BIOLOGICAL AND BEHAVIORAL DETERMINANTS OF LANGUAGE DEVELOPMENT

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10 Imitation, Grammatical Development, and the Invention of Protogrammar by an Ape

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The conservative nature of evolution, plus wide agreement that human language has a strong innate basis (Chomsky, 1965, 1967; Goldin-Meadow, 1978; Goldin-Meadow & Mylander, 1984; Lenneberg, 1967; Lieberman, 1984), suggests that much of the genetic basis of human language must be shared not only with present-day chimpanzees but also with our common primate ancestor. There is evidence that a species of chimpanzee, *Pan paniscus,* shows more resemblance than humans or the other great apes to this common ancestor (Zihlman, Cronin, Cramer, & Sarich, 1978). *Pan Paniscus* is also closer to humans in sociosexual behavior (Savage-Rumbaugh, 1984) and prolonged maturation (Kuroda, 1989) than the other, more commonly studied chimpanzee species, *Pan troglodytes.* For these reasons, our selected species, *Pan paniscus* (also known as the pygmy chimpanzee or bonobo) is a particularly promising model for the behavioral exploration of human evolution.

Our studies of imitation and protogrammar in the bonobo or pygmy chimpanzee provide new clues to the evolutionary origins of conversational competence and grammar in human language. Although we have exposed *Pan paniscus* to a humanly devised symbol system, we have not looked merely for chimpanzee analogues of what humans do with a symbol system, but have discovered languagelike phenomena that reflect the ape's own propensities and its way of life (McNeill, 1974).

Bypassing the vocal limitations of chimpanzees and other apes, research projects beginning in the late 1960s (summarized by Hill, 1978) used visual symbol systems to take apes much further into human language than previous attempts (Kellogg, 1968). Just how far became, however, very controversial (Bronowski & Bellugi, 1970; Chomsky, 1967; Limber, 1977; Petitto & Seidenberg, 1979; Terrace, Petitto, Sanders, & Bever, 1979, 1980).

Imitation

Terrace et al. (1979, 1980) have interpreted the presence of imitation in language-trained chimpanzees as an indication that chimpanzees differ significantly from human children in their language-learning ability. Implicit in this argument is the notion that imitation reflects a rote and mechanical approach that does not characterize true human language. According to this view, imitation displays an absence of conversational competence.

However, studies of imitation in human children suggest that it serves many different pragmatic functions in a conversation (Ochs Keenan, 1977). The rarest of these is rote imitation, defined as the intention to copy another (Ochs Keenan, 1977). Examples of the various functions repetition can serve in young children's speech are presented in Table 10.1. Only in the last example in Table 10.1 is the purpose of the repetition to imitate—and even there imitation is not rote. Instead, it is meaningfully selective. In sum, imitations in children (and humans more generally) reveal the presence of conversational competence.

An analysis of chimp–human discourse shows that two pygmy chimpanzees, Kanzi and Mulika, use partial or complete repetition of others' symbols as children do: They usually do not produce rote imitations, but rather use repetition to fulfill a variety of conversational purposes (Table 10.2). This analysis follows that used with human children by Ochs Keenan (1977) and should be equally acceptable for chimpanzees. Unfortunately though, there has tended to be a double standard for assessing the linguistic competence of human children and chimpanzees (de Villiers, 1984).

Grammar

Rules through which symbols may be combined in a potentially infinite number of ways constitute grammar, often considered the sine qua non of human language (Chomsky, 1965). Apes can learn to combine two or more symbols in nonrandom ways (Fouts & Couch, 1976; Gardner, R. A., & Gardner, B. T., 1969; Patterson, 1978, 1980; Terrace et al., 1979), including the use of sign language inflections (Patterson & Linden, 1981; Rimpau, Gardner, & Gardner, 1989). However, from a linguistic point of view, combinations alone, even inflected combinations, are not sufficient to demonstrate grammar. There are, at minimum, five basic criteria that must be met before a grammatical rule can be attributed to such combinations:

TABLE 10.1
Uses of Repetition by Humans

Function	Example
Confirm/Agree	(Matthew, age 12 months) Mother: *Is that the birdie?* Matthew: *dird* (bird), pointing to it. (Greenfield, unpublished data, 1969)
Excitement	(Twins, Toby and David, with their nanny, Jill) Jill: *And we're going to have hot dogs.* Toby: *Hot dogs!* (excitedly) Jill: *And soup.* David: *Mmm soup!* (Ochs Keenan, 1977)
Choose Alternative	(Katie, age 14 months, with caregiver at infant daycare center. Caregiver pretends to pour tea for both of them, and they pretend to drink it.) Caregiver: *Are you full, or do you want some more?* Katie: *More.* *(Leddick, unpublished observation, 1989)*
Imitation	(Twins, Toby and David, 2 yrs., 9 mos., with their nanny, Jill) Jill: *Aren't I a good cook? Say "Yes, the greatest!"* Toby: *Yes the greatest.* (Softly) Jill: *That's right.* David: *The greatest!* (loudly) (Ochs Keenan, 1977)

Note. Adapted with permission from "Comparing Communicative Competence in Child and Chimp: The Pragmatics of Repetition" by P. M. Greenfield and E. S. Savage-Rumbaugh. *Journal of Child Language* (in press).

1. Each component of a combination has independent symbolic status (Brown, 1973).
2. A reliable and meaningful (semantic) relationship exists between the symbols (Savage-Rumbaugh, 1990).
3. Relations between categories of symbols are involved, not merely relations between individual symbols (Bronowski & Bellugi, 1970).
4. Some formal device, either inflection or statistically reliable order (Braine, 1976; Goldin-Meadow & Mylander, 1984), is used to relate the symbol categories.
5. Rules are productive (Savage-Rumbaugh, Sevcik, Rumbaugh, & Rubert, 1985)

a. Utterances are *not* imitated (Petitto & Seidenberg, 1979)
b. A wide variety of combinations is produced (Bronowski & Bellugi, 1970)
c. Some new rules never modeled are created. (This last is not a criterion for the existence of a rule, but for the invention of a rule.)

