20 Grammatical combination in *Pan paniscus*: Processes of learning and invention in the evolution and development of language

Patricia Marks Greenfield and E. Sue Savage-Rumbaugh

In 1979, Terrace, Petitto, Sanders, and Bever asked "Can an Ape Create a Sentence?" Looking at the evidence from a syntactic, semantic, and conversational point of view, their answer was no. Their conclusion was based on evidence from their own research with a common chimp, Nim Chimpsky, as well as on their analysis of data from other studies of ape language (Gardner & Gardner, 1973; *Nova*, 1976; Premack, 1976; Rumbaugh, 1977). Our goal in this chapter is to demonstrate that with a different species, the bonobo or pygmy chimpanzee, under a different set of conditions, the answer can be yes.

The study of ape language is important in establishing the evolutionary roots of human language. This is a subject on which there has been tremendous controversy (Bronowski & Bellugi, 1970; Limber, 1977; Petitto & Seidenberg, 1979; Seidenberg & Petitto, 1979; Terrace et al., 1979; Terrace, Petitto, Sanders, & Bever, 1980; Terrace, 1983). Is human language unique? Is it in any sense discontinuous from all that has preceded it in evolution? (See Vauclair, P&G11.) Or can we find the evolutionary roots of human language in the linguistic capacities of the great apes?

The human being is a unique species, but so is each species. In addition to being unique, we have an evolutionary history. Our physical characteristics and our *behavior* have evolved over long periods of time.

Evolution is conservative: It modifies the material that already exists and builds on it. The conservatism of evolution is exemplified in the fact that 99% of our genetic material is held in common with the chimpanzees (King & Wilson, 1975), both the common chimps (*Pan troglodytes*) and the pygmy chimps or bonobos (*Pan paniscus*), who are the subjects of this chapter.

Evolutionary approaches to language contrast with an influential position on language: that of the linguist Noam Chomsky. Chomsky looks on language in general, and grammar in particular, as a sudden mutation in the human species. The anthropologist H. B. Sarles has called Chomsky the creationists' grammarian (Fouts & Couch, 1976; Sarles, 1972).

Grammar

Grammar, the combinatorial aspect of symbolic communication, is often considered the sine qua non of human language (Chomsky, 1965, 1980). Apes have been shown to acquire vocabularies of meaningful symbolic elements in humanly devised languages analogous to single words in human language (Hill, 1978; Savage-Rumbaugh, Rumbaugh, Smith, & Lawson, 1980; Terrace et al., 1979). They have also spontaneously combined two or more elements in nonrandom ways (Fouts, 1974a; Fouts & Couch, 1976; Gardner & Gardner, 1969, 1971; Patterson, 1980).

From a linguistic point of view, however, this is not sufficient to demonstrate that they have grammar. A grammar is a set of formal rules for marking relations between categories of semiotic elements. At the minimum, a grammatical rule should satisfy five criteria. These criteria are implicit in modern linguistics; research in child language and ape language has caused them to become increasingly explicit. Different subsets of criteria have been emphasized by different investigators, as the reference citations indicate. Our view is that any subset of criteria is not adequate. All five of the following criteria are in fact necessary for a grammatical rule:

1. Each component of a combination must have independent symbolic status (Brown, 1973).
2. The relationship between the symbols must be reliable and meaningful (semantic) (Terrace et al., 1979).
3. A rule must specify relations between *categories* of symbols across combinations, not merely a relation between individual symbols (Bronowski & Bellugi, 1970; Terrace et al., 1979).
4. Some formal device, such as statistically reliable order (Braine, 1976; Goldin-Meadow & Mylander, 1984), must be used to relate symbol categories across combinations.
5. The rule must be productive (Hill, 1978; Savage-Rumbaugh, Sevcik, Rumbaugh, & Rubert, 1985; Terrace et al., 1979): A wide variety of spontaneous combinations must be generated (Petitto & Seidenberg, 1979; Terrace et al., 1979, 1980).

Because grammatical rules are creative and productive (Criterion 5), they allow a relatively small number of individual symbols to be combined into a large number of new sentences. Terrace et al. (1979, 1980) claimed that it was in this respect that chimpanzee language failed to meet the criterion of grammatical competence.

For example, Lana (studied by Rumbaugh and colleagues), Sarah (studied by Premack), and Nim (studied by Terrace and colleagues) learned grammatical rules but did not use those rules productively to generate spontaneous new combinations. In the case of Nim, Terrace and colleagues concluded that a large number of Nim's combinations were imitations of the preceding utterances of the trainer, and Nim's remaining combinations appeared to be based on rules for combining specific vocabulary items. There was a dearth of evidence for general rules governing whole classes of words, such as the rules for combining the class "noun" with the class "verb" to form a subject–predicate relation in human language.

In the case of Lana and Sarah, the experimenters imposed the formal device of symbol order on them; that predetermined symbol order was requisite to reward or reinforcement. Although Lana and Sarah learned the required symbol orders, the creative aspect of human grammar was lacking.

Matsuzawa (1985) reported spontaneous use of an ordering rule in the combinations of a common chimpanzee. However, because reinforcement was contingent on a very particular combination of symbolic elements (albeit in any order), the *selection* of semiotic elements was not spontaneous, and in that sense the rule could not be said to be a completely creative one.

In addition, 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). However, because this limitation also exists at the two-word stage of child language (Braine, 1976), it is not a linguistic criterion that differentiates the chimp from the 2-year-old child.

Indeed, no previous study of ape language has demonstrated that apes satisfy all of the foregoing criteria. The grammatical evidence of other researchers has sometimes been compromised because they have not reported data completely or have not systematically eliminated immediate imitation from the analyses (Fouts, 1974a,b, 1975; Gardner & Gardner, 1969, 1971, 1974, 1978; Patterson, 1978, 1980; Terrace et al., 1979, 1980).

Delayed imitation is a hallmark of representational development at the end of human infancy. Comparative study of sensorimotor development among primates indicates that both the great apes and cebus monkeys are capable of delayed imitation (Chevalier-Skolnikoff, 1976, 1989; Parker & Gibson, 1979). Yet cebus has not shown symbolic capacities. Clearly, representation in the form of delayed imitation is not sufficient to assure symbolic communication, let alone productive grammar. (See Vauclair, P&G11, for a discussion of the disjunction between representation, symbols, and communication, both in human development and in cross-species comparison.) With respect to grammar, imitation leaves open the possibility that combinations may reflect productive use of grammar by human teachers rather than ape learners (Terrace et al., 1979).[1]

Grammatical rules should exist independently of highly structured training settings and imitation, and they should, 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 shed light on the evolution of grammar, it is necessary to demonstrate that apes have some capacity to invent grammatical rules. Although claims of innovative compound words abound in the language literature (Fouts, 1974a,b, 1975; Patterson, 1980), these are by their nature ambiguous one-time occurrences (Petitto & Seidenberg, 1979; Seidenberg & Petitto, 1979; Terrace, 1983; Terrace et al., 1979, 1980); in any case, such examples belong to the lexicon rather than to the grammar.

In contrast, we will demonstrate in the present chapter that a pygmy chimpanzee, member of a species virtually unstudied from the point of view of language, has not only *learned* but also *invented* productive protogrammatical rules. We use the term "protogrammar" to indicate the very simple nature of the rules; however, as the reader will see, the rules may well be as complex as those used by human 2-year-olds. If chimpanzees have but a protogrammar, so, it seems, do 2-year-old children.

Because so many semiotic and symbolic capacities have been found in the great apes in the last 20 years (Fouts, 1973; 1974a,b; 1975; Fouts & Couch, 1976; Gardner & Gardner, 1969, 1971, 1974, 1978, 1980; Greenfield & Savage-Rumbaugh, 1984; Jordan & Jordan, 1977; Miles, 1983; Patterson, 1978, 1980; Premack, 1970, 1971, 1976; Rumbaugh, 1977; Rumbaugh & Gill, 1976a,b; Rumbaugh, Gill, & von Glasersfeld, 1973; Savage-Rumbaugh, 1986; Savage-Rumbaugh, Rumbaugh, & Boysen, 1978a,b; Savage-Rumbaugh et al., 1980, 1985), Chomsky's emphasis on the uniqueness of human grammar has become the last bastion of the discontinuity theorists. Thus, the discontinuity position has come to hinge on the question whether or not language-trained apes have linguistic grammar above and beyond their imitation of human models (Terrace, 1983; Terrace et al., 1979, 1980).

The evolution of an innate capacity

Chomsky nevertheless emphasizes one point with which we would strongly agree: that human language has an important genetic basis. Ultimately this point works *against* Chomsky's creationist position vis-à-vis language. If 99% of our genes are held in common with contemporaneous chimpanzees (King & Wilson, 1975), and if language is an extremely multigenic function (Studdert-Kennedy, 1988), then it is likely that much of the genetic basis of language is shared with present-day chimpanzees and with our common primate ancestors.

The logic of an evolutionary approach to behavior is as follows: If we find capacities in common between two related descendant species of a common ancestor, it is possible that, in both species, the capacity was inherited in some form from the common ancestor species. If the same behavioral capacity is found in not just two, but *all* the species stemming from a common ancestor, the presence of the genetic basis for the behavioral trait in the common ancestor becomes quite certain (Parker, P&G1).

Two points are often neglected in a theoretical consideration of ape language and its evolutionary implications. One is that human language was, at its origins, and continues to be (Parker, 1985) invented – not merely learned from a previous generation. This suggests that the *invention* of grammatical rules by apes would be stronger evidence of evolutionary continuity than mere learning of rules that have been demonstrated or taught by others in the environment. Our findings with Kanzi, a pygmy chimpanzee (*Pan paniscus*), provide evidence that bonobos can learn a simple grammar, but more interesting and more important, they can invent new protogrammatical rules –

that is, rules never demonstrated by any human or animal in the chimpanzees' social environment.

The second point is that the search for grammatical competence among apes has been very anthropocentric. Not only have ape researchers looked for human grammar in a general sense, but they have also assumed that the grammatical development of apes, if it occurs, will ressemble that of young human children (especially American children!) down to the very details. It may be that apes can develop grammatical rules, but that, at least in part, the nature and developmental order of their grammar derive from their species-specific and individual way of life. If that is the case, we would expect the *details*, if not the overall structural pattern, of chimpanzee grammatical development to diverge in some respects from that observed in human children; a similar point was made by Wiener (1984) and McNeill (1974). Drawing on data from Kanzi, a pygmy chimpanzee, we will demonstrate in the present chapter that his way of life results in a grammar that in some respects differs from the initial grammars of young children.

A developmental approach to language evolution

A developmental approach has a particular role in the logic of evolutionary reconstruction. Evolutionary change modifies and builds on what is already there in a particular organism. A species' most recently evolved features *tend* to appear relatively late in ontogenetic development, although that is not an absolute law (Studdert-Kennedy, 1988). Nevertheless, the tendency can be explained as follows: The later a mutation or gene rearrangement (King & Wilson, 1975) occurs in ontogenetic development, the less likely it is to interfere with other, previously evolved, aspects of development. Consequently, the later a genetic change arises in development, the greater the chances of the altered organism's survival to reproduce, and consequently the greater the chances of the mutation's survival in the gene pool. Therefore, two related species generally are more divergent later in ontogenetic development, and more similar during earlier ontogenetic stages; von Baer's law (Gould, 1977) provides a slightly different rationale for this same conclusion. Applying this concept to language, one would expect chimpanzees' communicative systems to be more similar to the communicative systems of children during the earliest stages of language acquisition, less similar during later stages, and least similar during the adult stage. A developmental approach should therefore be more fruitful than the simple binary question "Do apes have language?"

Language does not appear full-blown in the human child. It develops quite gradually. Would we want to say that a 1-year-old has language? A 2-year-old? A 5-year-old? A 10-year-old? Clearly this would be a rather fruitless discussion, although, as Hill (1978) pointed out, there have been attempts to draw such a developmental line – for example, Limber (1977) proposed that human language begins at age 3. It is similarly fruitless to ask if apes

taught humanly devised symbol systems do or do not have language. More profitable in the case of both child and ape is to ask what elements of language are present and what elements are absent at a particular point in development.

Human grammar becomes more complex with development. Simpler structures are components of the more complex ones. Therefore, each major step in the development of grammatical structure is logically, as well as ontogenetically, dependent on the preceding ones. As Parker and Gibson (1979) pointed out, the logical dependence characteristic of the ontogeny of language must also characterize its phylogenetic evolution.

