

The Development of Spontaneous Gestures in Zoo-living Gorillas and Sign-taught Gorillas: From Action and Location to Object Representation

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Abstract: *We analyze the developmental sequence in which different types of representation appear in untaught signs in the repertoire of Koko, a signing gorilla, and in the gestures developed by zoo-living gorillas at different ages. There is a progression in all the subjects from pure action to iconic representation of action. The signing gorilla, in addition, depicts objects. This is done through hand shape, miming of an action related to the use of an object, or by tracing the outline of an object. The various spatial mediums (i.e., on the body versus in open space) in which signs are performed assist in understanding of the cognitive processes supporting ape representation and communication. The progression from ape “action mapping” to the level of representation found in human language is viewed as a series of stages that follow logically upon each other in a continuum of development, both in individuals and in possibly in the history of the hominoid family.*

Introduction

Research in recent decades has shown that zoo-living apes create gestures other than the obviously species-typical, and signing apes regularly employ signs that they have themselves created, in addition to taught signs. We explore the relationship of spontaneous gestures by zoo-living gorillas to those created by a sign language-taught gorilla.¹

1. In this paper we will use the word “sign” for human sign language taught to apes, and also for gestural inventions by signing apes. “Gesture” refers to inventions by zoo gorillas.

Particular attention is given to the development of iconic gestures because they require a type of understanding that can be linked to human representational abilities. *Here we define an iconic sign or gesture simply as one that depicts a physical aspect of its referent.* Zoo-living gorillas use iconic gestures for actions anticipated or desired (Tanner & Byrne, 1996, 1999); in both species of chimpanzee as well, iconic gestures have been observed both in untaught captives (Kohler, 1925; Yerkes, 1943; Hayes, 1951; Savage-Rumbaugh, Wilkerson, & Bakeman, 1977) and chimpanzees trained in symbol systems other than sign language² (Savage-Rumbaugh, 1986; Greenfield & Savage-Rumbaugh, 1990, Savage-Rumbaugh & Lewin, 1994). Signing apes also create novel iconic signs; unlike zoo captives, they spontaneously create signs to represent objects for which they have not been taught signs, and use such invented, untaught signs repeatedly and consistently (Gardner & Gardner, 1971; Patterson, 1980; Patterson & Cohn, 1990; Miles, 1978, 1993; Miles, Mitchell, & Harper, 1996). The usage of iconicity can be traced in the chronological development of gestures in individual gorillas, and the forms the iconicity takes and what it represents are important keys to understanding ape cognition.

We survey signs Patterson and Cohn (1990) list as invented by Koko during her first ten years of sign language instruction, with particular attention to those that appear to be iconic, and we note the types of iconicity that Koko uses and make comparisons with zoo gorillas' gestures. We assess modes of representation in terms of their order of appearance in Koko's individual development, and compare the developmental progression and age of appearance of similar gestures in zoo gorillas. We consider the spatial media in which gestures and signs are produced. We compare the usage of those gestures or signs that take the same form in both zoo gorillas' and Koko's usage to learn whether their "meanings" or functions are universal or variable. Though the gestures of gorillas have not been extensively studied by other researchers until very recently, where possible we incorporate any relevant data from other gorillas in zoos or the wild.

Subjects

Only two gorillas have been extensively taught a human sign language: Koko (a zoo-born female lowland gorilla) and Michael (a wild-born male lowland gorilla, now deceased). Koko resides at the Gorilla Foundation in Woodside, California. Koko was born at the San Francisco Zoo on July 4th, 1971, and is the full sister of Kubie, a principal subject of the first author's zoo observations. Koko's exposure to American Sign Language (ASL) and constant interaction with human companions began at the age of one year under the tutelage of the second author, Francine Patterson, who was at the time a graduate student at Stanford University. Koko was simultaneously exposed to a variant of American Sign Language and human (English) speech. Further detail of the education of gorillas Koko and Michael and the entire ongoing project can be found in Patterson (1978, 1979, 1980), Patterson & Linden (1981), Patterson & Cohn (1990), Patterson & Gordon (1993, 2002), and Bonvillian & Patterson (1993, 1999).

2. Because the researchers working with these apes do not describe their gestures in physical detail, they cannot be compared with those of signing apes or apes not taught a symbol system.

Information regarding the gestures of zoo-living gorillas is drawn primarily from Tanner & Byrne's long-term study of the gorilla group at the San Francisco Zoo (Tanner 1998, 2004; Tanner & Byrne 1993, 1996, 1999). See www.gorillagestures.info for video examples of the San Francisco Zoo gorillas' gestures and more about the research on the gorilla group there. From 1988 until 1997 observations were made outdoors at the San Francisco Zoo one morning each week for approximately three hours, conditions permitting. Further observations, on a less regular basis, have continued until this writing. The study team consisted of the first author and the camera operator, Charles L. Ernest. The general procedure was to videotape all social interaction continuously wherever it was possible to use the video camera. Later, videotape was analyzed and gestures were cataloged into a Filemaker™ database. As a working definition, the term "gesture" applied to all discrete, non-locomotor limb and head movements that appeared to be potentially communicative, regardless of receptive sensory modality.

The subjects, the gorillas at the San Francisco Zoo, are members of a stable social group; all of them have spent nearly all of their lives at this zoo. The San Francisco Zoo's present gorilla enclosure has been this group's home since 1980. It has an outdoors area of 2300 square meters, or 38 by 50 meters at maximum parameters. It is covered with grass and other vegetation and contains large, climbable live trees as well as several dead trees, large stumps, and two artificial rock hills including arches and cave-like areas.

The group at the time of the beginning of the study included first- and second-generation descendants of the wild-caught founder, Bwana, who had been at the zoo since 1958. A wild-caught female, Pogo, human-reared in her early years, grew up at the zoo with Bwana and is of about the same age. Two young females whose early rearing was by humans in zoo nurseries, Bawang and Zura, joined the group in 1981 and 1982 respectively, after the deaths of two older females. Bawang is the mother of Kubie's offspring, Shango, Barney, and Nneka, who have all been mother-reared. Bawang was always Kubie's preferred mate, but when she was pregnant or involved in caring for her first infant, Kubie switched his attentions and play activity to the younger female, Zura. All of these gorillas have been subjects of the Tanner and Byrne studies, but the interaction between Kubie and Zura received the most intense analysis; by far the greatest amount of gesturing was done by these two gorillas.

Untaught Signs by Koko and Michael

Most of Koko's and Michael's earliest taught sign language vocabulary that reached formal criteria³ of consistent usage was composed of iconic signs, in contrast to the vocabulary of deaf children. As the gorillas' vocabularies increased, the proportion of

3. Two sets of criteria were used: the Emitted criterion accepted as a vocabulary item each use of a recognizable sign used spontaneously in an appropriate context; the Patterson criterion accepted a sign only if it was observed and recorded by two different observers to be used appropriately and spontaneously on at least half the days during a period of a month. By the end of ten years, Koko had acquired 876 words by the Emitted criterion, 290 words by the Patterson criterion. The spontaneously invented signs discussed in this paper all met the Emitted criterion.

iconic signs decreased, though it remained higher than that of the human children studied by Bonvillian and Patterson (1993). Bonvillian and Patterson, however, acknowledge that the design of their study does not allow us to discern the influences from humans on the content of taught sign vocabulary. Also some taught iconic signs may represent aspects of the referent that would not be recognized by the learner as iconic. Here we will look only at signs that were created by the gorillas that were not part of their taught American Sign Language vocabulary.

