000 years ago

(Davidson, 1991)—presumes that tool use antedates language by at least 1.5 million years and that the cognitive capacities required to produce stone tools are considerably less complex than those required to develop a simple language. This view is hard to reconcile with the fact that children use language for some time before they begin to construct simple tools. Indeed, studies of the relation between tools and language have consistently looked at the emergence of tool *use* rather than tool *construction* (Bates et al., 1988) since language (both basic semantics and basic syntax) is rather well developed prior to the appearance of tool construction.

Toys involving elementary construction, such as Lego blocks, become popular with children after 3 years of age, after basic semantics and syntax are in place. Prior to this time, toys that reflect simpler schemata such as shaking, pushing, carrying, hitting, throwing, storing, stripping, opening, inserting, and extracting predominate. All these simpler schemata can be found among apes and are essential to their foraging strategies. For example, wild chimpanzees employ stones to crack nuts (Boesch, 1978). Stones used for these purposes are not modified in any manner, but they are transported for distances of several hundred meters. Because the dispersal of plant foods is predictable in space and time, it is possible to carry a rock several hundred meters, knowing that the nuts will be there waiting when one arrives. The abilities of apes to use simple tools, to plan ahead given that the environment is predictable, and to carry objects bear a remarkable similarity to the capacities of 2½-year-old children. Given the linguistic competencies of children at this age, it seems probable that early man utilized some form of language by at least 2 million years ago. Also, the fact that Kanzi displays comprehension skills that are equivalent to those of a 2½-year-old suggests that modern apes would be capable of a simple language if their vocal apparatus would but permit speech.

Ape versus Human Vocal Apparatus

Critics of ape language have often argued that, if apes could talk, they would be reported to do so in the wild (Harre & Reynolds, 1984). This perspective overlooks the fact that the vocal apparatus of the ape differs sufficiently from that of man to preclude speech. Conceivably, apes possess the cognitive capacities for language but lack the proper organ of expression. While apes are capable of a number of different sounds, their sounds grade into each other, making it difficult to determine where one sound ends and another begins (de Waal, 1988; Marler, 1976). All nonhuman primate vocalizations depend primarily on vowels. Humans alone are capable of producing phonemes with categorical boundaries such as /da/ and /ga/. The ability to produce consonants in association with vowels allows for the production of an exceedingly large number of discriminable sounds because of the phenomenon of categorical perception. Thus, any vocal language used by apes in the field would of necessity be restricted by the limited number of discriminable sounds that their oropharyngeal cavity could produce.

Of course, it is not the restructuring of the oropharyngeal cavity alone that results in speech. Along with this restructuring have also arisen the ability to control respiration and coordinate it with speech, the ability to produce voluntary sustained glottal pulses with controlled exhalation, and an increase in the degree of neurological control over fine movements of the lips and tongue. The production of each phoneme requires many muscular adjustments of the tongue, jaw, lips, soft palate, and vocal folds, in concert with the respiratory apparatus. The production of a succession of such sounds, as in the speech of modern human adults, entails motor planning of great complexity.

Nonetheless it is basically the ability to produce consonants that permits man to exploit the oral medium as a sophisticated mode of communication. Apes cannot produce consonants because the angle of articulation of their vocal-laryngeal tract prohibits velar closure (Crelin, 1987). Instances of damage to the vocal tract in human adults reveal that the ability to accomplish velopharyngeal closure is a critical dimension to the production of intelligible speech. Persons who have suffered complete loss of the tongue, half the mandible, and other oral structures can nonetheless produce speech that sounds almost normal and certainly intelligible. Yet failure of the velopharyngeal mechanism to permit closure makes speech communication virtually impossible (Perkins & Kent, 1986).

The need to balance the skull upright on the spine necessitated a rearrangement of the internal soft tissue and led to the possibility of at least partial velopharyngeal closure. Kanzi's ability to decode human sounds as well as syntactic constructions using combinations of these sounds suggests that ancestral *Homo* had developed a primitive linguistic skill that was awaiting the proper articulatory system. It seems quite probable, as Kuhl (1987) has suggested, that the articulatory system evolved to take advantage of the encoding properties already present in the mammalian auditory system. That is, the ability to produce speech was a recent evolutionary development that built on both the cognitive capacity to generate and comprehend complex ideas and the auditory capacity to perceive categorical boundaries. Once the ability to produce sounds with those acoustic properties appeared, language flowered because the other components were already in place. Early hominids could produce a greater variety of easily discriminable distinct sound units than they could form previously. The new consonants or consonant-like sounds could be used as boundaries around the vowel-like sounds that they already produced. The vowel-like sounds were thus bounded by easily discriminable units. Because of their categorical boundary properties, the consonant-like sounds were able to function as "edges" within what was previously a continuous sound system. Language was on its way.

IN CONCLUSION

Previous studies of the language capacities of apes have led to two widely accepted conclusions: (*a*) that they imitate their caregivers and (*b*) that they are not able to produce syntactically based sentences (Terrace et al., 1979). In spite of evidence that these conclusions were erroneous and premature (Greenfield & Savage-Rumbaugh, 1990, 1991; Savage-Rumbaugh, 1991; Savage-Rumbaugh et al., 1986), they have nonetheless gained wide acceptance. This has happened in part because no comparative data collected under similar conditions existed for apes and children; consequently, the ape has often been contrasted with the "idealized" child but has never been systematically compared with a real child.

Because this study focused on the comprehension of spoken English, and because Kanzi and Alia acquired this skill in similar environmental settings, they could be tested in a similar manner, permitting for the first time a systematic comparison of the language capacities of ape and child. The findings directly challenge the accepted dogma with regard to ape language capacities. Kanzi's comprehension cannot be attributed to imitation since there was nothing to imitate. The experimenter did not carry out a set of actions that Kanzi then followed. Information processing at a syntactic level was apparent throughout the data base, both in correct responses and in errors. Comprehension was evident not only for word order but for recursion as well. Additionally, the comprehension was not of an "invented language" but of spoken English, which entailed the parsing of phonemes and words as well as of sentence structure.

The fact that comprehension abilities of this level appear spontaneously in the bonobo reared in an environment similar to that encountered by a child strongly implies that apes have a heretofore unrecognized capacity for language. While it is generally assumed that bonobos exhibit no language-like communications in the field, such assumptions are based on minimal data and, in light of Kanzi's capacity, should be carefully reexamined.[2]

[2] The data in this *Monograph* supersede all previous preliminary reports. They reflect a more detailed scoring system and a review of all data mentioned in previous preliminary reports. Readers wishing to obtain further documentation and information about our work should contact E. Sue Savage-Rumbaugh, Language Research Center, Georgia State University, 3401 Panthersville Rd., Decatur, GA 30034.