With respect to major grammatical structures (e.g., the progression from one-word to two-word utterances, the progression from single-clause sentences to multiclause sentences), we would agree with Parker and Gibson that human language begins at age 3. It is similarly fruitless to ask if apes which it develops" (Parker & Gibson, 1979). Given that apes have not evolved humanlike language since diverging from the hominid line of evolution, they would at best be expected to have potentials for the primitive forms of linguistic grammar that may have been potential, or possibly even present, in our common ancestor. These historically early phylogenetic stages of grammatical structure, prerequisite to the more complex forms of human grammar today, could resemble developmentally early ontogenetic stages, similarly prerequisite to the complex structures of adult human grammar.

Therefore, we need to look for parallels between ape language and human language in the *earliest stage of development* and, having established these, see how far the apes can travel on the path toward human language. As a consequence, we searched for parallels to the earliest stages of children's grammar in the study of bonobo grammar to be reported here.

Our chief point of reference in the human literature will be the work of Goldin-Meadow and colleagues on sign language acquisition among deaf children of hearing parents (Feldman, Goldin-Meadow, & Gleitman, 1978; Goldin-Meadow, 1979; Goldin-Meadow & Feldman, 1977; Goldin-Meadow & Mylander, 1984). Like Kanzi, these children participate in the creation of their own language. Their caregivers, unfamiliar with sign language, do not provide a full-blown language model to be acquired. Without in any way implying that these deaf children are similar to apes, we believe that this parallel in their language learning conditions makes them the most interesting subjects of comparison for our study of grammar in *Pan paniscus*.

Overview of the study of Kanzi

The pygmy chimpanzee or bonobo (*Pan paniscus*) is of special interest because the sociosexual behavior of the species is more like that of humans than is that of the common chimpanzee (*Pan troglodytes*) (Savage-Rumbaugh & Wilkerson, 1978). The question that inspired the ongoing study of Kanzi and other bonobos was whether or not bonobo communicative behavior would also develop more as human language does. Although genetic studies in-

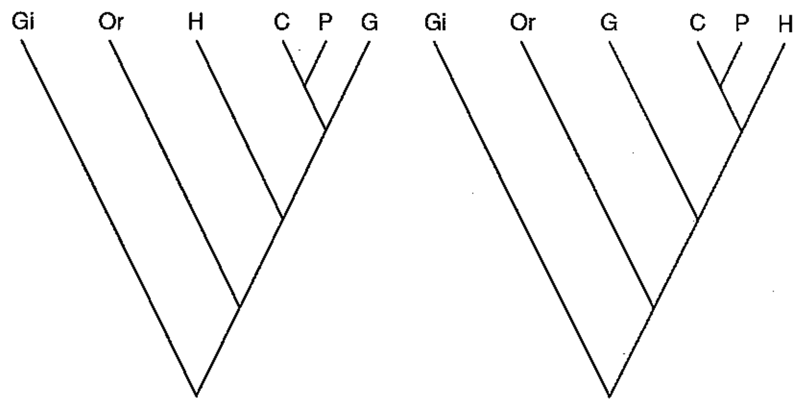


Figure 20.1. Two most likely family trees for apes and humans, based on genetic evidence: Gi = gibbon; Or = orangutan; H = human; C = chimpanzee; P = pygmy chimpanzee, bonobo; G = gorilla (from Weiss, 1987).

dicate that *Pan paniscus* and *Pan troglodytes* are equally close to the human species (Figure 20.1 shows the two most likely family trees), the small size and other morphological characteristics of the bonobo make it likely that *Pan paniscus* more closely resembles our common ancestor than does modern-day *Pan troglodytes* or *Homo sapiens* (Zihiman, 1979; Zihiman, Cronin, Cramer, & Sarich, 1978; Parker, P&G1).

The language learning environment of Kanzi and his half sister Mulika involved learning language in the ongoing course of communication, without formal training. Consequently, unlike Lana, Sherman, Austin, and other common chimpanzees previously trained by Rumbaugh, Savage-Rumbaugh, and colleagues (Greenfield & Savage-Rumbaugh, 1984; Rumbaugh, 1977; Rumbaugh & Gill, 1976a,b; Rumbaugh et al., 1973; Savage-Rumbaugh, 1986; Savage-Rumbaugh et al., 1978a,b, 1980), Kanzi and Mulika were not taught the names of objects by repeated practice that required them to associate the exemplar with its symbol. Although Kanzi and Mulika were exposed to the same basic system of lexigrams (geometric designs devised by humans to stand for things), unlike the common chimps mentioned earlier they were not restricted to the lexigram system.

Their human companions provided them with communicative models and encouraged communication. English was used freely around them, and as caregivers spoke they also pointed to the appropriate lexigram on the keyboard. Other informal gestures also served as a natural adjunct to speech. In addition, a number of American Sign Language (ASL) gestures were used by the caregivers, none of whom were fluent in ASL.

Comprehension of English words typically preceded the onset of lexigram usage (Savage-Rumbaugh, McDonald, Sevcik, Hopkins, & Rubert, 1986). That is, Kanzi and Mulika generally gave evidence of understanding a spoken word as it was used by their caregivers before they began to use its lexigram

themselves. Comprehension of the spoken word, which extends to synthesized speech, has been documented in detail by Savage-Rumbaugh et al. (1986).

Although other studies of great ape communication in captivity had provided a communication environment similar to that experienced by human children (Gardner & Gardner, 1971, 1978, 1985; Miles, 1983; Patterson, 1978, 1980), this study of Kanzi and Mulika was the first to combine a human environment vis-à-vis communication with a physical environment and a structure of daily activities that were approximations in important respects of what the species would experience in the wild.

These pygmy chimpanzees were reared in 55 acres of forest outside of Atlanta, Georgia, where they encountered a variety of natural plants and wildlife. Many of their communications revolved around foraging activities as they traveled that area each day to find their food. No attempt was made to structure their activities during the day, except for when tests of symbol competency were given. At all other times, communication revolved around whatever happened to be of immediate interest to them.

In the previous studies of symbol use in *Pan troglodytes* by Rumbaugh, Savage-Rumbaugh, and colleagues, the lexigram system was attached to a computer keyboard and electronic display screen for ease and accuracy of recording communicative output. That was necessary because the vagueness of their pointing gestures made it ambiguous to merely have them point to the symbol they wanted to use. Kanzi and Mulika had the use of a similar system (with the addition of synthesized speech output) when they were indoors. However, that system was not portable enough to go with the chimps as they traveled about their 55 acres. Although portable computer systems were tried, none proved rugged enough to survive the chimpanzee way of life. The fact that these pygmy chimpanzees produced clear pointing gestures (Savage-Rumbaugh, 1984) made it possible to use a portable system (a thin laminated board containing an array of lexigram symbols). Figure 20.2 shows such a board. Both caregivers and chimpanzees could then point to the desired symbol when they were traveling about outdoors.

In the woods, lexigram usage was recorded by hand and entered into the computer at the end of the day. To make sure that this method was accurate, an analysis was done of 4.5 hours of videotape in which real-time coding was checked against coding of the videotape. The scoring was done independently by two different observers, with one observer scoring the behavior in real time and the other scoring the tape. At the time the scoring was done, the real-time observer did not know that the data would be used in the future for a reliability check, and thus the real-time scoring was not altered by the knowledge that this was a reliability check. Thirty-seven utterances were noted by both observers; nine utterances were noted on the videotape that were not seen by the real-time observer, suggesting that a number of lexigram usages were not noted during the busy flow of social interaction. Typically, when that happened, Kanzi was able to gain someone's attention by repeat-

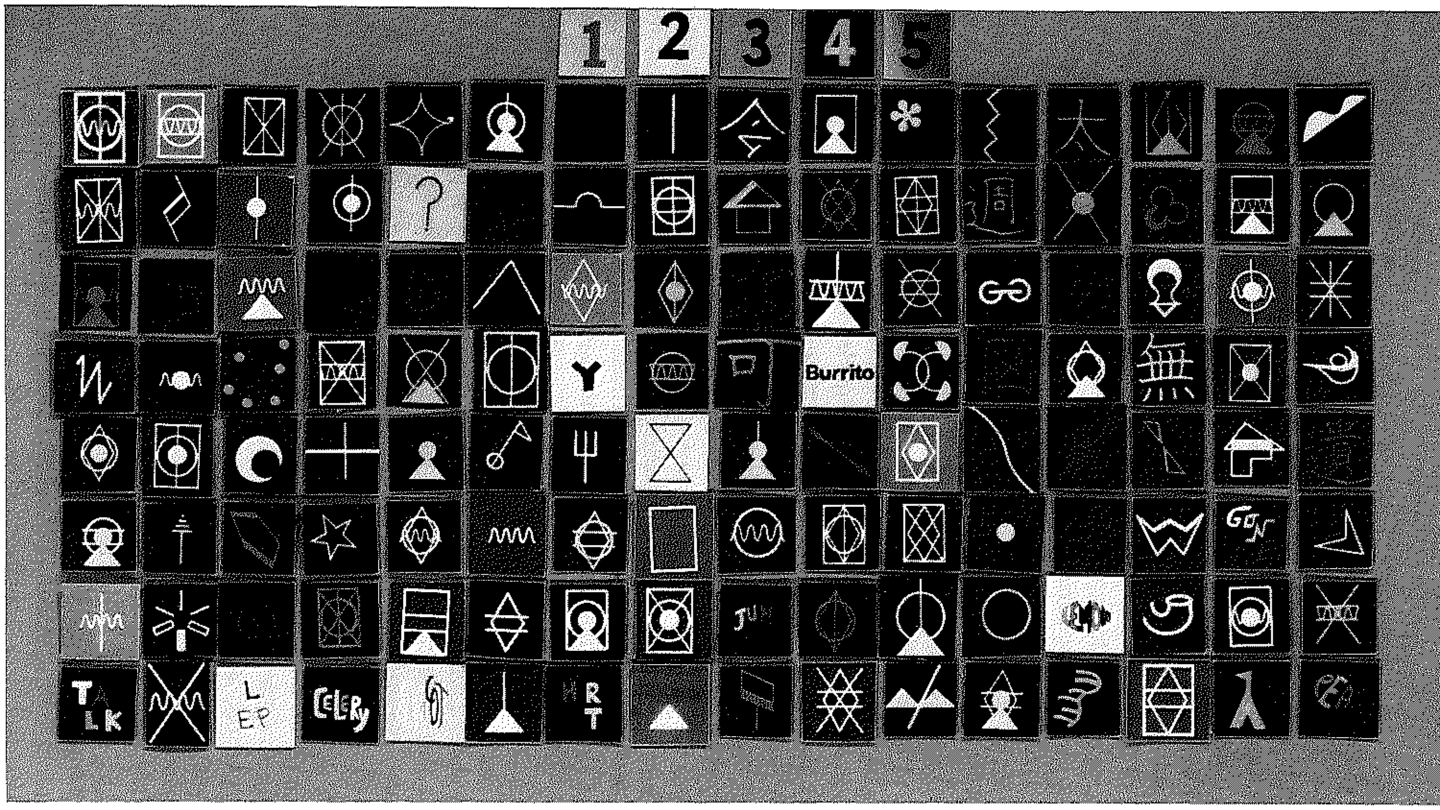
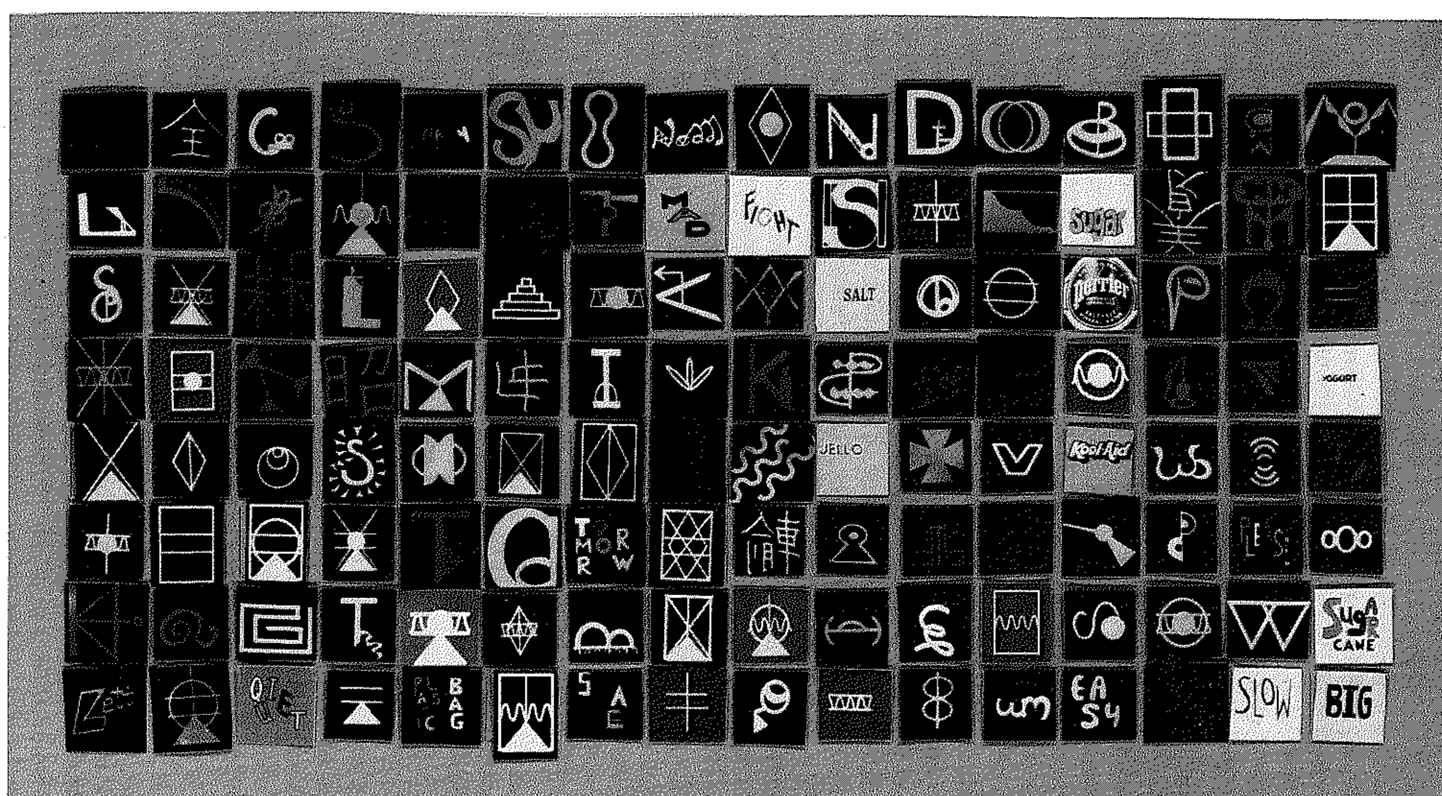