In summarizing the first ten years of Koko's vocabulary development, Patterson and Cohn (1990) list Koko's entire vocabulary during these ten years and indicate which of those signs were not taught, but used spontaneously by the gorilla. These spontaneous creations were not a result of deliberate human reinforcement of chance novelty; untaught signs were often not initially comprehended by Koko's human companions and were ignored or misunderstood until repeated context made the meaning clear. Thus Koko's untaught signs can be expected to be free from human influence in choice of referents. In some cases, the inventions were for actions, objects, or concepts for which Koko had not been taught a sign; others were for actions, objects, or concepts for which she had been taught a sign but for which she strongly seemed to prefer her own usage. Once acknowledged by humans as part of her vocabulary, untaught signs were neither discouraged nor encouraged, but simply accepted as part of Koko's repertoire of signs. (It is, of course, possible that humans have failed to understand and interpret some of Koko's signs. Also, because iconic signs are easier for us to attempt to translate, they might be over-represented in summarizing Koko's vocabulary.)

We categorize, according to type of iconicity or other form of reference, fifty signs that Patterson and Cohn (1990) characterized as "invented" by Koko. This was done with the help of an unpublished, internal-use video created by Dr. Francine (Penny) Patterson and Darlene Chan for Gorilla Foundation employees, unpublished lists of Koko's sign lexicon, published physical description of earliest signs (Patterson, 1978), as well as the first and second authors' personal experience and knowledge of Koko's signing. Not included are those listed as "natural" (Patterson & Cohn's term for signs or gestures they suspected to be species-typical) or "modulated or compounded" (*modulated* means modifying the taught articulation of a sign; *compounded* means combining aspects of taught signs to form a new sign). The total corpus of 50 signs, with descriptions and categories, is included as an appendix. Table 1 summarizes the referential categories of Koko's untaught signs, and Table 2 their types of iconicity or other modes of depiction. Plate 1 illustrates some of Koko's untaught signs.

Table 1. Referents of Koko's Untaught Signs (First 10 Years)

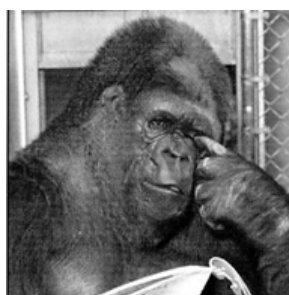
Total invented signs	50	
Signs for objects	27	54%
Signs for actions	17	34%
Other signs	6 (2 for qualities, 2 for states of attention, 2 deictic [pointing])	12%

Table 2. Types of Representation Used by Koko

Note that the categories of iconic representation of object shape and action are not mutually exclusive: there were a few signs that involved elements of both.		
Total signs using iconic mode of description	38	76% of total untaught signs
Signs depicting action iconically but not necessarily representing <i>an action</i> ; may represent an object by depicting action on or with that object.	27	54% of total untaught signs 70% of iconic untaught signs
Signs depicting shape of an object iconically	15	30% of total untaught signs 40% of iconic untaught signs



Browse



Eye makeup



Frown



Unattention



Bite



Hair barrette

Plate 1. Some of Koko's untaught signs

Of Koko's untaught signs during the first ten years of her life, approximately half represented objects and another third, actions (Table 1). Three-quarters of her untaught signs involved an iconic mode of depiction (Table 2). Among these, approximately 70% involved depiction of action, either of an action itself or of a customary action upon an object. Though these untaught signs were predominantly signs for objects, more than half of these objects were not represented by depicting their shape, but by an action performed upon or with them. For instance, modeling *clay* was signed by a motion of rolling the palms together, as when rolling out clay; a hand *puppet* by

the motion of putting the puppet on the hand. Some action mimes listed as representing objects might seem to be just as well translated as signs for actions, not for objects. However, Koko often used them to request the object in question (by accompanying pointing or reaching with eye contact), thus indicating that an object was the referent of the action.

In some cases the signs might be interpreted either way; in American Sign Language, many signs can represent either an object or an action depending on repetition and other differences in production. An action can refer to an object, and an object depiction may be part of an action request. Also, the categories of action and object depiction are not necessarily mutually exclusive because it is possible to indicate a shape and also an action in a single sign. An example is Koko's sign for *dental floss*, where Koko picked her teeth with an index finger (untaught), and then made the taught sign for *thread*, which traces the shape of dental floss.

About 40% of Koko's untaught iconic signs represented an object by depicting an element of the shape of the object. Since it is usually impossible to represent the entirety of an action or an object with the hands, a salient aspect must be chosen to represent it. Such condensation of depiction is an aspect of both ape and human signing. Koko's specific choices of forms of *metonymy*, i.e., representing an object or action by depicting just a part of it, will not be the focus here though well worthy of further study. (A description of the form of each untaught sign can be found in the Appendix.) Here we consider metonymic signs simply as iconic. Because our primary interest here is the cognitive processes leading to the physical representation, we consider a sign that describes any part of the physical form of an action or object to be the result of some kind of process of iconic representation. Koko's means of representation are discussed in detail later in the section entitled "Koko's Modes of Invention."

Some of Koko's untaught signs were not iconic. One was a deictic (pointing) sign that indicated the location of an object (Koko's early "notice" sign, glossed as *bird* at the time because she co-opted elements of this taught sign and used it in a deictic manner). Another sign simply located a referent on the self (e.g., body hair indicated by grasping hair between the fingers). Koko also created signs that involved cross-modal transfer of English sounds to a sign;⁴ for instance, blowing forcefully at someone to express that they "blew it," that is, performed an action she wasn't pleased with (she was quite familiar with the colloquial expression, frequently used in the spoken English of her companions, often to scold her). In this case, the "sign" is itself a sound, accompanied by characteristic body posture and facial expression. Some inventions were "blended" from several taught signs (e.g., apricot = the sign for *peach* made with an "A" hand shape like *apple*). A few were of unknown or indiscernible origin (like Koko's *lip* in reference to human females, performed by rubbing an index finger horizontally on her lips).

4. A study of Koko's response to alterations in vowels or consonants in spoken words illustrated that Koko can accurately perceive the sounds of human speech (Goodreau, Patterson & Tam, 1996; Patterson & Goodreau, 1987; Goodreau, 1987).

Another frequent element of Koko's untaught signs, as well as of taught signs she has altered to her personal preference, is locating them on her body as opposed to forming them in space away from the body. Of her untaught signs, 60% were placed on the body location of the referent.

Michael, Koko's male gorilla companion, also used untaught signs, and Koko subsequently adopted some of these for her own use. Untaught signs originated by Michael but co-opted by Koko during the first ten years of the project were *hit-in-mouth*, *hit-in face*, and *pull-out-hair*, all mimes of the described actions.