Terrace et al. (1979) have pointed out the deficiencies of studies of chimpanzee grammar in a number of these areas. Indeed, no previous study has satisfied all of these criteria. Some researchers have trained a predetermined symbol order (without establishing that the chimpanzees were able to use the individual symbols meaningfully) (Muncer & Ettlinger, 1981; Premack, 1970; Rumbaugh, Gill, & von Glaserfeld, 1973). In other research, symbol selection was constrained experimentally through reinforced associations (Matsuzawa, 1985). In still other research, repetitive question prompts were used to generate the corpus (Gardner, B. T., & Gardner, R. A., 1975; Van Cantfort, Gardner, & Gardner, 1989). The spontaneous, creative, or communicative aspects of grammatical combination were therefore lacking to one extent or another. Still other researchers have reported data incompletely or have not systematically eliminated imitations from the analyses (Gardner, B. T., & Gardner, R. A., 1974; Gardner, R. A., & Gardner, B. T., 1969; Miles, 1990; Patterson, 1978, 1980; Patterson & Linden, 1981; Rimpau, Gardner, R. A., & Gardner, B. T., 1989; Terrace et al., 1979, 1980). Imitation leaves open the possibility that combinations may reflect productive use of grammar by humans rather than by apes (Terrace et al., 1979).

Another problem in grammatical studies of ape language is that rules for ordering two symbols often have been idiosyncratic to particular signs rather than combinations between members of two symbol categories (Fouts & Couch, 1976; Terrace et al., 1979, 1980). At the two-word stage, the stage with which we are principally concerned in our analysis of chimpanzee grammar, this limitation sometimes exists for human children as well (Braine, 1976). In mature human grammar, however, basic syntactic rules (e.g., in English, subject precedes verb) involve a large number of lexical items that can function in each syntactic category (e.g., adult subject and verb categories each contain many lexical items). We show that Kanzi's emergent syntax also involves relations between categories, each of which is composed of diverse lexical items.

Rules must not only exist independently of highly structured training settings and imitation; they must, at least in part, be determined by the ape as well as by its models. Early protohumans invented language; they did not merely learn it. To truly shed light on the evolution of grammar, it is necessary to demonstrate some capacity to invent grammatical rules.

Although claims of innovative compound words abound in the ape language literature (Fouts, 1974, 1975; Patterson, 1980; Miles, 1975; Patterson & Linden, 1981), these are by their nature one-time occurrences and ambiguous (Petitto & Seidenberg, 1979; Terrace et al., 1979, 1980); in any case, such examples belong to the lexicon rather than grammar. In contrast, we present examples of statistically reliable protogrammatical rules that an ape has invented himself.

REARING ENVIRONMENT AND SUBJECTS

The primary communication system of the present study consists of lexigrams (printed geometric symbols). (Methodological details are presented in Savage-Rumbaugh, McDonald, Sevcik, Hopkins, & Rubert, 1986.) A few informal and American Sign Language gestures also are used alone and in combination with the lexigram system.[1] Human companions use English freely (for examples, see discourse in Table 10.2). Details of procedure are presented in an earlier publication (Savage-Rumbaugh et al., 1986).

Kanzi, a bonobo chimpanzee, received his first exposure to the use of lexigrams, gextures, and human speech at 6 months of age while in the care of his mother, who was in a language-training program (Savage-Rumbaugh et al., 1986). He produced his first lexigram at age 2½ years without training. A complete record has been kept of Kanzi's semiotic productions since that time.

Mulika, his half-sister, was born when Kanzi was 3 years old. She spontaneously produced her first lexigram at 12 months of age. A complete record subsequently was kept of her semiotic usage.

In contrast to other studies that have attempted to train symbols or signs (Asano, Kojima, Matsuzawa, Kubota, & Mutofushi, 1982; Fouts, 1973; Gardner, B. T. & Gardner, R. A., 1980; Gardner, R. A. & Gardner, B. T., 1969; Kellogg, 1968; Miles, 1983; Premack, 1970; Rumbaugh et al., 1973; Savage-Rumbaugh, 1986), the purpose of this research was to determine how much language the pygmy chimpanzee could acquire in the ongoing course of normal communication similar to what human children receive. Training has been avoided assiduously, even to the point of not asking the repetitive questions typically seen in early mother-child dialogue. The chimpanzees also are raised in a more natural environment. They have not been separated completely from their mother, and they forage daily in a large forest which is replenished with food.

As reported elsewhere (Savage-Rumbaugh et al., 1986), they have begun to comprehend spoken English, and such comprehension typically precedes

[1]Miles (1975, 1978) reports a closely related phenomenon in language-trained *Pan troglodytes* chimpanzees: combinations consisting of a formal American-Sign-Language sign, plus a natural communication element, such as a play posture.

TABLE 10.2
Uses of Repetition by Pygmy Chimpanzees (*Pan Paniscus*)

Confirm/Agree

(Kanzi, age 5, with Kelly)
With Kanzi on her shoulders, Kelly stops at the door leading outside to comment at the lexigram board.
Kelly: *We are GOing to see the GIBBONs* (as per Kanzi's earlier request).
Kanzi: *GIBBON,* vocalizing *eh-uh* in agreement.

(Mulika, age 2, with human caregiver/researcher, Kelly)
Kelly: *#Let's see what's on TELEVISION.*
Mulika: *TELEVISION* (Then Mulika went to the video deck and gestured to it, ready for Kelly to put a tape in.)

(Kanzi, age 5, with human caregiver/researcher, Rose)
Kanzi has indicated that he is interested in looking in the refrigerator. Rose opens it and Kanzi points to a bowl of raspberries. Rose takes out the raspberries and uses the keyboard.
Rose: *We will call these FOOD.* (This is because there is not a symbol for raspberries on the keyboard.)
Kanzi: *FOOD* (He does not indicate any desire to have the raspberries, however, but goes over and looks out the window.)