Figure 20.2. Kenzi's lexigram board. (The left side is shown above; the right side is shown below.)



ing himself. The two observers agreed 100% with regard to which lexigrams Kanzi used and whether or not they were used correctly in context. Thus, though the real-time observation may have lacked some of the redundancy of the chimps' natural conversation, it was very accurate and otherwise quite complete. Other details of the reliability check are available elsewhere (Savage-Rumbaugh et al., 1986).

Like their human caregivers, Kanzi and Mulika were not limited to lexigrams in their interspecies communication. The chimpanzees used gestures, as well as vocalizations. Although neither gestures nor vocalization had been formally taught, Kanzi and Mulika used both for communicative purposes. Human caregivers responded to the extent that they could appropriately interpret the chimpanzees' gestures and vocalizations.

Because Mulika, Kanzi's half sister, was younger and was not providing enough semiotic combinations for quantitative analysis, the data for the grammar study are based only on Kanzi, age 5½ years.

Kanzi was first exposed to the use of lexigrams, gestures, and human speech while in the care of his mother, who was being given language training. Beginning at the age of 18 months, he began to show some interest in the lexigrams. Kanzi did not display regular intentional symbol use until 2½ years of age, when he was separated from his mother for 4 months while she was housed at the Yerkes Field Station for breeding. The research team has kept a complete record of Kanzi's semiotic productions since that time. On the return of his newly pregnant mother, Kanzi chose to stay in the company of his human caregivers most of the time.

Data and analysis

The data base for our analysis consists of all of Kanzi's two-element combinations (consisting of two lexigrams or of a lexigram plus a gesture) produced over a 5-month period (April–August 1986) when Kanzi was 5½ years old. We also did a less intensive analysis of three-element utterance (three lexigrams or mixtures of lexigrams and gestures) during that same time period. The results of that analysis are reported at the end of this chapter.

Ours was not primarily a developmental analysis; rather, the goal was to ascertain whether or not Kanzi was using grammatical rules at his current, and therefore presumably his most advanced, level of functioning.

Normally, Kanzi had someone with him recording data 9 hours per day, 7 days per week. During that period, Kanzi produced a total of 13,691 utterances; 10.39% or 1,422 of those were combinations of two or more elements.

This is a much larger data base than any child studies have used to investigate grammatical development. Compared with our daily observations approximately 9 hours in length, longitudinal child language observations have averaged about 2 hours per month (e.g., Bloom, 1970; Bowerman, 1973a,b; Brown, 1973; Goldin-Meadow & Mylander, 1984). Even estimating that two observers were present to record context only half the time, we still are left with an average of about 4½ hours of observation per day.

Because, as Bloom (1970) discovered, the researcher cannot make inferences about grammatical relations without having information about meaning, we analyzed only the subset of the combinations for which sufficient situational context was recorded to make basic meaning relations clear. (That conformed to the practice used by Goldin-Meadow and Mylander, 1984, our major point of comparison for this analysis.) Context could be recorded only when two researchers were present with Kanzi (approximately half the time).

With reference to Criterion 5 – spontaneous productivity – we excluded partial or complete imitations (2.67% of total combinations) and utterances that were solicited in any way. In the latter category we omitted (1) Kanzi's responses to "test questions," where a human conversational partner already knew the "right" answer, and (2) Kanzi's responses to a human caregiver who withheld something contingent upon lexigram production.

The final corpus consisted of 723 spontaneous combinatorial two-symbol utterances, representing 51% of Kanzi's total recorded combinatorial output (some of which were longer utterances) during that period. The overwhelming majority of the eliminated utterances were not used simply because a second observer had not been present to record context.

This corpus of 723 two-element combinations is much more extensive than the usual child language corpus for a similar stage of development. Comparing our corpus specifically with those of Goldin-Meadow & Mylander (1984), we see that their data on semantic relations ranged from 20 to 437 utterances for the 10 subjects involved in the studies. Kanzi's sample of 723 utterances is clearly much larger than that for even their most productive child.

An important focus of our study was the source of any grammatical rules we might find. Could they have originated in a model provided by a caregiver, or were they Kanzi's own inventions? To get at the question of the grammatical models provided by humans, we examined video transcripts to ascertain the input provided by others in Kanzi's environment. In addition to this contemporaneous input, we examined video transcripts to analyze the communicative input provided 6 months earlier. These tapes, about 5½ hours in all, involved input from six caregivers, including all of the major ones. In general, the grammatical structure of the input was stable, and so we combined data from the two periods for the analyses that follow.

Grammar and symbols

A grammar is based on combining semiotic elements, that is, elements of meaning. A semiotic element is a representational device, called a *signifier*, that stands for something else, called a *referent* or signified (Vauclair, P&G11).

According to the philosopher of language Peirce (1931), three hierarchical levels define how a semiotic element or sign is, in a particular usage, related to the thing it stands for:

1. An *icon* resembles the thing it stands for, its referent. A drawing is an example of something that generally has an iconic relationship to its referent.
2. An *index* derives its meaning from being connected to its referent in a particular situation. Pointing may be considered part of the situation of touching something to which attention is to be drawn. Pointing can therefore be considered to have an indexical origin. It also has an iconic element, for it physically resembles the act of touching.
3. A true symbol must be a concept in the sense that it is understood to stand for a whole category of referents and is not limited by its indexical origins in a particular situation; in short, it is decontextualized (Volterra, 1987). A symbol may have, but does not need to have, a relationship of similarity to its referents.

A symbol that does not resemble its referent in form is said to be arbitrary. Arbitrariness is not, however, criterial for a true symbol in Peirce's scheme, as it is in de Saussure's. De Saussure's classification has been used developmentally by Piaget (1962) and phylogenetically by Vauclair (P&G11). Apart from definitional differences, there is a terminology difference: Peirce's *icon* is de Saussure/Piaget's *symbol*, Peirce's *symbol* is closest to Piaget's *sign*. Arbitrariness is the criterion for Piaget's highest symbolic level, the sign. Peirce's criterion for the highest level is, in contrast, the categorical nature of the signifier.

Although it is sometimes claimed that words are true symbols, early words often have an indexical characteristic, as Piaget (1962) pointed out, for they may be restricted in usage to the particular situations in which they were first associated with a referent.

In the field of child language, the study of grammatical combinations often has been separate from the study of the symbolic status of individual words. A word may be a meaningful component in a semiotic combination without attaining the highest level of symbolic development. Thus, an early sentence in child language may, for example, consist of a combination of indices rather than true symbols. Many researchers have neveretheless examined the rules by which the combinations have been formed and have called such rules "grammar."

Because we have included gesture–lexigram combinations in our investigation of grammar, this point is of crucial importance. Whereas lexigrams do not have an iconic element, gestures do. Whereas lexigrams can transcend their indexical origins in a specific situation, the critical gesture of pointing cannot. Its meaning is always derived from its relationship to a referent in a particular situation. Hence, gestures may be on a lower semiotic level than lexigrams.

What is to count as a semiotic element? First of all, Roger Brown (1973) first advanced the idea that for a combination to be meaningful, each element must have some life independent of the combination (Criterion 1). Otherwise, it is always possible that the combination is not truly a combination, but an amalgam whose elements are psychologically not separable.

Relevant to this criterion, an individual lexigram was classified as a distinct semiotic element in Kanzi's productive vocabulary if it could function in isolation in the following way:

1. It first occurred spontaneously on 9 of 10 occasions.
2. Kanzi demonstrated behavioral concordance on 9 of 10 of the subsequent occasions.

As an example of concordance, if Kanzi requested a banana using the BANANA lexigram, he would be presented with a number of favorite foods. Concordance would be scored only if he subsequently selected the banana. This criterion embodies the philosophical point (Greenfield, 1980) that, contrary to behavioristic assumptions and the usual practice in operational definition, semantic intention must be defined proactively, in terms of behavior that occurs *after* rather than *before* or *with* the utterance.

Eighty percent of the lexigram vocabulary used in the corpus of combinations to be analyzed met these criteria for meaningful, spontaneous production of individual lexigrams. In adddition, 86% of the lexigram vocabulary Kanzi used in combinations was tested by asking him to listen to an English word and choose (from among three alternatives) the appropriate lexigram (Savage-Rumbaugh, 1988). During those tests, the researcher was unaware of the location of the correct lexigram. Of the tested lexigrams Kanzi used in combinations, he passed 73% of items on 100% of the trials and 16% of items on 75% of the trials. He responded to a small minority (12%) of the lexigrams used in combinations at a chance level. Hence, the precondition for the existence of a grammar – that it involve combinations of individually meaningful elements – was generally fulfilled. Note that this sort of rigorous testing of individual lexical items has never been carried out in connection with studies of children's grammar.

Must a semiotic element be a word (i.e., a linguistic symbol) to be considered part of a grammatical system? Lexigrams are formally like words; they are devices that are arbitrary in the sense that they do not resemble their referents. In this way, they can potentially be Piagetian signs. They can also function as symbols in the Peircian sense that each has a potential meaning apart from the situation in which it is used. Hence, lexigrams are formally suited to be part of a grammatical system.

Our study also considers the grammar of gesture combined with lexigram. What status can such combinations have in a grammar? Gestures are not formally like words. They are often iconic – the gesture resembling its referent in its form. Some gestures are also indexical: They derive their meaning from being part of the total situation in which they are used. For example, when Kanzi made the gesture of touching a person to denote an agent, that was an abbreviation of the full action of pulling the person into position for a desired action. As another example, a particular pointing gesture derives its specific referent from being part of the situation in which it is used. Such gestures do not have the same symbolic status as lexigrams or most words. It can be argued, however, that words such as pronouns are also indexical and still function in human grammar.

It has also been argued among researchers (e.g., Goldin-Meadow & Mylander, 1984; Petitto, 1987) studying the development of visual language in humans (i.e., the development of sign language in deaf children) that gesture, even the pointing gesture, does function linguistically in sign language more than it does in spoken language. With respect to pointing, the case has been made that pointing at something should be given at least the linguistic status of a demonstrative pronoun such as "this" or "that." Volterra (1987) made the argument that gesture becomes symbolic through the developmental process of decontextualization. However, Volterra did not find the symbolic development of gesture to be unique to children acquiring sign language. She found that the gestures of hearing children acquiring spoken Italian also decontextualized into "true" symbols with age.

A comparative framework: Deaf children of hearing parents

Most relevant to the comparison we shall make, Goldin-Meadow and her colleagues (Feldman, Goldin-Meadow, & Gleitman, 1978; Goldin-Meadow, 1979; Goldin-Meadow & Feldman, 1977; Goldin-Meadow & Mylander, 1984) have intensively studied the communication systems of deaf children of hearing parents who do not expose their children to sign language because they believe in the oral method of deaf education. The systems of gestural communication these children develop under these conditions have been widely accepted as showing that human children invent grammar without a model. If this is true, it is clearly relevant to the evolution of human language.