From Action to Object in the Creation of Gestures and Signs: Zoo Gorillas and a Signing Gorilla Compared

Action and location, the preferred ways of depiction in Koko's untaught signs, are also frequently used in gestures of the gorillas observed at the San Francisco Zoo (Tanner & Byrne, 1993, 1996, 1999) to communicate about features of behavior and the environment. For both signing and non-signing gorillas, action and location (as the beginning or ending point of action) seem to be the basic building blocks for expression. It is a short journey from describing an action or indicating a location to describing an object, because the action and location of an object can be employed in describing it gesturally, as in many of Koko's inventions; and the outlining of action is not far from the action of outlining an object.

Zoo gorillas have been observed to create depictions of action of the self or another gorilla, and gestures of similar types have, though very rarely, been observed in the wild (Schaller, 1963). Gorillas in the wild have been observed to enact actions anticipated of the self or desired of others; zoo gorillas have been observed to trace the trajectory of such actions on another's body or in space.⁵ Captive studies (Tanner 1998; Tanner & Byrne 1999) give the approximate ages at which different classes of gestures appear (see Table 3).

Table 3 illustrates the progression in taught and untaught gorillas from depiction purely of action, to object depiction with signs or gestures. The developmental progression of sign invention by Koko can be found in records of her first untaught signs (Patterson, 1980); Table 3 is thus ordered chronologically. The chronology for zoo-living gorillas and gorillas in the wild is less precise because of more limited observation. Only one earliest example is given for each class of depiction in Table 3; in most cases there were other examples of each class, and in the discussion following, some of these are mentioned. Additional signs for each classification can also be found in the descriptions in the Appendix. For some categories "invented" signs by Koko are not found in available records but instead are listed as "natural" gestures in an earlier study. The dividing line between "natural" gesture and "invented" sign cannot be a

5. There have also been some observations in the wild, such as those found in Schaller (1963) and Robert Campbell's unpublished film for Dian Fossey at the National Geographic Society (viewed in entirety by the first author), that can give us an idea of at what stage mountain gorillas in their native environment make certain kinds of gestures.

Table 3. From Actions to Objects in Gesture and Sign Invention: First Appearances of Different Kinds of Representation.

What sign or gesture describes or indicates	How produced	Where formed	Example (English gloss)	Physical description	Zoo, wild gorillas, earliest age observed to be used	Signing gorilla, age in years and months when first used or invented
location indicated to other	touch location	on an object (other than self or other gorilla)	<i>knock</i> <i>that</i>	fist contacts object such as rock or tree; eye contact and response waiting to other gorilla index finger or fingers contact object	zoo age 7 <i>not seen</i>	knocks, age 1 but not to indicate location to other 1.0
location indicated to other	extend finger toward location	in space	<i>that, there</i>	index finger extended from hand toward location	<i>not seen</i>	1.0
action upon self desired from other	enacted	in space	<i>up</i>	arms raised to request or anticipate being picked up by adult	zoo age 1; wild infant	1.0
action desired of other	enacted non-forcefully	on other's body	<i>move away</i>	light push to other's body	zoo age 2; wild adults	1.0
action desired of other	mimed	on own body	<i>tickle</i>	index strokes under-arm or sole of foot	<i>not seen</i>	1.2
action desired of other	traced	on body of other	<i>turn around</i>	on other's waist, arm moves from one side of body to other	zoo age 7	1.11
object	hand shape, location	on own body	<i>bracelet, hand puppet</i>	cupped hand pats wrist	<i>not seen</i>	2.8
action desired of other	traced	in space	<i>away, go</i>	arm swept toward other	zoo age 6; wild all ages	2.9
action upon other anticipated	enacted	on own body	<i>bite</i>	biting self on hand or wrist	zoo age 7; wild juvenile	2.10
object	action on or of an object mimed	with hands in space in front of body	<i>clay</i>	flat hands, top hand moves back and forth over other palm	<i>not seen</i>	3.8
negation	altering facial expression	on own body	<i>Frown (KOKO)</i> <i>hide play-face (ZURA)</i>	manipulate face cover up face with hands	zoo age 7	4
object	tracing of shape of object	on own body	<i>eyeglasses</i>	index fingers trace lines from eyes to back of ears	<i>not seen</i>	6.1

Table 3. (Continued)

What sign or gesture describes or indicates	How produced	Where formed	Example (English gloss)	Physical description	Zoo, wild gorillas, earliest age observed to be used	Signing gorilla, age in years and months when first used or invented
location on self indicated to other	touch location	move arm in space, to location on own body	<i>armswing under (walk up bottom)</i>	arm swings from space in front of body to between legs	zoo age 7	6.4
object	formed by static hand shape only	in space	<i>pickle</i>	thumb and index extended from both fists held in space in front of body	<i>not seen</i>	7+
object	tracing of shape of object	in space	<i>thread</i>	two little fingers touch then move apart horizontally	<i>not seen</i>	<i>(used only when taught by humans)</i>

Observations of gestures in the wild come from the following sources, but primarily the publications of George Schaller and Dian Fossey: Baumgartel, 1976; Burbridge, 1928; Campbell unpublished film; Denis, 1963; Fay, 1989; Fossey, 1979, 1983; Mori, 1983; Schaller 1963/1976, 1964.

Sources: Patterson (1980); Patterson, Tanner & Mayer (1987); Patterson & Cohn (1990); Tanner (1998)
Arranged chronologically by order of appearance in signing gorilla.

firm one, as learning and genetics are so entwined for any behavior and further, since we do not have good observations of behavior for all groups of gorillas, especially in the wild. A better designation, which we use throughout, is simply between human-taught and untaught signs.

Koko's earliest recorded untaught signs were listed as "natural" signs, though her standard deictic sign, pointing with the index finger, has not been reported in untaught gorillas. Further untaught signs seen early in the first year of instruction (age 12–24 months) were *up*, requesting an action upon the self by another; and tactile signs such as a light push to another, indicating *move away*. By the end of the year a tactile sign using a tracing motion on another's body appeared, requesting a companion to *turn around*.

Gorillas at the San Francisco Zoo have been observed to use all the "natural" untaught gestures performed by Koko in her first year of sign instruction, except for pointing with the index finger. Later in development *knock* or *pound* (using the fist) and *slap* (open hand) are used by zoo gorillas to touch objects in a clearly deictic fashion, with eye contact and waiting for response from the partner gorilla.⁶ Such usage was observed repeatedly in a 7-year-old gorilla and her older play partner but may appear earlier; Tanner's zoo observations began when the younger of her principal subjects was already age 7. Subsequent observations of younger zoo gorillas by Tanner and others

6. See Leavens, Hopkins, & Bard, (1996), Leavens & Hopkins (1998, 1999), for discussions of variability of form in pointing by chimpanzees. The development of pointing in human children and the criteria for social pointing have been discussed by many scholars, for instance Butterworth (1996) and Bates, Benigni, Bretherton, Camaioni, & Volterra (1979).

(Pika, Liebal, & Tomasello, 2003) did not find such referencing, however. Likewise, tactile gestures on another's body, requesting directional movement of the other gorilla, were rarely seen in zoo gorillas until age 7.⁷ Miming on the gesturer's own body of the specific action desired of another was not observed at all in zoo gorillas.