Excitement

(Mulika, age 2, with human caregiver/researcher, Kelly)
Kelly: *GO A-FRAME* (informing Mulika of destination verbally and with lexigrams)
Mulika: *GO,* vocalizing excitedly

Choose Alternative

(Kanzi, age 5, with human caregiver/researcher, Rose)
Rose: *You can either PLAY or watch TV.*
Kanzi: *TV* (Kanzi watches after Rose turns it on.)

Imitation/Request

(Mulika, age 2, with human caregiver/researcher, Karen)
Mulika reaches for Karen's coke.
Karen: *COKE,* showing Mulika the lexigram
Mulika: *COKE*

Note. Italicized capital letters indicate lexigrams for the chimps, lexigrams plus spoken English for the humans; italicized small letters indicate spoken English. Adapted with permission from "Comparing Communicative Competence in Child and Chimp: The Pragmatics of Repetition" by P. M. Greenfield and E. S. Savage-Rumbaugh. *Journal of Child Language* (in press).

the onset of lexigram usage. Through formal vocabulary tests of comprehension and production (Savage-Rumbaugh, 1987; Savage-Rumbaugh et al., 1986), the researchers established the independent symbolic status of most of the lexical elements used in combinations (details are to be found in Greenfield & Savage-Rumbaugh, 1990).

IMITATION BY KANZI AND MULIKA

This analysis focuses on a month of data taken during October of 1985, when Kanzi was 5 and Mulika almost 2 years old. Table 10.2 presents qualitative examples of some of the communicative functions that repetition served for Kanzi and Mulika. Note that the functions parallel those presented in Table 10.1 for human children. In similar fashion, Kanzi and Mulika selectively repeat lexigrams produced by their conversational partners for pragmatic purposes: to confirm or agree, to express excitement, to choose an alternative, as well as to imitate. An important point is that these functions do not occur exclusively in request or instrumental situations; in the last CONFIRM/AGREE example, Kanzi confirms an identification, without wanting the identified item (FOOD). (The reader is referred to Greenfield & Savage-Rumbaugh (in press) for quantitative results and more detailed analysis.)

Terrace et al. (1979), in their treatment of imitation, pointed out that their chimpanzee, Nim, imitated more than the typical child (44%, including expansions) (Sanders, 1985). In contrast, ape language projects deemphasizing drilling and emphasizing a naturalistic communication environment have found lower rates of imitation than did Project Nim, which relied heavily on rote language drill as a teaching method (Greenfield & Savage-Rumbaugh, 1984; Miles, 1983, 1990; Patterson, 1979, 1981). Similarly, Kanzi and Mulika imitate less than Nim and do not differ from human children in this respect. Kanzi's rate of 6% immediate imitation is similar to figures for children up to age 3 years. Mulika's rate of 21% is not above the range of children between 1 and 2 years of age, just starting to talk (Goldin-Meadow & Mylander, 1984).

KANZI'S GRAMMAR

This analysis was based on 5 months of Kanzi's output, April through August 1986; Kanzi was 5½ years old. (Mulika's lexigram skills were not well enough developed for her to make frequent combinations.)

In order to assure the creativity of Kanzi's symbol combinations, we excluded all imitations (including reductions and expansions) from the analysis. We also analyzed video tapes to determine caregiver input and, hence, the possible environmental source of any rules that might develop. (See details in Greenfield & Savage-Rumbaugh, 1990.)

Following accepted methodology for studying word or sign combinations of children at the two-word stage (Brown, 1973; Goldin-Meadow, 1984; Schlesinger, 1971), we classified all two-element combinations (lexigram-lexigram and lexigram-gesture) for which contextual information was available into semantic relations such as agent-action and action-object. We used Kanzi's behavior subsequent to an utterance as the basis for judgments of semantic relations, thus resolving the problem of the subjectivity of "rich interpretation." Table 10.3 presents the distribution and examples of semantic relations; the examples also illustrate how Kanzi's behavior provided "behavioral concordance" for assigning combinations to semantic

TABLE 10.3
Distribution of Two-Element Semantic Relations in Kanzi's Corpus

Relation		*Example (of Dominant Order)*
Conjoined Actions[a]	92	*TICKLE BITE*, then positions himself for researcher/caregiver to tickle and bite him
Action-Agent[a]	119	*CARRY you (gesture)*, gesturing to Phil, who agrees to carry Kanzi
Agent-Action[a]	13	
Action-Object[a]	39	*KEEP-AWAY BALLOON*, wanting to tease Bill with a balloon and start a fight
Object-Action[a]	15	
Object-Agent[a]	7	*BALLOON you (gesture)*, Kanzi gestures to Liz; Liz gives Kanzi a balloon.
Agent-Object[a]	1	
Entity-Demonstrative[a]	182	*PEANUT that (gesture)*, points to peanuts in cooler.
Demonstrative-Entity[a]	67	
Goal-Action[a]	46	*COKE CHASE;* then researcher chases Kanzi to place in woods where Coke is kept
Action-Goal[a]	10	
Conjoined Entities[b]	25	*M & M GRAPE*. Caregiver/researcher: "You want both of these foods?" Kanzi vocalizes and holds out his hand.
Conjoined Locations[b]	7	*SUE'S-OFFICE CHILDSIDE;* wanted to go to those two places.
Location-Entity[b]	19	*PLAYYARD AUSTIN;* wants to visit Austin in the playyard.
Entity-Location[b]	12	
Entity-Attribute[b]	12	*FOOD BLACKBERRY*, after eating blackberries, to request more.
Attribute-Entity[b]	10	
Miscellaneous[b]	37	These include low-frequency relations (less than seven) such as attribute of action, attribute of location, affirmation, negation, and relations involving an instrument.
Two-Mode Paraphrase[b,c]	4	*CHASE chase (gesture)*, trying to get staff member to chase him in the lobby.
No Direct Relation[b]	6	*POTATO OIL;* Kanzi commented after researcher had put oil on him as he was eating a potato.
TOTAL	723	

Note. Italicized capital letters indicate lexigrams. Adapted with permission from "Grammatical Combination in *Pan Paniscus:* Processes of Learning and Invention in the Evolution and Development of Language" by P. M. Greenfield and E. S. Savage-Rumbaugh (1990), in S. T. Parker and K. R. Gibson (Eds.), *"Language" and Intelligence in Monkeys and Apes: Comparative Developmental Perspectives*, New York, Cambridge University Press.