However, it is interesting to note that none of the grammatical rules created by Goldin-Meadow and colleagues' subjects consisted exclusively of pure symbols; the reader is referred especially to the monograph by Goldin-Meadow and Mylander (1984), the most comprehensive report on that research. Instead, those combinations typically consisted of an index – a pointing gesture – used to indicate some entity (e.g., a jar), plus an iconic sign to represent some action (e.g., a turning motion for "open"). There was no indication in Goldin-Meadow's examples whether or not the iconic sign had the categorical meaning required to qualify as a true symbol (e.g., Could the same sign be used to denote "open" in the context "open door"?).

Despite the fact that these deaf children may not have produced any purely symbolic combinations, the regularities of their combinatorial system have been widely accepted as showing the presence of a grammatical system. The studies by Goldin-Meadow and colleagues have provided a comparative rationale for considering Kanzi's systematic lexigram–gesture and gesture–gesture combinations as potentially constituting a part of grammar. Indeed, the nature of the rules for combining semiotic elements is, in principle, independent of the nature of the elements themselves. Noting that the form of Kanzi's lexigram–lexigram combinations may have been on a higher symbolic level than any of those used by Goldin-Meadow's deaf children because of the arbitrary nature of lexigrams, we shall leave the semiotic level of individual signifiers aside and deal with our main focus: the rules for combining them.

We have adopted the methodology and criteria used by Goldin-Meadow and Mylander (1984) with their deaf children for identifying types of combinations and for establishing grammatical rules in Kanzi's semiotic productions. Indeed, the similarities in language learning conditions facing these children and Kanzi made it particularly appropriate to use Goldin-Meadow's methodology (and even to compare the results, which we shall do later in this chapter).

More specifically, there were three similarities in the language learning conditions and semiotic productions of Kanzi and the deaf subjects of Goldin-Meadow and colleagues:

1. Neither was learning a completely conventionalized language. Although the deaf children did communicate gesturally with their parents, they had no preestablished model to follow. Although Kanzi did have a preestablished model in individual lexigrams spontaneously used in English word order, that model was incomplete, for his caregivers did not have preset gestures or combinatorial rules for combining gestures with lexigrams. In addition, one of Kanzi's invented rules, to be discussed later, was imitated by his caregivers.

2. Although most of the communicative input for both Goldin-Meadow's subjects and Kanzi consisted of speech, neither was capable of speech output. Kanzi understood some English speech (Savage-Rumbaugh et al., 1986), and the deaf children also had limited access to English speech through lip-reading training (Goldin-Meadow & Mylander, 1984).

3. Pointing gestures were important parts of the semiotic combinations of both the deaf children and Kanzi.

Grammar and semantic relations

Grammars can be based on two different types of formal combinatoral devices: (1) morphological inflections (e.g., *s* in English for the plural) and (2) syntax (i.e., rule-governed ordering of semiotic elements). The early stages of human grammar, whether the learners be hearing or deaf, and whether the language be inflected or not, involve word order rather than inflectional rules (Slobin, 1973).

Given the nature of the lexigram system, morphological inflection is excluded as a possible basis for grammatical rules. There was no evidence for morphological modification in Kanzi's gesture repertoire. His caregivers, not being fluent signers, presented almost no sign inflections to Kanzi in their input. We therefore concentrate exclusively on ordering rules.

Because we have already shown that data from Kanzi meet Criterion 1 (independent symbolic status of lexigrams) for a grammar, we now concentrate on Criteria 2–5 in presenting data. Our focus is on rules that generate sufficiently large numbers of combinations to yield statistically significant evidence of ordering. We treat data on lexigram–lexigram combinations separately from data on lexigram–gesture combinations. The body of gesture–gesture combinations in the period under consideration was not large enough for analysis.

The rules to be presented involve the ordering of categories to create productive semantic relationships (Criteria 2–5 for a grammatical rule). We have preferred to label a category according to the role of its referents in the ongoing situation (e.g., entity, action) rather than to use parts-of-speech labels such as noun and verb. In the first place, these latter get their meaning from the existence of a grammatical framework. We cannot assume the presence of such a framework. In the second place, the categories of noun and verb are more general than anything observed in our data. These same arguments were used by Bowerman (1973b) to promote the use of semantic rather than part-of-speech labels in early child language.

The semantic roles that were used to categorize Kanzi's two-element combinations were similar to the category systems used in child language by Bloom (1971), Brown (1973), and Goldin-Meadow and Mylander (1984). They are shown in Table 20.1. We present this table to give a complete summary of the entire corpus used in the analysis. The corpus itself will appear in Greenfield and Savage-Rumbaugh (in press). The table demonstrates that the range of relations used by Kanzi included many of the relations described for children at the two-word stage (Bowerman, 1973a; Brown, 1973; Goldin-Meadow & Mylander, 1984; Schlesinger, 1971). The 10 major relations (conjoined actions, agent–action, action–object, agent–object, entity–demonstrative, goal–action, conjoined entities, conjoined locations, location–entity, and entity–attribute) accounted for 93.5% of Kanzi's two-element lexigram–lexigram and lexigram–gesture output. In the classic child language data of Brown (1973), eight major relations accounted for 70% of the output of most children. Most interesting from a comparative standpoint, seven of those eight major relations (agent–action, action–object, agent–object, entity–demonstrative, goal–action [termed action and locative by Brown], location–entity, and entity–attribute) were found in Kanzi's data. Kanzi did not produce one relation frequently found in children: possession. Kanzi did produce one relation not frequently found (or perhaps not found at all) in children at the two-word stage: conjoined action relations, to be discussed in detail later.

As can be seen from Table 20.1, Kanzi rarely paraphrased or repeated himself or formed combinations that were semantically unrelated. In addition, details presented in the notes to Table 20.1 indicate high interobserver reliability for categorizing semantic relations. In other words, Kanzi's productions satisfied Criterion 2, a prerequisite for grammatical rules: They expressed reliable and meaningful relations.

Table 20.1. *Distribution of two-element semantic relations in Kanzi's corpus*

Relation		Example (of dominant order)
Conjoined actions	92	TICKLE BITE, then positions himself for researcher/caregiver to tickle and bite him.
Action–agent	119	CARRY *person* (*gesture*), gesturing to Phil, who agrees to carry Kanzi.
Agent–action	13	
Action–object	39	KEEPAWAY BALLOON, wanting to tease Bill with a balloon and start a fight.
Object–action	15	
Object–agent	7	BALLOON *person* (*gesture*), Kanzi gestures to Liz; Liz gives Kanzi a balloon.
Agent–object	1	
Entity–demonstrative	182	PEANUT (*demonstrative gesture*), points to peanuts in cooler.
Demonstrative–entity	67	
Goal–action	46	COKE CHASE; then researcher chases Kanzi to place in woods where Coke is kept.
Action–Goal	10	

(The above relations are analyzed for their ordering regularities in the tables and text that follow. The relations below either lacked ordering structure or were too infrequent to be subject to such an analysis.)

Conjoined entities	25	M&M GRAPE; caregiver/researcher: "You want both of these foods?" Kanzi vocalizes and holds out his hand.
Conjoined locations	7	SUE'S-OFFICE CHILDSIDE; wanted to go to those two places.
Location–entity	19	PLAYYARD AUSTIN; wants to visit Austin in the playyard.
Entity–location	12	
Entity–attribute	12	FOOD BLACKBERRY, after eating blackberries, to request more.
Attribute–entity	10	
Miscellaneous	37	These included low-frequency relations (less than seven) such as attribute of action, attribute of location, affirmation, negation, and relations involving an instrument
Two-mode paraphrase[a]	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	

[a] There were no purely repetitious two-symbol utterances in the two-symbol corpus. This low-frequency category contains the closest phenomenon to a repetition.

[b] Although the "No direct relation" category was similar to the "Conjoined entities" category in consisting of two entities, the entities were linked by a common agent and action in the latter case, but not the former. In general, the system of semantic relations was based on those used for child language by researchers such as Schlesinger (1971), Brown (1973), and Goldin-Meadow and Mylander (1984).

Note: Two symbols were considered a combination if there was no other attentional focus intervening between the production of the two. Working from contextual notes, the first author categorized all utterances according to semantic relation. In order to test for interrater reliability, the second author then coded a randomly selected subset of 32 utterances, utilizing the same contextual notes. There was agreement on 29.5 of 32, or 92%, of all judgments. A reliability check also indicated that imitation could be judged as reliably from real-time coding as from videotape (Savage-Rumbaugh, McDonald, Sevcik, Hopkins, & Rubert, 1986).

Table 20.2. *Kanzi's two-element lexigram–lexigram combinations: Relations between action and object (animate and inanimate)*

Examples (lexigrams are in small capitals)

	Action	Object	
Inanimate object	HIDE	PEANUT	Kanzi then hides some peanuts.
Animate object	GRAB	KANZI	Kanzi stuck his foot out to her, to show that she was to grab him.

	Action–object	Object–action
Development of Kanzi's lexigram order		
Early (4/10–4/26/86)	3	7
Late (4/29–8/30/86)	31	6 ($p < .00000$)[a]
Kanzi's human caregivers' lexigram order		
	51	7

Comprehension of action–object lexigram relation
Correct: 17
Incorrect: 0

Example of correct understanding
Caregiver/researcher: PLAY HAT KEEPAWAY. Kanzi grabs the hat and shakes it at caregiver/researcher. (Note that this is not the obvious thing to do with a hat!)

Example of meaningful misunderstanding (Nov. 1985)
Caregiver/researcher: ICE (commenting on a big block of ice on TV). *Someone is HIDEing in the ICE.* Kanzi starts searching under the blankets. He apparently has understood the action–object relation, HIDE ICE, and is looking for the ice!

Complete corpus of examples from the late (rule-bound) period

Action–object order		Object–action order
BITE BALL (3)	HIDE AUSTIN (1)	BALL SLAP (4)
BITE ORANGEDRINK (2)	HIDE PEANUT (1)	SURPRISE HIDE (1)
BITE CHERRY (1)	HUG BALL (1)	WATER HIDE (1)
BITE COKE (1)	KEEPAWAY CLAY (4)	
BITE FOOD (1)	KEEPAWAY BALLOON (1)	
BITE TOMATO (2)	SLAP BALL (7)	
CARRY BALL (1)	TICKLE BALL (1)	
GRAB AUSTIN (1)		
GRAB KANZI (2)		
GRAB MATATA (1)		

Note: The variety of lexically distinct combinations indicates that position preferences of individual lexical items do not account for the action–object ordering rule of the late period. In addition, the fact that no one combination dominated provides even more conclusive evidence: The most frequent action–object combination, SLAP BALL, accounted for but a minority of the total instances of the late-period rule (7 of 31).

Not included in this table (but present in the totals for Table 20.1) are a small number (7) of action–object relations in which the object was expressed as a demonstrative gesture (e.g., GRAB

In the majority of frequent combinations, Kanzi tended toward a particular symbol order. We present our results by focusing on the category combinations that showed rule-bound regularity and that were productive enough to achieve statistical significance.

In terms of Criterion 5, productivity, we have satisfied the criterion of demanding a degree of spontaneity: All partial and complete imitations of the caregiver's prior utterances have been eliminated from the data to be presented in this chapter. Furthermore, in light of the claim by Terrace et al. (1979, 1980) that most of the combinations produced by Nim and other *Pan troglodytes* chimpanzees were imitated, it was significant that Kanzi rarely used imitation: Only 2.67% of the combinations in the period under study were full or partial imitations of the preceding utterances. That is at the low end of the range for normal children from age 2 to 3 years (Bloom, Rocissano, & Hood, 1976) and for deaf children without a sign model from about 1 to 4 years of age (Goldin-Meadow & Mylander, 1984 see also Miles, P&G19).

Development of a rule learned from environmental models: Action precedes object

Table 20.2 illustrates Kanzi's expression of action–object relations. During the first month of this study, Kanzi used no systematic order in these combinations. During the last 4 months, however, Kanzi employed, to a statistically significant degree, the symbol order used by his caregivers: action preceding object. This developmental trend from random ordering to an ordering preference was also found for human children at the two-word stage (Braine, 1976). Because his human caregivers generally overlaid lexigrams upon an English sentence, it was not surprising that his lexigram models followed English word order.

Unlike Nim (Terrace et al., 1979), Kanzi's preference for the action–object order was undisturbed by countertrends of individual lexical items. He thus fulfilled Criterion 4 for a grammatical rule: the presence of a formal device (order) relating the two semantic categories.

The variety of symbols he used in different utterances satisfied Criteria 3 and 5, a *productive* relation between *categories* of symbols.