The earliest untaught signs recorded as invented by Koko are *blow* and *tickle*, which depicted actions desired of another and appeared during her second and third months of sign instruction, when she was just over a year old. The earliest appearance of *blow* was putting her index finger to another's mouth when the person stopped blowing, perhaps simply pointing; Koko appeared to want the person to continue blowing. Koko then began to request the action "blow" by holding a finger up to her own mouth, transferring the features of another's body to her own. *Tickle* was likewise indicated by miming the action desired of another on her own body. Her next sign was a deictic sign, performed with two index fingers held together at the tips. This sign was directed toward interesting objects out of reach, but was glossed *bird* because it incorporated elements of a *bird* sign a teacher first used. Subsequently, however, Koko employed it for many referents other than the bird the teacher had originally been pointing out.

Koko's next type of untaught sign did not appear until over a year later, during which time her taught ASL signing progressed rapidly. This sign, at age 2 years 8 months, was *bracelet*, performed by a cupped hand patting the wrist, first used requesting a new bracelet she was shown. This was her first sign created for an object, and involved an iconic hand shape depiction as well as contacting the part of her own body where the object usually was worn, thus perhaps involving a tactile element as in earlier signs such as *tickle*. She later extended the use of the *bracelet* sign, referring to a hand puppet on a companion's hand as well as using the sign for bracelets. This seems to be an extension of the ability to point out location to another, which Koko did at the age of just one year. It is requesting "something on my body, wrapped around this location." A zoo gorilla (Kubie) comes close to this in a unique observation when he *pats his shoulders*, with eye contact, in interaction with another gorilla (Zura), resulting in her approaching Kubie and placing her hands on his shoulders (Tanner & Ernest, 1989).

Koko's next untaught sign, *bite*, appeared at age 2 years 10 months (see Plate 1). She placed the side of her hand or index finger in her mouth to request biting play from a companion. A similar gesture has been observed in both free-living and zoo juvenile gorillas and the first author has observed it in captive monkeys where a play partner was not physically available. Like Koko's earliest untaught signs, *bite* reproduced the action desired of another, on her own body. Around the same time, another untaught sign, *away* or *go*, appeared. It differed from the earlier sign, *up*, in that it depicted in space motion desired from another, not motion anticipated for the self. A similar gesture was used by zoo gorillas from age 6, and has been seen in the wild.

At age 3 years, 8 months, a new type of depiction appeared: Koko's sign for *clay*. Koko requested clay by miming the customary action performed on the object, rolling a

7. Tactile gestures consisting of reaching, stretching and touching are seen early on (also in gorillas studied by King, 2004) but not tracing a path of action or suggesting motion in a certain direction as found in older gorillas by Tanner and Byrne (1999).

ball of clay between the hands. This could be interpreted as depicting the activity of playing with clay rather than the object itself, but Koko used such signs to request objects. During Koko's first five years, all her iconic inventions reproduced *action* of or upon an object, or objects were indicated by simply placing an appropriate hand shape on her body. No signs depicting an object or its action have been observed in zoo gorillas.

At age 6 years a new mode of depiction appeared for Koko: tracing the shape of an object. Koko created a sign for *eyeglasses* where index fingers traced a line from the eye to the back of the ears. Eventually, Koko produced a total of 15 inventions describing objects that involved depicting the shape rather than the action of an object (see Appendix). A form of active "tracing" of the form of an object was used in five cases; in ten cases, her depictions of shape were produced instead by a descriptive hand shape (e.g., extended finger for a straight or narrow object, cupped hand for a rounded object, index and thumb extended for a small rectangular object) placed on an appropriate body location. Among Koko's 50 inventions from her first 10 years (listed in Appendix), all signs that depicted an action were performed on appropriate body locations, and nearly all that depicted a shape were also performed touching her body. An exception was her later invention at age 7 of a sign for *pickle* (described in Table 3), with appropriate hand shapes in the space in front of the body. The only category of object representation not found among Koko's untaught signs during her first ten years is the tracing of an object in space away from the body, though she uses such signs when taught. (*Thread*, a taught sign used in her untaught compound sign for dental floss, is such a sign).

Also between age 6 and 7, Koko produced a sign glossed *walk-up-bottom*, requesting her male gorilla companion to touch or tickle her bottom. A similar gesture was frequently observed in zoo gorillas, described as *armswing under*. For the zoo gorillas as for Koko, this gesture appeared in adolescence. For the zoo gorilla Kubie, this often included a tap to the other gorilla, and then swinging the arm to a location between the legs. His version actually was a phrase that can be glossed as "you come under," that is, a request to make contact with the gesturer gorilla's genital area.⁸

To summarize, the chronological development of modes of representation in Koko's spontaneously created signs is as follows:

- 1) (from age 1–2 years) *depicting actions* on her own body, another's body, or in space, to represent activity desired of another; and *pointing* to objects or locations desired or noted
- 2) (from age 2.8) *placing the hand-shape of an object* on an appropriate body location, to represent an object or action
- 3) (from age 3.8) *miming an action performed with or on an object* in order to represent an object
- 4) (from age 6) *tracing on her body the outline of an object to describe the object*
- 5) (from age 7) *tracing a shape in space* away from the body or using a *hand shape held in space* away from the body to describe an object

8. For more about gesture phrases, see Tanner 2004.

These last two were the rarest of Koko's means of representing objects, though these methods of depiction are common in American Sign Language and are employed in many of her taught signs.

Development of Gesture in Zoo Gorillas

In zoo gorillas, gestures were utilized to depict action or indicate location, as described above for Koko at age 1–2 years onward, but appeared later in the zoo gorillas. Tanner's zoo observations began when the two principal subjects, Kubie and Zura, were already young adults. The earliest information available on Kubie showed that nearly all his adult repertoire of gestures at age 13 was already present at age 8, in the context of sexual positioning and sexual play with an older and uncooperative female (Keller, 1984). Some play gestures were present at age 2 years. Sue Parker (1999), in a study when Kubie was an infant, lists Kubie's play "enticements" which include "slapping surface, arm waving, chest beating, foot stamping, tagging, hand clapping, head wagging." These gestures at age 2 do not appear to include gestures that indicate location or depict directional motion, tactile or otherwise.

A gesture used as a "negative" was seen in the zoo gorilla Zura from age 7; this was *hide playface*, used to suppress the urge to play and understood by her male play partner, who responded by not approaching (Tanner & Byrne, 1993); other gestures were used as negatives also (Tanner, 2004). Koko at age 4 used a facial alteration, *frown*, to show annoyance, disgust or negativity toward activities or objects. Later she used an *unattention* sign, hands covering face, to avoid things she did not want to see or participate in.