[a]These relations are analyzed for their ordering regularities in the tables and text that follow. [b]These relations either lacked ordering structure or were too infrequent to be subject to such an analysis. [c]There were no purely repetitious two-symbol utterances in the two-symbol corpus. This low-frequency category contains the closest phenomenon to a repetition.

relations. To supplement this table, the 5-month corpus of Kanzi's two-element combinations consisting of two lexigrams or one lexigram and one gesture is presented as an appendix. (Methodological details concerning reliability and coding appear in Greenfield & Savage-Rumbaugh, 1990.)

Next we discuss in detail all those relations in which Kanzi used symbol order as a formal device to construct a particular semantic relationship.

Rule Learned from Environmental Models: Action Precedes Object

The variety of action-object examples presented in the appendix illustrate the second criterion of a grammatical rule: Kanzi relates two symbol categories; he combines and recombines a category of nine action lexigrams with a second category of 13 object lexigrams.

Contrary to the claim that chimpanzees cannot make verbal statements but are limited to demands or instrumental requests (Petitto & Seidenberg, 1979; Sanders, 1985), the top of Table 10.4 presents a statement (*HIDE PEANUT*) by Kanzi of his impending action. Statements are in the minority in our data (4%), but they do occur.

The second part of Table 10.4 shows the development of a symbol-ordering rule. As children often do at the two-word stage (Braine, 1976), Kanzi moves from no significant ordering tendency at the beginning of the period (first row of figures) to a statistically significant preference for the action–object ordering found in English (second row of figures) (a preference that, unlike Nim's, is not disturbed by countertrends of individual lexical items [Terrace et al., 1980]). The fact that Kanzi's caregivers show this same action–object order in even stronger form than does Kanzi (Table 10.4, last row of figures), indicates that it originated in the environmental model presented to him.

Looking at this developmental trend another way, we can say that there is significant movement away from an object–action order, toward an action–object order ($p < .01$, χ^2 test). It may be of evolutionary significance that this movement parallels a common trend in the history of language away from an object–verb order and toward the verb–object order (Nocentini, 1988).

To test whether the semantic relation between actions and objects actually was understood by Kanzi at the time of his production data, we looked at naturally occurring examples of comprehension and miscomprehension of action–object lexigram relations expressed by human caregivers during the same period of time. The results show that Kanzi not only used but understood this relationship (Greenfield & Savage-Rumbaugh, 1990). Here is an example of correct comprehension:

Caregiver/researcher: *PLAY HAT KEEPAWAY*
Kanzi grabs the hat and shakes it at caregiver/researcher.

TABLE 10.4
Kanzi's Two-Element Lexigram-Lexigram Combinations: Relations Between Action and Object (Animate and Inanimate)[a]

Examples	*Action*	*Object*	
Inanimate Object	*HIDE*	*PEANUT*	Kanzi then hides some peanuts.
Animate Object	*GRAB*	*HEAD*	Caregiver/researcher has been biting and grabbing Kanzi's head. Kanzi gets into her lap (into position to be grabbed).

	The Development of Kanzi's Lexigram Order		
	Action-Object	*Object-Action*	
Early (4/10/86–4/26/86)	3	7	
Late (4/29/86–8/30/86)	31	6	$p < .00000$[b]
	Kanzi's Human Caregivers' Lexigram Order		
	Action-Object	*Object-Action*	
	51	7	$p < .00000$[b]

Note. Lexigrams are in italicized capital letters. Adapted with permission from "Grammatical Combination in *Pan Paniscus:* Processes of Learning and Invention in the Evolution and Development of Language" by P. M. Greenfield and E. S. Savage-Rumbaugh (1990), in S. T. Parker and K. R. Gibson (eds.), *"Language" and Intelligence in Monkeys and Apes: Comparative Developmental Perspectives*, New York, Cambridge University Press.

[a]Because there was evidence (to follow) that gestures were treated separately from lexigrams in Kanzi's formal rules, combinations in which an object was symbolized by a demonstrative gesture were not included in the action-object rule. However, these examples are included in the appendix.

[b]Test for significance of a proportion (one-tailed). (Bruning & Kintz, 1977).

This example is all the stronger because playing keepaway is not the obvious action to do with a hat.

The next example is of a misunderstanding that strongly indicates that Kanzi constructs action–object relations in his own mind:

> Caregiver/researcher: *ICE,* commenting on a big block of ice on TV. *Someone is HIDing in the ice.*
>
> Kanzi starts searching under the blankets. He has apparently understood the action–object relation, HIDE ICE, and is looking for the ice!

As with children, an error provides the best evidence of Kanzi's own constructions. This particular misunderstanding provides evidence for constructive comprehension of an action–object relation.

Invented Rules

A Formal Rule: Gesture After Lexigram. Kanzi's human caregivers have exposed him to the English word-order model, agent before action (Human Caregivers' order, third and fourth row of figures, Table 10.5). His own lexigram-lexigram combinations (second line of figures in Table 10.5) show signs of following this rule, but they are too infrequent for statistical reliability. However, Kanzi makes up his own rule for combining agent gesture with action lexigram: His highly significant ordering rule, "Place gesture last" (the first line of figures, Table 10.5), uses the opposite ordering strategy from that of his caregivers' English-based rule. Note that Kanzi's caregivers conform to their English-based ordering strategy even in their gesture plus lexigram utterances (third line of figures, Table 10.5).

Kanzi's rule, "Place gesture last," has considerable generality as well as originality. The remainder of Table 10.5 shows how this rule is manifest in three other semantic relations: entity-demonstrative, goal-action, and object-agent. In the case of these three relations, Kanzi's rule operates in the absence of a human model, as the human model figures in Table 10.5 show.