Notes to Table 20.2 *(cont.)*

[demonstrative gesture]). All but one of these examples appeared in the last month of observation, and action–object order was dominant in this period (5 of 7 cases). However, the sample size was too small for the ordering trend to achieve statistical significance. We could consider this phenomenon of using a demonstrative gesture rather than the object lexigrams used earlier as an analogue of pronominalization development. (Note that the lexigram–gesture ordering rule presented in Table 20.3 may have overdetermined the symbol ordering pattern of these examples.)
[a] One-tailed significance test.

To determine if that semantic relationship was actually understood by Kanzi at the time he produced the combinations we are analyzing, we tallied naturally occurring examples of comprehension and miscomprehension of action–object lexigram relations expressed by human caregivers during the same period of time. The results (last figures in Table 20.2) show that Kanzi not only used but also understood that relationship. As in child language, errors (such as the last example in Table 20.2) were especially revealing: They showed a mental construction that could not have been environmentally cued.

Invented rules

Place gesture after lexigram

Not all of Kanzi's rules were learned from environmental models. Kanzi's human caregivers exposed him to the English model of word order: agent before action ("Human caregivers' order" in Table 20.3). His own lexigram–lexigram combinations (second row of figures in Table 20.3) showed signs of following this rule, but they were too infrequent to be statistically reliable. Kanzi made up his own rule, however, for combining agent gesture with action lexigram: His highly significant ordering rule, "place lexigram first," used the *opposite* ordering strategy from that of his caregivers' English-based rule (first row of figures in Table 20.3).

Data on Kanzi's comprehension from the same period reveal that he understood that symbols could represent relations in which agents carried out actions ("Comprehension of agent–action relations" in Table 20.3).

Kanzi's rule, "place lexigram first," had considerable generality as well as originality. The remainder of Table 20.3 shows how that rule was manifest in statistically significant symbol order for three other semantic relations (Criteria 4 and 5 of a grammatical rule). Most important, in none of the relations was there a human model for the rule. This is strong evidence for creative productivity (Criterion 5).

Although three of the four relations involved a demonstrative gesture, the fourth, goal–action, involved combining a lexigram with one of several other action gestures. Thus, to a limited extent, that rule involved relations between two categories (Criterion 3 of a grammatical rule): a larger category of lexigrams and a smaller category of gestures. In addition, the gestures conformed to Volterra's criteria (1987) for decontextualized symbols: According to her criteria, Kanzi's gestures would be considered symbolic signs, as found in deaf sign language, not mere gestures.

Note the regularity of the rule, even though the opposite order was equally possible and would be meaningful (indeed, it is used in English). This finding parallels the highly conventionalized (as opposed to random or idiosyncratic) use of pointing gestures observed by Goldin-Meadow and colleagues (Goldin-Meadow & Mylander, 1984) in the deaf children they studied.

Table 20.3. *Kanzi's ordering rule: Gesture follows lexigram*

Relations between agents and actions

Lexigram–gesture (10/10/85): CHASE (*gesturing to Mary*). Kanzi pulls on Mary. He is asked what he wants and communicates the foregoing. But Mary is playing with Mulika and denies his request until later. Later he produces the following:

Lexigram–lexigram (10/10/85): MARY CHASE. Mary agrees and chases after Kanzi.

	Agent–action	Action–agent
Kanzi's order		
Lexigram action–gesture agent	7	116 (p = .00000)[a]
Lexigram–lexigram	6	3
Human caregivers' order		
Lexigram action–gesture agent	14	0
Lexigram–Lexigram	14	0

Comprehension of agent–action relations

Correct: 6

Incorrect: 0

Example of correct understanding

Caregiver/researcher: KELLY *and* ROSE CHASE. Kanzi looks at Rose, then Kelly. He then touches Kelly and pushes her arm toward Rose, signing CHASE. (Essentially, Kanzi has translated a lexigram sentence into a gestural sentence.)

Complete corpus of examples of agent–action relations

Lexigram–gesture combinations

Order: Lexigram action–gesture agent (examples of rule)	Gesture agent–lexigram action (counterexamples to rule)
CHASE (dem. gest. to dog) (1)	(dem. gest. to person) CHASE (5)
CHASE (dem. gest. to person) (53)	
BITE (dem. gest. to person) (18)	
SLAP (dem. gest. to person) (10)	
CARRY (dem. gest. to person) (9)	(dem. gest. to person) CARRY (2)
TICKLE (dem. gest. to person) (8)	
HIDE (dem. gest. to person) (7)	
HUG (dem. gest. to person) (4)	
GRAB (dem. gest. to person) (4)	
KEEPAWAY (dem. gest. to person) (2)	

Lexigram–lexigram combinations (too few for statistically significant rule)

Order: Lexigram action–lexigram agent	Lexigram agent–lexigram action[b]
HIDE AUSTIN (2)	MATATA BITE (1)
CHASE DOG (1)	MATATA CHASE (1)
	MULIKA CHASE (1)
	MULIKA BITE (1)
	PENNY TICKLE (1)
	LIZ HIDE (1)

Table 20.3 *(cont.)*

Further examples of Kanzi's rule: Place gesture after lexigram

	Entity	Demonstrative
Kanzi	FOOD	(dem. gest.)

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

Partial corpus of examples of demonstrative–entity relations

Order: Demonstrative gesture 2nd (examples of rule)	Demonstrative gesture 1st (counterexamples to rule)
APPLE (dem. gest.) (1)	(dem. gest.) APPLE (3)
AUSTIN (dem. gest.) (1)	
BALL (dem. gest.) (2)	
BALLOON (dem. gest.) (2)	
BANANA (dem. gest.) (8)	(dem. gest.) BANANA (5)
BLACKBERRY (dem. gest.) (4)	(dem. gest.) BLACKBERRY (1)
BLUEBERRY (dem. gest.) (7)	(dem. gest.) BLUEBERRY (1)
BREAD (dem. gest.) (1)	(dem. gest.) BREAD (1)
BURRITO (dem. gest.) (3)	
BUTTER (dem. gest.) (1)	
CARROT (dem. gest.) (4)	(dem. gest.) CARROT (2)
CHERRY (dem. gest.) (2)	(dem. gest.) CHEESE (1)
COKE (dem. gest.) (9)	(dem. gest.) COKE (1)
EGG (dem. gest.) (4)	
FOOD (dem. gest.) (8)	(dem. gest.) FOOD (6)
GRAPE (dem. gest.) (10)	(dem. gest.) GRAPE (2)
HAMBURGER (dem. gest.) (2)	(dem. gest.) HAMBURGER (1)
	(dem. gest.) HOTDOG (1)
ICE (dem. gest.) (1)	(dem. gest.) ICE (3)
JELLY (dem. gest.) (6)	(dem. gest.) JELLY (2)
JUICE (dem. gest.) (10)	(dem. gest.) JUICE (4)
KEY (dem. gest.) (1)	

	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

Table 20.3 *(cont.)*

Complete corpus of examples of goal–action relations expressed as lexigram–gesture combinations

Order: action gesture 2nd (examples of rule)		Action gesture 1st (counterexamples to rule)
AUSTIN (go gesture) (8)	ORANGE (open gesture)[c]	None
AUSTIN (come gesture) (1)	PEANUT (go gesture) (2)	
BALL (go gesture) (1)	POTATO (go gesture) (1)	
BALL (chase gesture) (1)	STRAWBERRY (go gesture) (1)	
BLUEBERRY (come gesture) (1)	SURPRISE (come gesture) (2)	
CHILDSIDE (go gesture) (1)	SURPRISE (go gesture) (1)	
CLOVER (go gesture) (1)	SWEET-POTATO (go gesture) (1)	
DOG (go gesture) (1)	TOOLROOM (come gesture) (1)	
ICE (go gesture) (1)	WATER (come gesture) (1)	
MELON (go gesture) (1)	WATER (go gesture) (1)	
M&M (go gesture) (1)		

	Object	Agent
Kanzi	BALLOON	(dem. 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

Complete corpus of examples of agent–object relations

Order: agent gesture 2nd (examples of rule)	Agent gesture 1st (counterexamples to rule)
BALL (dem. gest. to person) (1)	
BALLOON (dem. gest. to person) (2)	
JUICE (dem. gest. to person) (1)	
PEACH (dem. gest. to person) (1)	
PLAYYARD (dem. gest. to person) (1)	
SURPRISE (dem. gest.) (1)	(dem. gest. to person) SURPRISE (1)

Note: Kanzi's ordering rule seems to have considerable generality, involving a large class of lexigrams and a small class of gestures (demonstrative and action). This small class of gestures resembles the "pivots" in children's two-word constructions. The rule is also quite complex, for it involves changing the position of the action symbol, depending on whether action is expressed by a lexigram (action lexigram–agent gesture) or by a gesture (goal lexigram–action gesture).

The alternative demonstrative–entity order, while in the minority, may represent the use of the demonstrative to indicate, while the other order is used to locate. This distinction has been reported by the Gardners (Gardner & Gardner, 1978) for *Pan troglodytes* and by Brown (1973) and Braine (1976) for human children. We would need to do further analysis of video data to know if Kanzi also makes this distinction.

(cont.)

Perhaps most interesting from a theoretical perspective is the seemingly arbitrary nature of this invented rule. The rule that "gesture follows lexigram" does not seem to have any basis in functional convenience. At one point Kanzi was observed to move away from a person he later would indicate as agent, go to the board (where he indicated an action lexigram), and then return to the person (using a gesture to designate her as agent). In that situation, the rule Kanzi had invented demanded extra motor steps and therefore seemed purely arbitrary.

Ordering conjoined actions

We continue by describing a second rule that Kanzi invented for himself: a rule for combining sequences of two action lexigrams. It was a rule that clearly manifested the interests and life-style of a pygmy chimpanzee, rather than a human. Table 20.4 presents all of the types of conjoined action combinations. Although at first it seemed that these were simply lists of actions, without any structure, we checked the privileges of occurrence in first or second position, drawing on an established method of linguistic fieldwork. We wanted to know if certain vocabulary items could appear only in the first position in a two-element combination, whereas others were constrained to the second position. This analysis yielded evidence of structure (Table 20.4). Certain action lexigrams (CHASE, TICKLE) had a statistically significant tendency to appear in the first position; others (HIDE, SLAP, BITE) tended to appear in the second position (Criterion 4). Still others (GRAB, HUG) showed no position preference. When we placed the first-positon actions in one category and the second-position actions in another, we got the categorical groupings shown in Table 20.4.

Notes to Table 20.3 *(cont.)*

Kanzi also produced 26 lexigram–lexigram combinations involving a relationship between action and goal. These, however, showed no ordering regularity (16 goal–action vs. 10 action–goal). There were no lexigram–lexigram combinations produced for the agent–object relation; lexigram–lexigram combinations were not possible for the entity–demonstrative relation because there was no demonstrative lexigram on the symbol board.

Note that the gestures for "go," "come," "bite," "tickle," "chase," "yes," "open," and "bad" entailed distinct topographies. Demonstrative gestures (dem. gest. in the table) indicating either people or things generally were produced by either pointing to or touching the person or the object of reference. This list of gestures is exhaustive for the two-element corpus under study.

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

[b] This is the English word order modeled by researchers.

[c] Kanzi wanted to open the cooler to get the orange.

Table 20.4. *Conjoined action lexigram combinations*

	No. times 1st	No. times 2nd
Prefers in 1st position		
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

Examples of preferred orders (2/5/87)

Kanzi: CHASE HIDE. After producing this lexigram combination, Kanzi gestures to the door to indicate that he wants to go out of the room to do this. He and Sue go out, and he runs away to be chased. He goes around to another room, where he tries to run in and hide behind the door. When Sue approaches, he rushes and hides behind the other door.

Kanzi: CHASE BITE. He runs away to be chased. Instead, Sue tries to bite him first. He will not let her. Only after she has chased him does he get in position to be bitten.

Human model: In 6 hours of videotape for November 1985, when Kanzi was already producing frequent action–action combinations, there was only one example of a caregiver combining the action words listed above, and that one example was a direct imitation of Kanzi. In April 1986, in about 2 hours of videotape, there were 10 examples, but the caregiver was imitating Kanzi in 9 of the 10 cases.