Because it was impossible to know whether gestures observed in the adult zoo subjects might originally have appeared earlier, the question of when different kinds of gestures develop was addressed later through observation of two male infants, Shango and Barney, born into the group during the course of the study (Tanner & Byrne, 1999). Their earliest discrete gestures were audible ones produced by contact with a surface (e.g., ground, rock, tree or own body), actions that were also included in Kubie's early gestures listed by Parker (1999). They used reaches and arm extensions toward their mother or other gorillas or toward objects of interest that another gorilla possessed, but without the eye contact and response waiting that are hallmarks of real indication. (However, responses from older gorillas to arm extensions may eventually lead to awareness of their efficacy and establish them as indicating gestures.) New gestures gradually appeared in the older brother, Shango; he began to use a few tactile gestures, but at age 6 still used neither the silent gestures in space nor self-indicating gestures that the young adults used. Barney, the younger brother, began at age 2 to frequently use the *armshake* gesture observed in his father, but older brother Shango almost never used it. *Armshake*, by iconically depicting action, may show desire for another gorilla to approach and take play action. Other gestures by adult Kubie indicated approach was desired to various body locations; examples are *head nod*, *armswing under*, *slap shoulders*, and *extended palm*. Some gestures indicated locations in the environment; such indicating gestures were all observed in gorillas aged 6 years and above. Repre-

sentation of objects or individuals found in the gorillas' environment seemed to be absent. In summary, the zoo gorillas, without any human instruction, would depict on their own body, on another's body, or in space, actions desired from another, and would manually indicate objects or locations of concern, but mostly after age 6. These kinds of gestures were produced by Koko by age 2.

Discussion: Koko's Modes of Invention

Whether the tracing of a shape or use of a "frozen" hand shape is the more abstract method of depiction is an open question, but depiction of an object with hand shape appeared earliest for Koko. The hand shape was placed on the relevant body location, a development that seems to follow on from pointing to locations by touching them. Tracing would seem to be a more precise or detailed way of mapping a shape. Koko used both tracing and hand shape modes of depiction in taught signs before using similar modes in untaught signs. In both types of signs, the concept of one's own body as a mirror of something "out there" is necessary. Consistent with this, Koko has shown the ability to use mirrors appropriately (Patterson & Cohn, 1994).

Another aspect of Koko's untaught signs for objects is that nearly all of her 27 object signs were for referents that she could, and presumably did, touch and handle. The motion, previously experienced, of rolling clay is easily performed when the clay is not in the hands. Another invention, *barrette*, (see plate) reproduces the motion of touching the length of a barrette (hair clip). *Thermometer* places a finger under the arm, just like the real thermometer touches the underarm when Koko is given veterinary treatment. The early invention, *stethoscope*, combines the learned sign *necklace* with the placing of fingers in the ears, a mirror reproduction of the doctor's action, also a tactile reproduction when allowed to handle the stethoscope herself. Active tactile experience with objects appears to play a part in eliciting manual expressions representing absent objects.

"Tracing" untaught signs were the latest to appear in Koko's repertoire, only created after 6 years of age. *Long-hair* refers to long-haired humans, and traces the hairline of a human's long hair on her own body, again a mirroring of something seen outside of herself. *Filmers/reporters* is likewise a tracing sign on her body, delineating the straps of camera equipment on news reporters who visited her.

Koko had two frequent signs that also appeared after age 6, woman (*lip*) and man (*foot*), that are not clearly iconic. They did, however, perhaps draw upon characteristics of men and of women that were particularly salient for Koko, thus employing metonymy, the representation of an object or concept by depiction of only a part of the object. Like many signs in human sign languages, *lip* and *foot* are opaque and arbitrary to anyone without an intimate knowledge of their origins (Kendon, 1988; Armstrong, Stokoe, & Wilcox, 1995). "Woman" (*lip*) is an index finger rubbed horizontally back and forth across the lips. Perhaps this is related to *lipstick*, a similar motion performed with the thumb. However, *lip* is similar to another earlier sign of unknown origin, glossed *note*, which Koko used before pointing to something of interest; this *note* sign dropped out of her vocabulary after early years. "Man" (*foot*) appeared after

she began to take sexual interest in a human visitor not amongst her caretakers, a laboratory worker who wore heavy boots, and it has been speculated that Koko was using the boots as a point of reference; this visitor also sometimes played a game tickling Koko's foot, and she may have extended her foot to him then. There is another possible derivation, however. A gesture observed several times in the zoo female Zura (see Table 4), consisted of turning the rear toward and extending a *foot back* to another gorilla, a mounting reference possibly derived during development from a signal commonly used by a mother for a youngster to get on her back. Zura sometimes tapped the sole of her extended foot with her index finger as part of this signal, sometimes only tapping the foot without presenting the rear, in the context of sexual play. This *tap foot* is identical to Koko's "man" (*foot*) sign, which Koko used frequently in the context of human men, but not, for instance, for a "family" member such as her "surrogate father" Ronald Cohn. If the derivation suggested is correct, it would be an example of an adaptation of a "natural" behavior to a new context.

Untaught signs created by Koko after her first ten years have not been formally described in academic publications but many are described in articles in the Gorilla Foundation's semi-annual *Journal*. Signs now regularly glossed as *above* and *below*, whose meaning at first eluded researchers, have become a standard part of Koko's repertoire (Patterson & Tanner, 1988). These depict spatial location by moving a flat palm forward off the top of the head (*above*) or moving a flat palm from between the legs when seated (*below*).⁹ Another sign noted only in recent years has been glossed as *take-off*, referring to removal of clothing, lifting both flat hands quickly off the top of the head. Koko has also continued to transfer sounds of human speech into signed form, as in her frequent sign for vegetable *browse* (see Plate), a term for which she was not given a sign. The spoken word was not used until a change in diet when browse items of leafy green vegetables began to be distributed to Koko at intervals throughout the day. Koko makes the *browse* sign by placing a fist ("S"-hand) on her *brow*, with the tapping motion of the sign for "lettuce" from American Sign Language (Menendez & Patterson, 1994).

As well as inventing signs for referents for which she had not been provided with an ASL sign, Koko replaces some of her taught signs with untaught ones for the same referent, perhaps because her own versions are more meaningful to her when clearly iconically related to a referent or touching her body. Also, as previously noted, she seems to prefer signs without intricate hand configurations, substituting signs easier for gorilla hands to articulate, and signs that touch her body. An example is her usage (a cross-modal transfer) of *knee* (tapping a finger on her knee) for "need," for which she had a taught sign; the ASL version of *need* is performed with a crooked index finger moving downward in the open space in front of the body. Another untaught sign that makes use of gorilla anatomy is Koko's exaggerated version of *frown*, using her hands to pull her lower lip down rather than simply tracing downward lines at the corner of the mouth as in the ASL sign. In many ASL signs she retains the motion and place of a sign but changes or simplifies hand shape; in some she retains motion and

9. This depiction of the concept that something is located below something else seems to be a directional reversal of Koko's walk-up-bottom sign and Kubié's frequent armswing under gesture.

hand shape but changes the place, usually to her body or a surface in her environment such as wall or floor.

Gestures Found in Both Signing Gorillas and Zoo Gorillas

The number of communicative gestures shared by taught and untaught gorillas may be underestimated. Patterson and Tanner (1988) list untaught signs of Koko's that duplicate gestures described for one or more of the gorillas at the San Francisco Zoo. Table 4 lists gestures of Koko's that have also been observed in zoo gorillas or in the wild. A few gestures listed here overlap with those listed among Koko's "invented" signs from Patterson and Cohn (1990); at the time of observation, these were not known to be used by other gorillas. Though not all have been seen in all gorillas, most have been observed in more than one zoo gorilla. Some of the gestures have not been reported in gorillas other than Koko and the San Francisco Zoo gorillas and may be similar because of a capacity of gorillas (and other apes) to form iconic gestures, rather than the gestures themselves being genetically predetermined. Similar gestures have been observed in other ape species (Fouts, 1997; Miles, 1978, 1993), and often have different functions both in different species and for individuals within a species (Tanner, 1998). Functions of many gestures are similar for both Koko and the zoo gorillas, but there are also some differences. All these shared gestures are social in function, used in interaction with other individuals to regulate actions and locations of activity. For Koko, such gestures were incorporated into her signed discourses and thus were used linguistically regardless of their origin. Non-sign-taught apes, who have been trained with lexigrams or computers, also incorporate "species-typical" gestures into their communications (Savage-Rumbaugh, 1986; Greenfield & Savage-Rumbaugh, 1990). For the zoo gorillas too, gestures often did not stand alone but were incorporated into strings of other gestures (Tanner, 2004).