Although three of the relations involve a demonstrative gesture, the fourth, goal-action, involves combining a lexigram with one of several action gestures. Thus, to a limited extent, this rule involves relations between two categories, a larger category of lexigrams and a smaller category of gestures.

The rule "Place gesture last" may have been a purely arbitrary formal rule. It was not merely an artifact of lack of vocabulary on the lexigram keyboard. For example, the lexigram LIZ was always on the keyboard. It was produced in first position in LIZ HIDE (agent-action relation in appendix). However, at other times Kanzi did not use a lexigram to refer to Liz; he gestured instead (see *BALLOON you [gesture referring to Liz]* in Table 10.3). Although Kanzi could have used the lexigram LIZ in this last example, he chose to denote Liz through gesture, and, at the same time, the expression of Liz as agent moves from first position as a lexigram to second position as a gesture.

Nor was the order, gesture-after-lexigram, strictly a matter of physical convenience. In one video, Kanzi was relatively near a person and far from the lexigram board. Yet he moved to the board to touch a lexigram, then returned to gesture toward the person. In this situation, producing the gesture last involved greater physical effort and more time than producing the gesture first would have. Although this observation confirms the impression of a purely formal arbitrary rule, a defining feature of human language, there is another possibility that cannot be eliminated. Kanzi's caregivers often waited for him to confirm or behaviorally specify the meaning of a lexigram utterance; Kanzi often did this by means of a gesture.

TABLE 10.5
Kanzi's Ordering Rule: Gesture Follows Lexigram

RELATIONS BETWEEN AGENTS AND ACTIONS

Example:	Action	Agent
Kanzi:	*CHASE*	*you (demonstrative gesture)*

Kanzi says this after caregiver/researcher, suggests going to sandpile for food. Kanzi touches caregiver/researcher, who agrees to chase him there.

	Kanzi's Order		
	Agent-Action	*Action-Agent*	
Lexigram Action-Gesture Agent	7	116	$p = .00000$[a]
Lexigram-Lexigram	6	3	

	Human Caregivers' Order	
	Agent-Action	*Action-Agent*
Lexigram Action-Gesture Agent	14	0
Lexigram-Lexigram	14	0

ENTITY-DEMONSTRATIVE RELATIONS

Example:	Entity	Demonstrative
Kanzi:	*FOOD*	(demonstrative gesture)

He requests food from cooler by pushing FOOD key and then pointing to cooler.

	Demonstrative Gesture 1st	*Demonstrative Gesture 2nd*	
Kanzi	67	182	$p = .00000$[a]
Human Model	3	2	

GOAL-ACTION RELATIONS

Example:	Goal	Action
Kanzi:	*DOG*	*(go gesture)*

He then led to the dogs' pen.

	Action Gesture 1st	*Action Gesture 2nd*	
Kanzi	0	30	$p = .00000$[a]
Human Model	0	0	

OBJECT-AGENT RELATIONS

Example:	Object	Agent
Kanzi:	*BALLOON*	*You (demonstrative gesture to person)*

Kanzi gestures to researcher; she gives Kanzi a balloon.

	Agent Gesture 1st	*Agent Gesture 2nd*	
Kanzi	1	7	$p < .03$[a]
Human Model	0	0	

Note. Lexigrams are in italicized capital letters. Adapted with permission from "Grammatical Combination in *Pan Paniscus:* Processes of Learning and Invention in the Evolution and Development of Language" by P. M. Greenfield and E. S. Savage-Rumbaugh (1990), in S. T. Parker and K. R. Gibson (Eds.), *"Language" and Intelligence in Monkeys and Apes: Comparative Developmental Perspectives*, New York, Cambridge University Press.

[a]Test for significance of a proportion (two-tailed) (Bruning & Kintz, 1977).

Thus, the structure of the communicative situation may have inadvertently influenced the "gesture last" rule.

Kanzi "Teaches" his Human Caregivers an Invented Rule: Symbol Order Reflects Action Order. Kanzi frequently combined two action lexigrams (see first example in Table 10.3 and first category in Appendix). At first glance, these combinations seemed to be mere unstructured lists. Unlike the other rules discussed up to now, they lack the minimum requirements of a proposition: one predicate and one argument; conjoined action combinations simply chain two predicates. However, these combinations revealed unsuspected regularities (Table 10.6), reflecting natural action categories and preferred action orders in social play. Kuroda observed some of these same preferred behavior sequences among pygmy chimpanzees in the wild (S. Kuroda, personal communication, July 1987), as has Boehm (1988) with other species of chimpanzee, *Pan troglodytes.* Table 10.6 presents quantitative evidence that Kanzi translates regularities of action order into regularities of lexigram order.

Most important, Kanzi has not only created these symbol ordering rules for action-action sequences himself, but he has also invented the very relation of conjoined action. In 6 hours of videotape, dating 5 months before the start of the corpus, when Kanzi was already producing frequent conjoined action combinations, there was only one example of a caregiver combining the action words involved in the conjoined-action ordering rule; and that one example was a direct imitation of Kanzi. Five months later, at

TABLE 10.6
Conjoined Action Lexigram Combinations

Prefers in 1st Position	*No. Times 1st*	*No. Times 2nd*	
CHASE	19	8	$p < .04$[a]
TICKLE	29	15	$p < .04$[a]
Prefers in 2nd Position			
HIDE	2	9	$p < .04$[a]
SLAP	1	6	$p < .06$[a]
BITE	21	38	$p < .04$[a]
No Position Preference			
GRAB	5	4	
HUG	7	5	

Note. Lexigrams are in italicized capital letters. Adapted with permission from "Grammatical Combination in *Pan Paniscus:* Processes of Learning and Invention in the Evolution and Development of Language" by P. M. Greenfield and E. S. Savage-Rumbaugh (1990), in S. T. Parker and K. R. Gibson (eds.), *"Language" and Intelligence in Monkeys and Apes: Comparative Developmental Perspectives*, New York, Cambridge University Press.