Complete corpus of examples of conjoined action relations

Conform to above rules	Counter to above rules	Conflicting rules apply
CHASE HIDE (7)	HIDE CHASE (2)	BITE HIDE (1)
CHASE BITE (6)	BITE CHASE (2)	BITE SLAP (2)
CHASE HUG (4)	HUG CHASE (1)	TICKLE CHASE (3)
TICKLE HIDE (1)		CHASE TICKLE (2)
TICKLE SLAP (3)		
TICKLE BITE (21)	BITE TICKLE (13)	
TICKLE GRAB (1)		
GRAB BITE (4)	BITE GRAB (2)	
GRAB SLAP (1)	SLAP GRAB (1)	
HUG BITE (6)	BITE HUG (1)	
Totals 54	22	8

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

Note: KEEPAWAY was used in only one conjoined action lexigram combination and was therefore omitted from the analysis. In addition, seven conjoined action combinations consisted of a lexigram plus a gesture and were therefore not included in the lexigram–lexigram analysis. All included a gesture representing "come" or "go"; in 5 of 7 cases the ordering followed the "gesture last" rule discussed earlier.

Clearly, there is an association between certain types of relations and their modes of expression. Whereas Kanzi, for example, favored two lexigrams to express conjoined action and action–object relations, he favored lexigram plus gesture for the goal–action and action–agent relationships. (The data in this table are slightly revised from those appearing in Savage-Rumbaugh 1988.)

Before concluding that these ordering tendencies constituted a rule, it was necessary to show that there was semantic reason to group TICKLE and CHASE in one category and BITE, SLAP, and HIDE in another (Criterion 1). Kuroda's formulation of the first-position lexigrams is that they function as invitations to play, whereas the second-position lexigram represents the play content that follows (S. Kuroda, pers. commun., 1987). In short, Kanzi's grammatical ordering reflected his action ordering. Grounded in action, this rule is fairly concrete. Note that the rules of human action would not have yielded such a syntactic rule, and indeed conjoined action combinations generally are rare in the speech of human children. In effect, Kanzi's rule of syntactic order corresponded to Kanzi's own rules of behavioral order and, indeed, to those of pygmy chimpanzees in general in the wild (S. Kuroda, pers. commun.).

Unlike the rules discussed up to now, these conjoined action order preferences lacked the minimum requirements of a proposition: one predicate and one argument. Conjoined action combinations simply chain two predicates. Lest we conclude that these structures were unrelated to human language, however, we must point out that many human languages have serial verbs where "conjoined action" word-order rules apply. Even in English, it is correct to say "go get," but not "get go." Although the particular conjoined action sequences were specific to Kanzi, and pygmy chimps more particularly, the concept of a rule-governed verb order certainly belongs in the ballpark of human language. Children at the two-word stage also formed conjoined structures (Brown, 1973), often expressing two arguments with no predicate.

Thus far, we have demonstrated a meaningful semantic relationship between the elements (Criterion 2) and consistent ordering to the point of statistical significance (Criterion 4). We have also demonstrated that the grammatical rule involved relations between categories of symbols (Criterion 3), for both categories in this invented rule involved at least two symbols each (although the categories were smaller than in the case of the previously discussed rules).

In addition to involving spontaneous, rather than imitative, combinations, the productivity criterion also requires a wide variety of combinations embodying the rule (Criterion 5). Of the 16 predicted combinations that would follow the rule, 10 were found in this period of data collection (Table 20.4, left column of "Complete corpus").

An even more stringent standard of productivity is novelty. The individual combinations were novel in the sense that they had not been modeled in Kanzi's environment; even more interesting, the rule itself was a novel creation ("Human model" in Table 20.4).

This phenomenon of creativity was similar to that found by Goldin-Meadow and Mylander (1984) for deaf children of hearing parents raised without sign language input. Most interesting, like the deaf children of hearing parents, Kanzi provided a model of this invented rule that caregivers ultimately imitated and, potentially, learned from him.

Difference in symbol order signals difference in meaning

Kanzi showed an incipient ability to use difference in symbol order to signal difference in meaning. When animate beings functioned as agents in Kanzi's lexigram–lexigram combinations, he tended to place them first, although there were too few for the trend to be statistically significant. When animate beings functioned as objects of action, Kanzi tended to produce them last, a trend that was significant at the .008 level (two-tailed binomial test). A χ^2 test showed the difference between the orders used to signal the two different meanings to be significant at the .05 level. As an example, Kanzi produced GRAB MATATA, when Matata was grabbed, but MATATA BITE when Matata functioned as an agent. This is the beginning of autonomous syntax, in which symbol order signals meaning relations without the help of a disambiguating context.

Three-symbol utterances

Kanzi differed from Nim in that he produced *nonredundant* three-element combinations in which a pair of two-element combinations would be linked to add new information (Savage-Rumbaugh et al., 1986).

Only one three-element pattern reached sufficient productivity in the period under study to be analyzed quantitatively: the action–action–agent (demonstrative gesture) pattern. These combinations combined and preserved the ordering rules of their constituent two-element combinations perfectly (7 of 8 cases, p = .0000, two-tailed significance-of-proportion test) (Bruning & Kintz, 1977), as do children's early multiword utterances (Braine, 1976). An example of this pattern is CHASE BITE person (demonstrative gesture). Here the actions chase and bite are ordered in accord with the conjoined action rule (Table 20.4), and the gesturally specified agent also conforms to the rule "place gesture last" (Table 20.3).

Limitations of the grammar

Kanzi showed some important differences from children in grammatical development. First, Kanzi's development was much slower. He took about 3 years from his first symbol to make the grammatical progress that children attain in about a year. Even at the point in the study just described, Kanzi was producing a much smaller proportion of combinations than a child would normally produce after 3 years of speech. Finally, in terms of pragmatic content, Kanzi had a much smaller proportion of indicatives or statements (4%), in comparison with requests (96%), than would be normal for a human child. This has also been observed in *Pan troglodytes* and may relate to a lesser proclivity for symbolization per se (Greenfield, 1978a; Terrace, 1985). However, part of the difference may reflect a bias stemming from the fact that in captivity, a chimpanzee's behavior and environment are under the control of humans, from whom he must request activities or objects. In the wild, a given animal might, for example, *state* his planned activity, rather than *requesting* it. This difference is quantitative rather than qualitative and may reflect a tendency on the part of the researchers to code chimpanzee statements as requests in the interests of conservative interpretation. The basic capacity to make a statement is present; evolutionary change could well have expanded on it.

Although Kanzi had been combining lexigrams for several years at the time of the grammar study, most combinations still were of only two elements, and most utterances still were single symbols. That was the same length limitation Terrace et al. (1979, 1980) found for Nim. In Kanzi's case, short symbol combinations may also have reflected a modality difference. Although his 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.

Discussion: Implications for the evolution of language

The role of action

Kanzi's self-created symbol-ordering rules seemed action-based:

1. In the conjoined action rule, symbol ordering followed the ordering of play action sequences.
2. In the "gesture follows lexigram" rule, symbol ordering arbitrarily sequenced two modalities of symbolic action.

The first invented rule seems to provide specificity and substance to the notion that language evolved as an instrument to plan coordinated action among human beings. Certainly, Kanzi's conjoined action utterances function as a means for him to plan his sequences of social play. A potential evolutionary implication is that grammatical combination arose partly as a tool to convey to others the planning of complex sequences of socially coordinated activity. Kanzi's conjoined action rule is pragmatically motivated, rather than arbitrary or abstract, but similar rules could have served as an evolutionary foundation for later, more abstract grammatical forms.

The second invented rule is, by contrast, arbitrary. Its function for Kanzi could be to enable him to order two symbolic modalities – lexigram and gesture – automatically, thereby minimizing physical awkwardness and facilitating the more rapid production of cross-modal symbol combinations. This interpretation rests on Lieberman's notion (1984) that syntax evolved to automaticize speech production, thereby enabling rapid speech output.

In sum, the nature of these particular rules suggests that the evolutionary origin of grammar lies in rules for sequencing actions. Insofar as the early stages of human ontogenetic development reflect our ape origins more strongly than do later stages, Greenfield's findings of the development of grammars

of action in human infancy lend further support to this view. In the research of Greenfield and colleagues (Greenfield, 1978b; Greenfield, Nelson, & Saltzman, 1972), the parallels between action grammars and linguistic grammars are closest for the earliest stages of language. This suggests that linguistic grammars evolve, both phylogenetically and ontogenetically, out of rules for ordering action sequences, but that they transcend these origins in later stages of phylogenetic and ontogenetic development.

Comparison with children at the two-word stage

While creativity is the rule in normal language acquisition, the degree of independence from a model of Kanzi's invented combinatorial rules is probably matched only by that of young deaf children of hearing parents studied by Goldin-Meadow and colleagues (Goldin-Meadow, 1979; Goldin-Meadow & Feldman, 1977; Goldin-Meadow & Mylander, 1984). In addition, Kanzi's way of using gestural indication to specify the agent in an agent–action relation was paralleled by these same deaf children (Goldin-Meadow, 1979; Goldin-Meadow & Mylander, 1984).

With respect to hearing children, Kanzi's development of a generative action–object symbol-ordering rule replicates a pervasive tendency in normal language acquisition to induce word-order rules from syntactic models presented in the environment (Baker & Greenfield, 1988; Greenfield, Reilly, Leaper, & Baker, 1985; Slobin, 1973).

Another important source of similarity to human children was the range of semantic relations, displayed in Table 20.1, which overlaps so much with Brown's analysis (1973) of children acquiring a variety of human languages at the two-word stage. Not only do the high-frequency relations overlap, as mentioned earlier, but also the low-frequency relations overlap. For example, the conjoined entities and conjoined locations relations in Table 20.1 are equivalent to Brown's low-frequency relation of conjunction. Conjoined actions constitute a form of conjunction also, but Brown (1973) does not mention any conjoined actions in his analysis.

Although a "true" grammatical rule must use some formal device such as word order to mark the semantic relation, children do not always do this at the two-word stage (Bowerman, 1973b; Brown, 1973; Goldin-Meadow & Mylander, 1984). Some children use word order more consistently than others, but even relatively consistent children show variability when analyses such as that shown in Table 20.1 are done (Bowerman, 1973b; Brown, 1973; Goldin-Meadow & Mylander, 1984). Consequently, the fact that only a subset of Kanzi's semantic relations demonstrated statistically reliable order was in line with the findings from child language.

Indeed, out of six relations tested for ordering patterns by Goldin-Meadow and Mylander, the modal deaf child in their study did not show *any* statistically significant ordering patterns for two-sign sentences, and the mean was .9 (less than one ordering pattern per child). However, it must be remembered that the lack of ordering patterns, where it occurred in the deaf children, was correlated with an extremely small corpus of data. Nevertheless, Kanzi's data provided more evidence for the use of the formal device of symbol order in two-symbol utterances than did the data of these deaf children, widely considered to have created language.

In addition, the deaf children of hearing parents were limited to semantically based ordering rules; they did not create purely formal syntactic rules (Goldin-Meadow, 1979). Kanzi, in contrast, not only invented a semantically based rule (for symbolic ordering of serial actions) but also invented a purely formal rule of symbol order (place gesture after lexigram).

The creation of ergativity by children and chimpanzees

An ergative language is distinguished by the fact that objects of transitive verbs receive grammatical marking identical to subjects of intransitive verbs, whereas transitive subjects receive a distinctive marking. Ergative languages stand in contrast to another class of language, termed accusative. In an accusative language (such as English), both transitive and intransitive subjects receive identical grammatical marking, in contrast to the different marking of transitive objects. Ergative and accusative languages implicitly categorize grammatical roles in different ways.

Goldin-Meadow (1979) found that her deaf subjects of hearing parents provided evidence of an incipient ergative system. Kanzi also created an incipient ergative system: He placed both intransitive agents and transitive objects after the action symbol.

Whereas the deaf children initiated ergative structure in the absence of a grammatical model in their environment, Kanzi produced the rudiments of an *ergative* system in the face of the *accusative* model presented by his English-speaking caregivers. Ergativity was, therefore, a creative invention on Kanzi's part, just as it was for the deaf children.

Kanzi's ergative system was incomplete because he produced too few three-term transitive utterances (with agent, action, and object) to permit an analysis of the ordering of transitive agents. Except in the case of one subject, the deaf children's data were also incomplete. Another point to note about Kanzi's ergative system is that although his action–agent utterances had an intransitive surface structure, they usually were interpreted by his caregivers as being partial realizations of underlying transitive relations.

Kanzi's specific syntactic ordering – placing intransitive agent and transitive object *after* the action symbol – differed from that of the one deaf child with more complete data, who placed intransitive agent and transitive object *before* the action element. However, the important point is that Kanzi, like the deaf child, marked his intransitive agents and transitive objects in an identical fashion. In so doing, he implicitly created an ergative categorization of basic grammatical rules.