General Discussion

A gorilla tutored in sign language and gorillas living in a zoo both create signs or gestures that depict and invite action and point out objects and locations, but signs that refer to objects themselves are invented only by the signing gorilla. Many of the untaught signs of signing apes and the gestures of non-signing apes have iconic characteristics. Iconic descriptions can be formed in several different ways, depending on what aspect of an action or object is chosen as salient, i.e., what kind of metonymy is employed. Gestures describing similar actions or objects, therefore, may vary within and between different groups of apes (Tanner, 1998). On the other hand, some gestures or signs that are physically very similar are shared between signing and non-signing apes but may not have the same functions; these may be iconic gestures that are similar in appearance because they describe similar material, or may be hitherto little known species-typical gestures elicited by a relevant social environment (see Table 4).

Table 4. Koko's Untaught Gestures Seen in Other Gorillas

Koko's untaught signs also observed in other gorillas	Koko's usage with Gorilla Foundation gloss	Usage at San Francisco Zoo	Where observed (zoo, wild)
<i>armacross</i>	(glossed as <i>catch</i>) used in activities involving tossing and catching of objects; chase games, playing hard to get; also requesting embrace or desirable objects	play contexts; function otherwise unknown	zoos and wild
<i>armshake</i>	(glossed as <i>play</i> or <i>hurry</i>) invitation to play; also expression of excitement or impatience	play invitation, readiness for activity; sometimes warning or threat (only used this way by one individual)	SF Zoo, not in wild
<i>armswing under</i>	(glossed as <i>walk-up-bottom</i>) sexual solicitation or request for tickling of bottom	invitation for contact in sexual play	SF Zoo, not in wild
<i>away</i>	(glossed as <i>stop</i>) to stop advance of another individual	agonistic contexts, avoidance of contact	zoos and wild
<i>backhand</i>	(glossed as <i>darn</i>) expresses annoyance or frustration	gaining attention in play situations, also used in agonistic display or protest	zoos and wild
<i>bite</i>	in playful excitement, referring to biting	in play, before or after biting play	zoos and wild
<i>chestbeat</i>	excitement, agitation, but also in a more controlled form glossed as <i>gorilla</i>	excitement, agitation, attention getting	zoos and wild
<i>circle hands</i>	(glossed as <i>gentle</i>) request for gentle behavior	unknown, but seen in play contexts	zoos and wild
<i>clap</i>	playfulness or excitement	in play, often solitary and before performing a physical action like jumping or balancing	zoos and wild
<i>deictic (pointing) gestures</i>	(glossed as <i>me, you, that, there, your</i>) designating numerous referents and locations; Koko performs points with extended index finger. <i>Your</i> is performed with outstretched palm, may designate another's property or turn for action.	designating other or self as object or agent of action; also designating locations. Performed with open hand, knuckles or fist. Glossed as <i>chest fist pat, tap other, pound, extended palm</i>	zoos and wild
<i>extended palm (could be included with deictic gestures)</i>	(glossed as <i>come-gimme</i>) requesting objects or the approach of other individuals	invitation to contact or request for food	zoos and wild
<i>facewipe</i>	(glossed as <i>toilet, b.s.</i>) expression of disbelief, uncertainty or annoyance	annoyance, avoidance	SF Zoo
<i>foot</i>	designating the body part, also referring to human males	seen in a zoo gorilla, a variation of foot back sexual invitation performed by tapping the foot with the hand	one SF Zoo gorilla
<i>hand between legs</i>	(glossed as <i>below</i>) performed seated; hand moving out from under body designates location below or under another object. When forceful slapping motion, a masturbation activity.	play, sexual invitation (usually patting motion)	SF Zoo, Rio Grande Zoo

Table 4. (Continued)

Koko's untaught signs also observed in other gorillas	Koko's usage with Gorilla Foundation gloss	Usage at San Francisco Zoo	Where observed (zoo, wild)
<i>hands behind back</i>	(glossed as <i>walk-up-back</i>) requesting companions fingers walked up back, tickling	inviting play activity or approach from companion seated behind self	zoos
<i>head nod</i>	(glossed as <i>yes</i>) agreement, assent	inviting approach or visual attention of other gorilla	one SF Zoo gorilla, wild
<i>head shake, head turn</i>	(glossed as <i>no</i>) dissent	head shake used in playful contexts; head turn sometimes avoidance or possible request for change of direction	zoos and wild
<i>knock, pound (fist hand shape)</i>	attention getting, or cross-modal transfer of English "obnoxious"	get visual attention in playful context; indicate location or direction	zoos and wild
<i>slap surface (flat hand)</i>	(for Koko, glossed as <i>pound</i>) play invitation of challenge; referential use to request pounding on her back	play or chase invitation attention getter	zoos and wild
tactile gestures	indicate movement desired from another by non-forceful contact or motion upon other's body; can take many different forms: can take many different forms: moving hand down back vertically or across horizontally, patting, gentle pulling of hand, light push away, and others	indicate movement desired from another by non-forceful contact or motion upon other's body; can take many different forms: moving hand down back vertically or across horizontally, patting, gentle pulling of hand, light push away, and others	zoos and wild
<i>up</i>	for movement upward; request to be picked up	request or intention to move upward	zoos and wild

Observations of gestures in the wild come from the following sources, but primarily the publications of George Schaller and Dian Fossey: Baumgartel, 1976; Burbridge, 1928; Campbell unpublished film; Denis, 1963; Fay, 1989; Fossey, 1979, 1983; Mori, 1983; Schaller 1963/1976, 1964.

(Koko's usages from Patterson, 1980; Patterson & Tanner, 1988; zoo data from Tanner, 1998)

The fact that some of the gestures performed by signing apes resemble those of apes in the wild has been seized upon by some as evidence that apes do not really learn human sign languages, but only perform gestures that they would "naturally" use anyway (Pinker, 1994; Wallman, 1992). The accumulation of evidence does not support contentions that signing apes do not really use sign language but only adapt their species-typical gestures. "Natural" or species-typical gestures are indeed used by symbol-taught apes, but they may often elaborate upon them and have opportunities to use them in a greater variety of contexts than do apes in the zoo or in the wild. In addition to such species-typical gestures, apes with different upbringings are likely to invent gestures similar to each other's, given a common ability for iconic representation, similar anatomies, and similar material to describe. In addition, signing apes, of course, use a large vocabulary of taught standard sign language in addition to species-typical gestures and untaught signs. Even when modified by anatomy of the ape hand,

much of this signing is nothing like their “natural” gestures. Few gestures resembling American Sign Language signs are spontaneously formed by untaught apes, who use a limited number of hand shapes compared to apes taught ASL.¹⁰

The iconic gestures a signing gorilla creates are more numerous and elaborate than those of zoo captives, probably because of intensive exposure to symbolic modes of communication and interaction with humans. Early input may alter brain utilization in humans (for instance, a heightened sense of pitch in humans blind since infancy, Gougoux, Lepore, Lassonde, Voss, Zatorre, & Belin, 2004) and no doubt in apes (Bard & Vaclair, 1984; Povinelli, 1994). A recent experiment with marmosets (South American monkeys) showed that in only one month, those monkeys housed in larger and more enriched environments actually developed denser neuron growth and had more of the synaptic proteins the brain uses in relaying messages between neurons, in contrast to control subjects housed in minimal caged situations (Kozorovitskiy, Gross, Kopil, Battaglia, McBreen, Stranahan, & Gould, 2005).