[a]Test for significance of a proportion (two-tailed) (Bruning & Kintz, 1977).

the start of our corpus, in about 2 hours of videotape, there were 10 examples of conjoined-action combinations produced by caregivers; however, a caregiver was imitating Kanzi in 9 out of 10 cases. (Two caregivers were sampled in the earlier period; the same two, plus two more, were sampled in the later period.) The fact that, in virtually all instances, the caregivers imitated Kanzi's conjoined-action utterances indicates that Kanzi not only invented conjoined action meaning rules; he also taught them to his human caregivers!

A Rule for Combining Three Lexigrams

Only one three-element pattern reached sufficient productivity in the period under study to be analyzed quantitatively: the conjoined-actions-plus-agent (gesture) pattern. These combinations combined and preserved the ordering rules of their constituent two-element combinations, as children's early multiword utterances do (Braine, 1976). An example of this statistically significant pattern is CHASE BITE you (gesture). Here CHASE and BITE are ordered in accord with the conjoined-action rules (Table 10.6), while the combination also conforms to the "Place gesture last" rule (Table 10.5). Table 10.7 presents the other examples of conjoined-action-plus-agent combinations.

Strengths and Limitations of Kanzi's Grammar

Productivity. The productivity of the relations that Kanzi constructs and the fact that they consist of functional categories that cannot be reduced to preferences associated with particular words is illustrated by Kanzi's use of the lexigram AUSTIN, the name of a *Pan troglodytes*

TABLE 10.7
Kanzi's Three-Element Lexigram-Lexigram Combinations: Conjoined Actions Plus Agent

Complete Corpus of Examples of Rule-Governed Order
CHASE BITE you (demonstrative gesture) (3)
GRAB BITE you (demonstrative gesture) (2)
CHASE HIDE you (demonstrative gesture) (2)
Complete Corpus of Counterexamples to Rule-Governed Order
GRAB TICKLE you (demonstrative gesture) (1)
Rule-governed order is significantly dominant, $p < .00000$*.

Note. Lexigrams are in italicized capital letters. Numerals in parentheses indicate frequencies.
*Test for significance of a proportion (one-tailed). (Bruning & Kintz, 1977).

chimpanzee also at the Language Research Center. Kanzi uses the lexigram AUSTIN in 11 different semantic relations (action-agent, action-goal, action-object, affirmation-goal, attribute-entity, conjoined locations, entity-demonstrative, entity-location, goal-agent, goal-instrument, recipient-object). (See appendix for specific utterances.)

A Difference in Symbol Order Signals a Difference in Meaning. Even more important, Kanzi shows an incipient ability to use a difference in symbol order to signal a difference in meaning. When animate beings function as agents of action in Kanzi's lexigram-lexigram combinations, he tends to place them first. When they function as objects of action, he tends to produce them last. A chi-square test shows this difference to be significant at the .05 level. As an example, he contrasts GRAB MATATA, where Matata is grabbed, with MATATA BITE where Matata functions as agent. This is the beginning of autonomous syntax, in which symbol order signals meaning relations without the help of a disambiguating context.

Although apes have been reported to use a difference in sign order to signal or to comprehend a difference in meaning, the evidence is either anecdotal (Fouts, 1975) or partial imitation is at play (Gardner, B. T., & Gardner, R. A., 1978); in still others the extent of imitation is unknown (Patterson, 1978). Kanzi, in contrast, has shown himself consistently able to use a reversal of word order to signal a change of meaning in his spontaneous symbol combinations.

Utterance Length. Although Kanzi had been combining lexigrams for about 3 years at the time of the grammar study, most combinations (90%) were still of only two elements and most utterances were still single symbols. This length limitation agrees with Terrace et al.'s (1979) observation of Nim. In Kanzi's case, short symbol combinations also may reflect a modality problem. Although caregivers spoke in normal English sentences, they most frequently inserted only one or two lexigrams per sentence, reflecting the mechanical difficulty of the lexigram mode in generating longer utterances. However, Kanzi does differ from Nim in that he produces *nonredundant* three-element combinations in which two two-element combinations have been linked to add new information (see also Savage-Rumbaugh et al., 1986).

CONCLUSION

Imitation in the chimpanzee, as in the human child, reveals not a lack of conversational competence (Sanders, 1985; Terrace et al., 1979) but its presence. The ability to use repetition of others to fulfill various pragmatic functions is not unique to *Pan paniscus*, but is shared with *Pan troglodytes*, as inspection of published data from Sherman and Austin shows (Greenfield & Savage-Rumbaugh, 1984, in press).

In the area of grammar, Kanzi shows the ability to learn a productive symbol-order rule governing relations between two categories of symbols. Although there have been claims that apes use English word order in constructing two-symbol combinations, this is the first time an ape has used word order that is not dependent on either partial imitation of the preceding utterance or position preferences for specific lexical items (Gardner, B. T., & Gardner, R. A., 1974; Patterson, 1978; Terrace et al., 1980). It is also the first time an ape consistently has used a difference in symbol order to signal a difference in meaning when imitated utterances have been systematically excluded.

An alternative explanation for these results might be that Kanzi's symbol combinations, with their ordering regularities, are simply learned habits. First, ignoring symbol order for the moment, we see that the combinations in the corpus (appendix) are both spontaneous (not imitated from preceding context) and encode meanings that are consistent with the conversational and extralinguistic context, including Kanzi's own behavior and goals in the situation (see Table 3). Second, no differential reinforcement was given for particular symbol orders or for particular meaning relations. Third, when an ordering rule has been modeled by caregivers (action-object combinations), the data indicate that Kanzi has acquired a generative rule, rather than specific position habits. Several lines of evidence support this point:

1. There are a large number and variety of spontaneous action-object combinations (see appendix for complete list).
2. Given lexical items appear in different positions in different ordering rules expressing different semantic relations. A good example is the lexigram BITE which is generally produced first in action-object combinations (see appendix), but is most often produced second in conjoined action combinations (Table 10.6).
3. As noted earlier, Kanzi uses a reversal of symbol order to signal a difference in meaning when he combines an action lexigram with a lexigram representing an animate being.