Pan paniscus, Pan troglodytes, and human children

Brown (1970, 1973) and Gardner and Gardner (1971) have compared Washoe's two-sign utterances to those of children. Based on a set of six semantic relations that Brown used in his 1970 paper, the Gardners reported that 78% fell into those six categories (equivalent to our entity–attribute, goal–action, agent–action, action–object, and agent–object, plus possession, which we did not observe). Although we do not know how many of the 294 utterance types (any word pair could appear only once in the corpus) were imitated, and how many were spontaneous, the similarity to Kanzi's semantic relations, as well as to those of children, is striking.

Because the Gardners (1971) reported that they did not record sign order for the two-sign utterances, we do not know if any of the reported relations were marked by consistent ordering patterns. Nor did they report, with respect to their data, whether or not relations were marked with the inflections that are more important in American Sign Language than sign order. They did report one three-sign pattern that employed a consistent order pattern. Whereas Kanzi's three-symbol rule was an invented rule, Washoe's was modeled by her caregivers (Gardner & Gardner, 1971). Given this modeling effect, it would be particularly important to know to what extent these patterned three-sign utterances were direct imitations and to what extent they were spontaneous. Terrace and associates claimed that Washoe generally imitated her caregivers. But their conclusions were based on analyzing two commercial films, rather than on complete data. Whether or not Washoe's semantic relations were spontaneous to a significant degree, the data indicate that Kanzi's level of syntactic invention was greater than Washoe's both at the two-symbol level and at the three-symbol level.

The problem of a double standard

Comparative developmental psycholinguistics has been plagued by a double standard. Because children ultimately develop language, their early stages are interpreted as having greater linguistic significance than the same stages in primates (de Villiers, 1984; Nelson, 1986). When children make up novel words on a one-shot basis, it is called lexical innovation (e.g., Clark, 1983). When chimpanzees do the same thing (e.g., Washoe's famous water-bird) (Fouts, 1974a), it is termed ambiguous (Terrace et al., 1979, 1980). One possible conclusion is that methodological standards in child language should be more rigorous. Another, more important conclusion is that we should compare developing behaviors across species objectively, without being influenced by the nature of later stages in either species. This methodological stricture is important because without it, it becomes impossible to compare developments in species whose early stages may be more similar than their developmental endpoints. Yet it is just such comparisons that may yield the most interesting behavioral data on the evolution of language.

Language development, language history, and language variability: The role of context

From this perspective, let us consider the controversy about rich interpretation. The fact that it is necessary to interpret the nonverbal context to assign meaning relations to children's two-word utterances has caused critics to say that the structure may be in the observer rather than in the child. If we move from the ontogeny of the child to the historical development of the language, Rolfe (1988) points out that the characteristic of early stages of language evolution is that the structures are not explicit, but require inference on the part of the listener. We may say the same for the child. Rich interpretation is required exactly *because* explicit syntactic and semantic marking is the product of development; it is not a characteristic of the early stages. Just as the early stages in language evolution are characterized by the necessity to infer structure from context, so are the early stages of child language. It is of evolutionary interest that bonobo language, like early human languages and like the language of young children, requires the listener to infer structure from context.

Moreover, even modern human languages, spoken by mature speakers, vary considerably in their reliance on inference from context, versus explicit grammatical marking (Comrey, 1987). Where relatively little information is grammatically marked, languages are termed "pragmatic." For example, as Duff (1989) points out, Chinese is considered to be just such a pragmatic language, in which much information must be recovered from context (e.g., agents, time reference), just as is required by Kanzi's productions and those of deaf children of hearing parents (Goldin-Meadow, 1979).

Concluding comments

A number of qualitative similarities between the two species, bonobo and human, have potential evolutionary significance:

1. The capacity for grammatical rules (including arbitrary ones) in Kanzi's semiotic productions shows grammar as an area of evolutionary continuity. Here we might prefer to speak of protogrammar rather than grammar. However, as stated earlier, the comparative data are such that if we speak of bonobo rules as protogrammar, we should apply the same term to the 2-year-old child.

2. The existence of action-based rules shows that the ordering of action sequences might be one of the evolutionary roots of grammar, even though this connection does not exist in normal human adults. Here it is interesting to note that when linguistic grammar breaks down in the agrammatism of Broca's aphasia, the grammar of manual action, as measured by a hierarchical construction task (Greenfield & Schneider, 1977), also breaks down (Grossman, 1980).

3. The finding of rule creation has implications for the evolutionary continuity of language. At various points in the history of our species, grammatical rules for human language were created, not merely learned. Although the rules just described were simple, they nevertheless were created de novo by Kanzi. This suggests that some rudiments of the ability to create a grammar have an ancient evolutionary history in a common ancestor of our chimpanzee and human species.

4. The particular grammatical structures invented by Kanzi, while distinct from those modeled by his caregivers, resemble those used by human beings:

(a) *Kanzi's conjoined action rule.* Ordered conjoined action sequences occur widely in human languages, where they are called serial verbs. Serial verbs are particularly important features of certain languages, figuring prominently in many West African languages, for example (Lord, 1989).

(b) *Combining gesture and lexigram.* The creative combination of semiotic elements from different symbolic levels was done by deaf children of hearing parents, who combined indexical points with iconic signs (Goldin-Meadow, 1979; Goldin-Meadow & Mylander, 1984). Kanzi's invented rule for combining lexigram with gesture (place gesture last) also involved different symbolic levels: He combined indexical gestures with arbitrary lexigrams.

(c) *Ergativity.* Kanzi invented a primitive version of an ergative grammatical system, despite the fact that an accusative system was modeled for him. In so doing, a bonobo chimpanzee spontaneously created one of the two logically possible grammatical groundplans utilized by all human languages (A. Duranti, pers. commun., November 1989).

Ideally, an evolutionary reconstruction is based on finding the same trait in all members of a genus. However, the more sophisticated grammatical qualities described in this chapter – notably protogrammatical rule invention – have not, so far, been either claimed or established in *Pan troglodytes*. At this point, we do not know if that is because of a true species difference or merely because of a difference in research methodology. An ongoing study involving the rearing of a pygmy chimpanzee with a common chimpanzee by Savage-Rumbaugh should begin to answer this question.

Simple recapitulationism is not a possible model for relating the evolution of human language to modern-day primate species, who have themselves evolved since the branching of the evolutionary tree. However, our evidence bears out the idea that structural dependencies govern development and therefore evolution (Parker & Gibson, 1979). Kanzi, like a human child, first acquired individual lexical items. At a later stage, he combined those elements into two-term relations. Still later, Kanzi systematically combined two-term relations into three-element utterances. Although the specific semantic content and formal nature of some of Kanzi's rules seemed unique to his species and symbol system, his global development of grammatical structure and his array of semantic relations mirrored that of the human child. Evolution could not have reversed this transspecific developmental sequence from simple to more complex structures.

In addition, Kanzi's array of semantic relations and the presence of rule-bound sequencing resembled the early language productions of human children. Because of the generally greater similarities in related species at the earlier points in ontogenetic development, these resemblances do not seem like an evolutionary coincidence. Finally, Kanzi's capacity to invent simple grammatical or protogrammatical rules provides clues as to the evolutionary origins of grammar, as well as a mechanism for historical language change in the absence of genetic evolution. This inventive capacity suggests that the ancestor of the pygmy chimpanzee may have had the cognitive prerequisites to invent a protogrammar. This protogrammar could then have provided an evolutionary foundation for the later development of full-blown grammar, just as the two-word stage of child language forms a developmental foundation for the more complex and abstract adult grammar that follows.

Note

1. For dissenting views on cebus imitation see Gibson, P&G7; Parker & Poti', P&G8; Visalberghi & Fragaszy, P&G9.

Acknowledgments

We would like to thank Elizabeth Rubert, Jeannine Murphy, Phillip Shaw, Rose Sevcik, and Kelly McDonald for assistance in all aspects of the data collection. Thanks also to Penny Nelson for help with data analysis and to Duane Rumbaugh and Terrence Deacon for stimulating discussion and to Laura Weiss for manuscript preparation. Alessandro Duranti provided helpful information concerning comparative linguistic structure. We very much appreciated the helpful comments on the first draft by Sue T. Parker and Susan Goldin-Meadow and the bibliographic assistance provided by Sue T. Parker.

The work described in this chapter and its preparation were supported by National Institutes of Health grant NICHD-06016, which supports the Language Research Center, cooperatively operated by Georgia State University and the Yerkes Regional Primate Research Center of Emory University. In addition, the research is supported in part by RR-00165 to the Yerkes Regional Primate Research Center of Emory University. PMG was supported by the Bunting Institute, Radcliffe College, by a grant from the Office of Naval Research to the Bunting Institute, Radcliffe College, by an award from the UCLA College Institute, and by the UCLA Gold Shield Faculty Prize.

References

Baker, N. D., & Greenfield, P. M. (1988). The development of new and old information in young children's early language. *Language Sciences*, *10*, 3–34.

Bloom, L. (1970). *Language development: Form and function in emerging grammars*. Cambridge, MA: M.I.T. Press.

Bloom, L. (1971). Why not pivot grammar? *Journal of Speech and Hearing Disorders*, *36*, 40–50.

Bloom, L., Rocissano, L., & Hood, L. (1976). Adult–child discourse: Developmental interaction between information-processing and linguistic knowledge. *Cognitive Psychology*, *8*, 521–552.

Bowerman, M. (1973a). *Early syntactic development: A cross-linguistic study with special reference to Finnish*. Cambridge University Press.

Bowerman, M. (1973b). Structural relationships in children's utterances: Syntactic or semantic?

In T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 197–213). New York; Academic Press.

Braine, M. D. S. (1976). Children's first word combinations. *Monographs of the Society for Research in Child Development*, *41* (1, Serial No. 164), 1–96.

Bronowski, J., & Bellugi, U. (1970). Language, name, and concept. *Science*, *168*, 669–673.

Brown, R. (1970). The first sentences of child and chimpanzee. In R. Brown (Ed.), *Psycholinguistics* (pp. 208–231). New York: Free Press.

Brown, R. (1973). *A first language: The early stages*. Cambridge, MA: Harvard University Press.

Bruning, J. L., & Kintz, B. L. (1977). *Computational handbook of statistics*. Glenview, IL: Scott, Foresman.

Chevalier-Skolnikoff, S. (1976). The ontogeny of primate intelligence and its implications for communicative potential: A preliminary report. *Annals of the New York Academy of Sciences, 280,* 173–216.

Chevalier-Skolnikoff, S. (1989). Spontaneous tool use and sensorimotor intelligence in *Cebus* compared with other monkeys and apes. *Behavioral and Brain Sciences*, *12*(3), 561–588.

Chomsky, N. (1965). *Aspects of the theory of syntax*. Cambridge, MA: MIT Press.

Chomsky, N. (1980). Human language and other semiotic systems. *Semiotica*, *25*, 31–44.

Clark, E. (1983). Meaning and concepts. In P. Mussen (Ed.), *Handbook of child psychology: Cognitive development* (Vol. 3, pp. 787–840). New York: Wiley.

Comrey, B. (1987). Paper presented at the international Pragmatics Association, Antwerp.

de Villiers, J. (1984). Limited input? Limited structure. Commentary on Goldin-Meadow & Mylander. *Monographs of the Society for Research in Child Development*, *49*, 122–129.

Duff, P. (1989, March). *"Protogrammar" in bonobos and deaf children (without ASL input)*. Unpublished paper, Applied Linguistics Program, UCLA.

Feldman, H., Goldin-Meadow, S., & Gleitman, L. (1978). Beyond Herodotus: The creation of language by linguistically deprived deaf children. In A. Lock (Ed.), *Action, symbol, and gesture: The emergence of language* (pp. 351–414). New York: Academic Press.

Fouts, R. S. (1973). Acquisition and testing of gestural signs in four young chimpanzees. *Science*, *180*, 978–980.

Fouts, R. S. (1974a). Language: Origins, definitions and chimpanzees, *Journal of Human Evolution*, *3*, 475–482.

Fouts, R. S. (1974b). Capacities for language in great apes. In R. H. Tuttle (Ed.), *Socioecology and psychology of primates* (pp. 371–390). The Hague: Mouton.

Fouts, R. S. (1975). Communication with chimpanzees. In I. Eibl-Eibesfeld & G. Kurth (Eds.), *Hominisation und Verhalten* (pp. 137–158). Stuttgart: Gustav Fisher.

Fouts, R. S., & Couch, J. B. (1976). Cultural evolution of learned language in chimpanzees. In E. Simmel & M. Hahn (Eds.), *Communicative behavior and evolution* (pp. 141–161). New York: Academic Press.

Gardner, B. T., & Gardner, R. A. (1971). Two-way communication with an infant chimpanzee. In A. Schrier & F. Stollnitz (Eds.), *Behavior of nonhuman primates* (pp. 117–183). New York: Academic Press.