Where great apes have been shown to possess capacities once reserved for humans, such as the ability to imitate goal-directed actions and understand their reflection in mirrors and employ referential pointing, the apes have often been individuals raised by humans (discussions of the strong claim that human-rearing “enculturates” apes, giving them human capacities they do not naturally develop, are found in several chapters in Parker, Mitchell, & Boccia, 1994). Skills salient in humans would be likely to be more utilized in apes with a good deal of exposure to humans (Povinelli, 1994; Gomez, 2004). Iconic representation is, after all, related to imitation in that it is a form of mime, and requires the taking of another’s perspective when depicting an action or object outside the self as well as kinesthetic/visual matching (Mitchell, 1994; Byrne, 1995). Expressing, in iconic fashion, action desired from another appears relatively late in Koko’s inventions (age 2) and even later in zoo gorillas’ development (age 6–7). Request for another’s action upon the gesturer’s own body appears earlier. Gestures requesting action of another require understanding of the other as an independent agent and also an understanding of the other’s point of view. For instance, the gorilla must have an awareness that the visual attention of the partner is necessary for communicating with gestures; such understanding was present in the adolescent zoo gorillas studied by Tanner and Byrne (and in younger gorillas; see Gomez, 1990, 1991, 1994, 1996).

Koko moves further than zoo subjects with her untaught signs: from depicting social action, to use of a “still” image to represent an object, to reproduction of customary behavioral action upon an object to represent that object, then to tracing the outline of an object. Thus there is a transition from pure behavior and “intention movements” to representation of proposed action from others (rather than one’s own action), and finally to non-action representation of objects.

Signing apes and zoo captives have in common action and location as the most prevalent descriptive elements used in forming their gestural creations, even those un-

10. American Sign Language has nineteen primary hand shapes plus twice as many variations; a deaf human child untutored in sign language created nine hand shapes (Goldin-Meadow, 1984). Untutored gorillas seem perhaps to have three: open palm, fist, and knuckle hand.

taught signs of the gorilla Koko that represent objects. This may be because of the gorilla's limited comfort with the intricate hand shapes utilized in human sign language that would more precisely describe object shape, but are not suited to gorilla anatomy. Alternatively, however, preference for action as a descriptive mode may be related to cognitive processing. The brain has specialized cells for visual reception of hand and limb movement that respond strongly to hand-object interactions (Perrett et al., 1989). More recently neurons termed mirror neurons have been found to react to actions performed on objects, but do not react to an object alone, or to the same action performed without an object involved (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Fogassi, & Gallese, 1996; Rizzolatti & Arbib, 1998; see Rizzolatti & Craighero, 2004, for a review of mirror neuron research, and Roy & Arbib, 2005; Arbib, 2002, 2005, regarding implications for language production and perception). Most recently, research has shown that the understanding of others' manual actions is influenced by context (objects nearby) that implies what the subject's intention might be (Iacoboni, Molnar-Szakzacs, Gallese, Buccioni, Mazziotta, & Rizzolatti, 2005). The implication that actions are understood through their context and that objects are understood through the actions performed on or with them aligns well with the fact that the majority of Koko's untaught signs for objects were made by portraying a customary action associated with the object.

Within the framework of the function of mirror neurons, Arbib provides a scenario that neatly parallels the progression we have found in moving from zoo gorillas' spontaneous gestures depicting action, to Koko's inventions for objects. Demonstrating how bridging from action to language could take place, Arbib (2002) provides a hypothetical sequence for development of gesture in evolutionary history that moves from pragmatic action towards a goal object, to imitation of such actions (required in order for Koko to establish an iconic sign for new objects/actions), to pantomime produced away from the goal object (what Koko does when establishing a new sign in her vocabulary, getting the observer to focus on a specific action, or an object associated with it). The next stages Arbib posits are: abstracting gestures from their pragmatic origins, which is what happens when Koko makes a (metonymic) choice of what aspect of action to use to henceforth represent the target action or object; then using the new sign in compounds with other previously established taught or untaught signs, as she does. Koko presumably jumps up to the latter phases, not found in zoo gorillas or other untaught apes, because her enculturation with human communication enhances her understanding of shared attention and conventions of language.

The predominance of descriptive action in untaught signs may be biologically facilitated by the mirror neuron system; proximately, it may be due to the fact that it is through shared action that social discourse takes place between gorilla and gorilla, or gorilla and human companion in Koko's case. For Koko, the introduction of a new and unfamiliar object like a stethoscope or modeling clay would be meaningless without a demonstration of the usage of that object, and it is that usage that makes the object come alive as a part of the shared interaction involving it.

In Koko's development, actions were depicted earlier than hand-shape object descriptions, and tracing of outlines of objects was latest to appear. Tracing a shape is

cognitively very close to drawing or writing (as noted by Edwards, 1979). Koko is able to paint depictions of objects that are correctly placed in their relative spatial and size locations and to select appropriate paint colors, but her paintings are not always detailed in reproduction of shape (for a photograph of a painting and its model see Patterson, 1985).¹¹ Because the tracing of shapes for Koko seems to be most comfortably and extensively performed on the surface of her own body, there might also be a tactile element involved in some of her signs; the hand shape for *glasses*, for instance, might involve a tactile memory of touching the frames of glasses on one's head, or for *scarf*, the feeling of a scarf covering her head. Koko, in her learned ASL signs, was taught numerous signs for objects that were not touchable, or could not be touched by her: examples might be *clouds*, *sun*, *tree*, and *house*. These signs, however, are not among her most frequent spontaneously used vocabulary items.

Though a tactile element is part of many of Koko's untaught gestures, some of these signs apparently originate from transfer of a visual feature observed on someone else onto herself, as in her sign for *filmmers/reporters* (tracing the outline of the straps seen on camera bags). Transferring features observed on someone else to one's own body is rather like touching oneself on a location observed in a mirror. For humans, feeling that one is actually tracing the outline of an object in a tactile manner when putting it on paper has been shown to produce accurate and natural artistic depictions, even by those with no artistic training; most people, however, instead perform the intermediary step of mentally representing, or visualizing, an object to oneself and only after this drawing it on paper (Edwards, 1979). In the zoo gorillas, tracing of motion on another gorilla's body is a frequent medium of requests for action. This tactile propensity, born from physical interaction, may underlie many of the inventions of both the zoo gorillas and Koko. The model object was present when Koko first created her "shape tracing" signs, but she also used them later in the absence of the original model, implying memory of either the shape of the object or her previous actions.