This evidence precludes rote association between lexigram and serial position as an explanation of the relevant symbol-ordering rule.

Kanzi also has shown the ability to invent primitive grammatical rules for ordering symbols. These are rules that cannot have been learned as "habits" or otherwise induced from information in the environment, for analysis of input indicated either that no models at all had been provided for the semantic relation in question (e.g., conjoined-action combinations) or that an opposite symbol order had been modeled by human caregivers (agent-action combinations).[2]

This type of inventive capacity has now been established for deaf children being raised without a sign-language model (Goldin-Meadow, 1978; Goldin-Meadow & Mylander, 1984), as well as for hearing children, who develop word-order regularities in their speech, despite the absence of such regularities in the input model provided by certain languages (Slobin, 1966). In the case of Kanzi, as for children, these inventions indicate an internal or innate predisposition for meaningful symbol combination structured by regularities of symbol order.

Unique among apes, Kanzi also is beginning to use ordering rules to combine two semantic relations into meaningful and rule-bound three-element combinations. The grammar of the three-element combinations was almost certainly also invented by Kanzi, for the structure is based on combining his other two invented rules, conjoined action and "place gesture last." Most interesting, Goldin-Meadow and Mylander (1984) reported that the most frequent "complex" sentence structure created by deaf children being raised without a sign-language model are conjoined action utterances. Such structures consist of two action signs, plus pointing to indicate the agent. It is striking that the most frequent complex structure created by these deaf children is also the most frequent complex structure created by a bonobo chimpanzee.

Both of Kanzi's invented rules are action-based. "Place gesture after lexigram" is a rule that orders the action mode of the symbolic communication itself. The rule may provide automaticity at the level of sequencing, freeing deliberate cognitive processes to formulate meaning relations. Automatic ordering is particularly functional where one must coordinate communication in two modes. Note Kanzi has invented a rule based on arbitrary formal (rather than semantic or pragmatic) criteria.

Kanzi also has invented a semantically and pragmatically motivated symbol-order rule—based on ordering actions in species-specific play sequences that also occur in the wild (Boehm, 1988; S. Kuroda, personal communication, July 14, 1987). This finding suggests that grammar may have evolved originally partly in response to the need to coordinate complex action sequences with conspecifics. In this way, a primitive syntactic structure would have taken advantage of an available action structure, an evolutionarily natural proposal (cf. Greenfield, in press). From a slightly different perspective, conventionalized ordering in social play has been transformed into conventionalized ordering in symbolic communication.

[2]Patterson and Linden (1981) report that Koko the gorilla uses a sign order (noun-adjective) that is the opposite of the model provided by human caregivers. Although examples are provided, there is no quantitative data.

In conclusion, these results suggest that the potential to invent (as well as learn) a rudimentary grammar (or protosyntax) and to use language conversationally was present approximately 5 million years ago when hominids and chimpanzees split in the phylogenetic tree.

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APPENDIX:
Corpus of Kanzi's Spontaneous Two-Element Combinations (Two Lexigrams or Lexigram plus Gesture), April–August 1986

Conjoined Actions
Bite chase 2*
Bite grab 2
Bite hide
Bite hug
Bite slap 2
Bite tickle 13
Carry go(g)
Chase bite 6
Chase go(g)
Chase hide 7
Chase hug 4
Chase tickle 2
Come(g) chase
Come(g) hide
Grab bite 4
Grab slap
Hide chase 2
Hide come(g) 3
Hug bite 6
Hug chase
Slap grab
Slap keep-away
Tickle bite 21
Tickle chase 3
Tickle grab
Tickle hide
Tickle slap 3

Action-Agent
Bite you(g) 18
Carry you(g) 9
Chase dog
Chase dog(g)
Chase you(g) 53
Grab you(g) 4
Hide Austin 2
Hide you(g) 7
Hug you(g) 4
Keep-away you(g) 2
Slap you(g) 10
Tickle you(g) 8

Agent-Action
Liz hide
Matata bite
Matata chase
Mulika bite
Mulika chase
Penny tickle
You(g) carry 2
You(g) chase 5

Action-Goal
Chase Austin
Chase banana
Chase food
Chase grouproom
Chase M&M
Chase melon

Chase mushroom-trail
Chase sourcream
Chase tree
Go Austin

Goal-Action
Austin come(g)
Austin go(g) 8
Ball chase(g)
Ball go(g)
Blueberry come(g)
Childside bite
Childside chase
Childside go(g)
Clover go(g)
Coke chase
Colonyroom bite
Dog go(g)
Food chase
Gibbon carry
Grouproom open 2
Ice go(g)
Juice hug
M&M chase 2
M&M go(g)
Melon go(g)
Orange open(g)
Outdoors chase 2
Peanut go(g) 2
Play-yard slap
Potato go(g)
Strawberry go(g)
Surprise chase
Surprise come(g)
Surprise go(g) 2
Sweet-potato go(g)
Tool-room come(g)
Trailer go**
Water come(g)
Water go(g)

Action-Instrument
Chase ball
Tickle ball

Instrument-Action
Ball chase
Water chase

Action-Attribute
Chase bad
Chase one
Chase two
Hide three

Attribute-Action
Bad chase
One hide

Action-Object
Bite ball 3
Bite cherry
Bite coke
Bite food
Bite orange-drink 2
Bite tomato 2
Carry ball
Chase that(g)
Grab Austin
Grab head
Grab Kanzi 2
Grab Matata
Grab that(g) 2
Hide Austin
Hide peanut
Hug ball
Keep-away balloon
Keep-away clay 4
Keep-away that(g)
Slap ball 9
Slap that(g)
Tickle ball

Object-Action
Ball slap 7
Ball tickle 3
Surprise hide 2
That(g) grab
That(g) keep-away
Water hide