Gardner, B. T., & Gardner, R. A. (1974). Comparing the early utterances of child and chimpanzee. In A. Pick (Ed.), *Minnesota symposium on child language* (pp. 3–23). Minneapolis: University of Minnesota Press.

Gardner, B. T., & Gardner, R. A. (1978). Comparative psychology and language acquisition. *Annals of the New York Academy of Sciences*, *309*, 37–76.

Gardner, B. T., & Gardner, R. A. (1980). Two comparative psychologists look at language acquisition. In K. Nelson (Ed.), *Children's language* (Vol 2, pp. 331–369). New York: Gardner Press.

Gardner, B. T., & Gardner, R. A. (1985). Signs of intelligence in cross-fostered chimpanzees. *Philosophical Transactions of the Royal Society*, *B*, *308*, 159–176.

Gardner, R. A., & Gardner, B. T. (1969). Teaching sign language to a chimpanzee. *Science, 165*, 654–672.

Gardner, R. A., & Gardner, B. T. (producers). (1973). Teaching sign language to the chimpanzee (film). University Park, PA: Psychological Cinema Register.
Goldin-Meadow, S., & Feldman, H. (1977). The development of language-like communication without a language model. *Science, 197*, 401–403.
Goldin-Meadow, S. (1979). Structure in a manual communication system developed without a conventional language model: Language without a helping hand. In H. A. Whitaker (Ed.), *Studies in neurolinguistics* (Vol. 4, pp. 125–209). New York: Academic Press.
Goldin-Meadow, S., & Mylander, C. (1984). Gestural communication in deaf children: The effects and noneffects of parental input on early language development. *Monographs of the Society for Research in Child Development, 49*, (3–4, Serial No. 207), 1–120.
Gould, S. J. (1977). *Ontogeny and phylogeny*. Cambridge, MA: Harvard University Press.
Greenfield, P. M. (1978a). Commentary on Developmental processes in the language learning of child and chimp, by Savage-Rumbaugh and Rumbaugh. *Behavioral and Brain Sciences, 4*, 573–574.
Greenfield, P. M. (1978b). Structural parallels between language and action in development. In A. Lock (Ed.), *Action, gesture, and symbol: The emergence of language* (pp. 415–445). London: Academic Press.
Greenfield, P. M. (1980). Towards an operational and logical analysis of intentionality: The use of discourse in early child language. In D. Olson (Ed.), *The social foundations of language and thought: Essays in honor of J. S. Bruner* (pp. 254–279). New York: Norton.
Greenfield, P. M., Nelson, K., & Saltzman, E. (1972). The development of rulebound strategies for manipulating seriated cups: A parallel between action and grammar. *Cognitive Psychology, 3*, 291–310.
Greenfield, P., Reilly, J., Leaper, C., & Baker, N. (1985). The structural and functional status of single-word utterances and their relationship to early multi-word speech. In M. Barrett (Ed.), *Children's single-word speech* (pp. 233–267). London: Wiley.
Greenfield, P. M., & Savage-Rumbaugh, E. S. (1984). Perceived variability and symbol use: A common language–cognition interface in children and chimpanzees. *Journal of Comparative Psychology, 98*, 201–218.
Greenfield, P. M., & Savage-Rumbaugh, E. S. (in press). Imitation, grammatical development, and the invention of protogrammar. In N. Krasnegor, D. M. Rumbaugh, R. Schiefelbusch, & M. Studdert-Kennedy (Eds.), *Biobehavioral foundations of language development*. Hillsdale, NJ: Erlbaum.
Greenfield, P. M., & Schneider, L. (1977). Building a tree structure: The development of hierarchical complexity and interrupted strategies in children's construction activity. *Developmental Psychology, 3*, 299–313.
Greenfield, P. M., & Smith, J. H. (1976). *The structure of communication in early language development*. New York: Academic Press.
Grossman, M. A. (1980). A central processor for hierarchically-structured material: Evidence for Broca's aphasia. *Neuropsychologia, 18*, 299–308.
Hill, J. H. (1978). Apes and language. *Annual Review of Anthropology, 7*, 89–112.
Jordan, C., & Jordan, H. (1977). Versuche zur Symbol-Ereignis-Verknupfung bei einer Zwergschimpansen (*Pan paniscus* Schwarz, 1929). *Primates, 18*, 515–529.
King, M. C., & Wilson, A. C. (1975). Evolution at two levels in humans and chimpanzees. *Science, 188*, 107–116.
Lieberman, P. (1984). *The biology and evolution of language*. Cambridge, MA: Harvard University Press.
Limber, J. (1977). Language in child and chimp? *American Psychologist, 32*, 280–293.
Lord, C. (1989). *Historical change in serial verb constructions in languages of West Africa*. Unpublished doctoral dissertation, University of California at Los Angeles.
McNeill, D. (1974). Sentence structure in chimpanzee communication. In K. Connolly & J. Bruner (Eds.), *The growth of competence* (pp. 75–94). New York: Academic Press.
Matsuzawa, T. (1985). Colour naming and classification in a chimpanzee (*Pan troglodytes*). *Nature, 315*, 57–59.

Miles, H. L. (1983). Apes and language: The search for communicative competence. In J. De Luce & H. T. Wilder (Eds.), *Language in primates* (pp. 43–61). New York: Springer-Verlag.
Nelson, K. (1987). Reply to Seidenberg and Petitto. *Journal of Experimental Psychology: General, 116*(3), 293–296.
Nova (1976). The first signs of Washoe (film). New York: Time-Life Films.
Parker, S. T. (1985). A social technological model for the evolution of language. *Current Anthropology, 26*, 617–626.
Parker, S. T., & Gibson, K. R. (1979). A developmental model for the evolution of language and intelligence in early hominids. *Behavioral and Brain Sciences, 2*, 367–408.
Patterson, F. G. (1978). The gestures of a gorilla: Language acquisition in another pongid. *Brain and Language, 5*, 72–97.
Patterson, F. G. (1980). Innovative uses of language by a gorilla: A case study. In K. Nelson (Ed.), *Children's language* (Vol. 2, pp. 497–561). New York: Gardner Press.
Peirce, C. S. (1931). Division of signs. In C. Hartshorne & P. Weiss (Eds.), *The collected papers of Charles Sanders Peirce* (pp. 134–155). Cambridge, MA: Harvard University Press.
Petitto, L. A. (1987). On the autonomy of language and gesture: Evidence from the acquisition of personal pronouns in American Sign Language. *Cognition, 27*(1), 1–52.
Petitto, L. A., & Seidenberg, M. S. (1979). On the evidence for linguistic abilities in signing apes. *Brain Language, 8*, 162–183.
Piaget, J. (1962). *Play, dreams, and imitation*. New York: Norton.
Premack, D. (1970). A functional analysis of language. *Journal of the Experimental Analysis of Behavior, 14*, 107–125.
Premack, D. (1971). Language in chimpanzee. *Science, 172*, 808–822.
Premack, D. (1976). Language and intelligence in ape and man. *American Scientist, 64*, 674–683.
Rolfe, L. H. (1988, July). *Pragmatics and the evolution of syntax*. Paper presented at the NATO Advanced Workshop on the Evolution of Language, Cortona, Italy.
Rumbaugh, D. M. (Ed.). (1977). *Language learning by a chimpanzee: The Lana Project*. New York: Academic Press.
Rumbaugh, D. M., & Gill, T. V. (1976a). Lana's mastery of language skills. *Annals of the New York Academy of Sciences, 280*, 562–578.
Rumbaugh, D. M., & Gill, T. V. (1976b). Language and the acquisition of language-type skills by a chimpanzee (*Pan*). *Annals of the New York Academy of Sciences, 270*, 90–124.
Rumbaugh, D. M., Gill, T. V., & von Glasersfeld, E. C. (1973). Reading and sentence completion by a chimpanzee. *Science, 182*, 731–733.
Sarles, H. B. (1972, June). *The search for comparative variables in human speech*. Paper presented at the Animal Behavior Society meetings, Reno, NV.
Savage-Rumbaugh, E. S. (1984). *Pan paniscus* and *Pan troglodytes*: Contrasts in preverbal communicative competence. In R. L. Susman (Ed.), *The pygmy chimpanzee: Evolutionary biology and behavior* (pp. 395–413). New York: Plenum.
Savage-Rumbaugh, E. S. (1986). *Ape language: From conditioned response to symbol*. New York: Columbia University Press.
Savage-Rumbaugh, E. S. (1988). A new look at ape language-comprehension of vocal speech. In D. Leger (Ed.), *Comparative perspectives in modern psychology. Nebraska Symposium on Motivation* (Vol. 35, pp. 201–256). Lincoln: University of Nebraska Press.
Savage-Rumbaugh, E. S., McDonald, K., Sevcik, R. A., Hopkins, W., & Rubert, E. (1986). Spontaneous symbol acquisition and communicative use by pygmy chimpanzees (*Pan paniscus*). *Journal of Experimental Psychology: General, 115*, 211–235.
Savage-Rumbaugh, E. S., & Rumbaugh, D. M., & Boysen, S. (1978a). Linguistically mediated tool use and exchange by chimpanzee (*Pan troglodytes*). *Behavioral and Brain Sciences, 1*, (1–28), 539–554.
Savage-Rumbaugh, E. S., Rumbaugh, D. M., & Boysen, S. (1978b). Symbolic communications between two chimpanzees (*Pan troglodytes*). *Science, 201*, 641–644.
Savage-Rumbaugh, E. S., Rumbaugh, D. M., Smith, S. T., & Lawson, J. (1980). Reference: The linguistic essential. *Science, 210*, 922–925.

Savage-Rumbaugh, E. S., Sevcik, R. A., Brakke, K. E., Rumbaugh, D. M., & Greenfield, P. M. (in press). Symbols: Their communicative use, combination, and comprehension by bonobos (*Pan paniscus*). In L. P. Lipsitt & C. Rovee-Collier (Eds.), *Advances in infancy research*, Vol. 7. Norwood, NJ: Ablex.

Savage-Rumbaugh, E. S., Sevcik, R. A., Rumbaugh, D. M., & Rubert, E. (1985). The capacity of animals to acquire language: Do species differences have anything to say to us? *Philosophical Transactions of the Royal Society, B 308*, 177–185.

Savage-Rumbaugh, S., & Wilkerson, B. J. (1978). Socio-sexual behavior in *Pan paniscus* and *Pan troglodytes*: A comparative study. *Journal of Human Evolution, 7*, 327–344.

Schlesinger, I. M. (1971). Production of utterances and language acquisition. In D. Slobin (Ed.), *The ontogenesis of grammar: A theoretical symposium* (pp. 63–101). New York: Academic Press.

Seidenberg, M. S., & Petitto, L. A. (1979). Signing behavior in apes: A critical review. *Cognition, 7*, 177–215.

Slobin, D. I. (1973). Cognitive prerequisites for the development of grammar. In C. A. Ferguson & D. I. Slobin (Eds.), *Studies of child language development* (pp. 175–208). New York: Holt, Rinehart & Winston.

Studdert-Kennedy, M. (1988, June). *Introduction: Language development from an evolutionary perspective.* Paper presented at a conference on the biobehavioral foundation of language development. Leesburg, VA.

Terrace, H. S. (1984). Apes who "talk": Language or projection of language by their teaching? In J. De Luce & H. T. Wilder (Eds.), *Language in primates* (pp. 19–42). New York: Springer-Verlag.

Terrace, H. S. (1985). In the beginning was the "name." *American Psychologist, 40*, 1011–1028.

Terrace, H. S., Petitto, L. A., Sanders, F. J., & Bever, T. G. (1979). Can an ape create a sentence? *Science, 206*, 891–900.

Terrace, H. S., Petitto, L. A., Sanders, F. J., & Bever, T. G. (1980). On the grammatical capacity of apes. In K. Nelson (Ed.), *Children's language* (Vol. 2, pp. 371–496). New York: Gardner Press.

Volterra, V. (1987). From single communicative signal to linguistic combinations in hearing and deaf children. In J. Montanger, A. Tryphon, & S. Dionnet (Eds.), *Symbolism and knowledge* (pp. 89–106). Geneva: Jean Piaget Archives Foundation.

Weiss, M. L. (1987). Nucleic acid evidence bearing on hominoid relationships. *Yearbook of Physical Anthropology, 30*, 41–73.

Wiener, L. F. (1984). The evolution of language: A primate perspective. *Word, 35*, 255–269.

Zihlman, A. L. (1979). Pygmy chimpanzee morphology and the interpretation of early hominids. *South African Journal of Science, 75*, 165–168.

Zihlman, A. L., Cronin, J. E., Cramer, D. L., & Sarich, V. M. (1978). Pygmy chimpanzee as a possible prototype for the common ancestor of humans, chimpanzees, and gorillas. *Nature, 275*, 744–746.

Index