Action-Recipient
Give(g) Kanzi

Action-Volitional Object
Hug surprise

Volitional Object-Action
Juice hide
Milk hug
Orange-juice hug
Raisin hug

Affirmation-Goal
yes Austin

Agent-Object
You(g) surprise

Object-Agent
Ball you(g)
Balloon you(g) 2
Juice you(g)
Peach you(g)
Playyard you(g)
Surprise you(g)

Attribute-Entity
Austin that(g)
Austin tv
Coke water
Egg food
Good mushroom
Ice water
Surprise ball
Surprise food 2
Sweet-potato food

Entity-Attribute
Food banana
Food blackberry 3
Food grape
Food melon
Food orange
Food surprise 2
Surprise balloon
Surprise carrot
Videotape(g) Austin

Comitative-Action
That(g) come

Conjoined Entities
Bread banana

Bread juice
Cheese blackberry
Grape yogurt
Hamburger peanut
Hotdog cereal
Ice oil
Ice tv
Juice banana
Juice orange-drink
M&M egg
M&M grape 2
Melon orange-drink
Orange-drink melon 2
Orange-drink peanut
Peanut hamburger
Peanut jelly
Potato bread
Potato burrito
Sourcream ball
Tomato potato
Water ice 2

Conjoined Locations
Austin gibbon
Austin peanut 2
Austin Sue's-office
Sue's-office childside
Staff-office grouproom
Melon orange-drink

Demonstrative-Entity
That(g) apple 3
That(g) banana 5
That(g) blackberry
That(g) blueberry
That(g) bread
That(g) carrot 2
That(g) cheese
That(g) coke
That(g) food 6
That(g) grape 2
That(g) hamburger
That(g) hotdog
That(g) ice 3
That(g) jelly 2
That(g) juice 4
That(g) kiwi 3
That(g) kool-aid 2
That(g) lettuce
That(g) melon 6
That(g) milk
That(g) orange-drink 2
That(g) peach 2
That(g) peanut
That(g) raisin 4
That(g) sourcream 2
That(g) surprise
That(g) tomato 6
That(g) yogurt 2

Entity-Demonstrative
Apple that(g)
Austin that(g)
Ball that(g) 2
Balloon that(g) 2
Banana that(g) 8
Blackberry that(g) 4
Blueberry that(g) 7
Bread that(g)
Burrito that(g) 3
Butter that(g)
Carrot that(g) 4
Cherry that(g) 2
Coke that(g) 9
Egg that(g) 4
Food that(g) 8
Grape that(g) 10
Hamburger that(g) 2
Ice that(g)
Jelly that(g) 6
Juice that(g) 10
Key that(g)
Kiwi that(g) 5
Kool-aid that(g) 3
Light that(g)
M&M that(g) 2
Melon that(g) 6
Milk that(g) 2
Oil that(g) 2
Onion that(g)
Orange-drink that(g) 10
Orange-juice that(g) 2
Peach that(g) 14
Peanut that(g) 7
Potato that(g) 10
Raisin that(g)
Sourcream that(g) 3
Strawberry that(g) 12
Surprise that(g) 7
Tomato that(g) 2
TV that(g) 2
Water that(g) 3

Effect-Negative Cause
Bad mushroom-trail

Entity-Affirmation
Blueberry yes(g)

Entity-Location
Austin playyard
Austin tv
Banana peanut
Food grouproom 2
Ice grouproom
Peanut Austin
Peanut trailer
Playyard outdoors
Water ice 2
Water playyard

Location-Entity
Bread jelly 2
Group-room water
Kool-aid strawberry
Logcabin food
Mushroom-trail mushroom
Playyard Austin 4
Playyard ball(g)
Playyard Matata
Sandpile tomato
Staff-office water 2
Sue's-office Sue
Trailer dog
Trailer peanut 2

Goal-Agent
Austin you(g)

Goal-Instrument
Austin key
Child-side key

Instrument-Object
Can-opener milk
Knife(g) kiwi
Staff-office playyard

Location-Agent
Playyard you(g)

Location-Comitative
Grouproom Matata

Attribute-Location
Childside playyard

Nonexistence-Entity
No balloon
No coke

Possession-Entity
You(g) burrito

Recipient-Object
Austin balloon(g)

Object-Recipient
Egg Austin
Hotdog Austin
Peanut Kanzi

Transport-Location
Vehicle trailer***

2-Mode Paraphrase
Chase chase(g)
Bad bad(g) 3

*Frequencies are denoted by a numeral following the example. If there is no numeral, the frequency is one.

**He wants to go to the trailer.

***He is not describing a vehicle trailer, but wants to go in a car (vehicle) to the mobile-home (trailer), a location.

Note: The six lexigram combinations bearing "no direct relation" to each other are not included in the appendix, as they are not comprehensible without context. An example, with context, is presented at the end of Table 3.

III

Language Acquisition in Children

This part of the book contains six chapters that elucidate behavioral, social, cognitive, motor, neural, and logical factors deemed to be of high relevance to the ontogeny of normal language acquisition in children. The work presented includes both experimental studies and observations concerning the emergence and/or elicitation of language behavior in structured laboratory situations which provide insights into how meaning is mapped onto utterances.

In chapter 11, Charles Catania provides his views on behavioral mechanisms that may have operated to influence the evolution of language. Catania's central argument is that language developed in the social context of hominid evolution due to the functional effects that the utterances of the speaker had upon the listener. As the author puts it: "What we transmit in language is the verbal behavior itself, and its primary function is to get someone else to do something. By talking, we change each other's behavior." Further, ". . . [language] evolved as a form of social control, in a progression from vocal releasers to varied verbal functions shaped by social consequences. . . ." Catania also describes the results of experimental studies carried out by him and his colleagues to investigate contingency-shaped and rule-governed behaviors as these factors relate to the control that language exerts upon the guidance of behavior. The empirical work reviewed covers research that examines the ontogeny of rule-governed behavior and the relevance of equivalence classes in ". . . extending verbal control that already has been established."

Next, Andrew Lock discusses the relevance of both social context and social practices for development of the cognitive skills necessary to establish