Gorilla gestures, both of zoo and signing gorillas, seem to arise from an understanding of paths of action that can be tactile, visual or locomotor. Underlying the gestural abilities of all great apes is the anatomical characteristic of rotational movement of the joints, a characteristic that humans share, derived originally as an adaptation to brachiation under tree limbs and arboreal "clambering." The locomotor adaptations permitting brachiation in apes allow a much greater flexibility of limb control than possessed by monkeys, which potentially has consequences for all manual activities (Morbeck, 1994). Several theories have been put forward that specifically relate ape cognition to demands of the physical environment (reviewed in Byrne, 1997). Parker and Gibson (1977, 1979; see also Bard, 1990) propose that seasonal foraging, on foods that require extraction from a matrix, selected for tool-using propensities and abilities. Povinelli and Cant (1995) (see also Chevalier-Skolnikoff, Galdikas, & Skolnikoff, 1982, p. 643) propose that arboreal clambering, by an animal too large to risk a fall, selected for the ability to imagine itself in a detached, objective way and thus plan safe routes through the canopy, dealing with constantly changing conditions in transferring

11. Chimpanzees and other apes have also painted; for a most extensive illustrated discussion, see Morris, 1961, and Hoyt's (1941) early description for the gorilla Toto.

from tree to tree. Orangutans use supports that are flimsy relative to their weight much more often than do monkeys in the same habitat, and use multiple supports, whereas monkeys prefer single supports. On this theory, viewing the self as an object led to the ability in apes to recognize their own selves reflected in a mirror.

Both the extractive foraging and complex locomotion accounts focus on a single modern species (the tool-using chimpanzee, the arboreal clambering orangutan) as models of the common ape ancestor, making them difficult to test against comparative data. Byrne (1997, 1998, 2000, in press) proposes that feeding competition from sympatric monkeys—smaller animals with lower metabolic needs, more efficient long-range travel, and ability to eat less ripe fruit—selected for skills in manual foraging, allowing apes to exploit foods unavailable to their competitors, such as insects within mounds or trees, and plants defended by spines or stings. All modern apes feed in ways that are manually skillful compared with monkeys, involving complex, hierarchically organized techniques that are unlikely to be invented by a solitary individual (Byrne, 2002). Critical to skill acquisition, then, is the ape's ability to decipher the skilled manual actions of others and thereby learn novel techniques (Byrne & Russon, 1998; Byrne, 2003; Whiten, Horner, de Waal, 2005). Behavior parsing and hierarchical program-building abilities, functioning to allow apes to exploit a wider range of foods by allowing traditions of skill to accumulate by social learning, have been explicitly related to the origins of gestural communication (Byrne, 2000, in press).

Building up hierarchically structured action-plans, from simpler building blocks of actions in the ape's extensive manual repertoire, is seen as the evolutionary origin of the syntactic structuring of language components. However, none of these theories deals specifically with the iconic abilities that have been a prominent focus of the present analysis. Iconic gestures are anticipations of action, including actions of others as well as anticipated or previously experienced actions of the agent itself, that the gesturing gorilla must be able to represent mentally and then express through a kind of mime. Moreover, the gorilla is apparently able to translate between different scales, expressing desired large-scale body movements of others by using the smaller compass of its own hand gestures.

We propose that *action mapping* in three-dimensional space is an important capability of all great apes. *Action mapping* can be defined as the mental ability to picture motion in space, predict its results before performing it, and translate from the large-scale of real world motions of bodies (whether observed, remembered, or anticipated) into the smaller scale of hand movements that iconically describe them. The capacity to map seamlessly from observed bodily motions to corresponding actions of the self appears closely related to the "active intermodal matching" theory, proposed by Meltzoff & Moore (1977) (Meltzoff, 1996) to underlie the ability of very young children to copy the facial gestures of adults. They suggest that humans are born equipped with the ability to match their own muscular movements with the movements they see others make, a 1:1 system of correspondence that bridges across modalities. The action mapping concept also is supported by the existence of mirror neurons and their functions, as discussed earlier. In a communicative context, as in gorilla gesturing, action mapping would mean mentally picturing motion in space and its possible results (either on the basis of memory or anticipatory planning) and then performing it, without

the need for any step-by-step shaping process. In communication, action in real space can be “miniaturized,” mapped in hands or arms.¹²

Though it seems that many gestures may be mapped directly to the hands from action in the real world, some form of imitative process is often posited as a way in which novel communication might be propagated. Let us look at the evidence for imitation, or any kind of social learning, of gestures. Frans de Waal describes the spread of a behavioral tradition in captive chimpanzees (de Waal & Seres, 1997). The capacity to reproduce nonfunctional limb motions demonstrated by a human in a “do as I do” task has been shown in captive chimpanzees (Custance et al., 1995) and also in gorillas (Byrne & Tanner, 2006 in press). Orangutans imitate elaborate human activities, sometimes involving a series of several actions (Russon & Galdikas, 1993), and imitation at a program level seems to be the best explanation for the complex, hierarchically-organized, and highly plant-specific feeding techniques seen in mountain gorillas (Byrne & Byrne, 1993; Byrne & Russon, 1998). For gorillas raised in a signing environment, imitation of a human’s signs is a frequent way of learning new signs, even in a gorilla not formally taught signs. Ndume, an adult male gorilla brought to the Gorilla Foundation to be a companion to Koko, was never formally taught any sign language, but began gradually to use some of the same signs that Koko and her gorilla companion Michael had been taught, and to compound signs (Patterson & Gordon, 2002; Patterson, 2005).

At the zoo, some evidence speaks against imitation as a way of learning gestures. Many of the gestures shared by all the gorillas in the San Francisco group are generally accepted as species-typical. The use of a few gestures by some but not all members of the group remains unexplained. The gesture *armshake*, for instance, is not seen in all gorillas, though it has been recorded at several zoos and was used by several members of the San Francisco Zoo group. Kubie’s son, Shango, who at an early age watched many of the play sessions between Kubie and Zura during which *armshake* was frequent, never developed *armshake* as a part of his gestural repertoire, and it has only very rarely been observed in his mother, Bawang. On the other hand, Shango’s younger brother Barney *armshakes* frequently and seemed to move from, in earliest observations, using *armshake* in a solitary way, to using it socially. Pika et al. (2003) found some gestures that were widespread among members of one zoo group studied, but not found at all in another group elsewhere. Stoinski (2006) in a survey of gorillas in different zoos found that numerous behaviors, including gestures, varied considerably from zoo to zoo, indicating each zoo had its own set of potentially cultural behaviors.

Another indication of gorillas’ capacity to remember and reproduce actions comes from the observation of repeated sequences of actions, gestural and otherwise, by gorillas in the San Francisco Zoo group (Tanner, 1998), in contexts of play and display. Though they involved the reproduction of a gorilla’s own previous actions, not those of another, these sequences show that the memory capacity necessary for reproduction of complex activities is available for the gorilla. Ability to reproduce complex sequences of functional activities makes sense in the action mapping context.

12. Gestures in adults are miniaturized in comparison to those of young children (McNeill, 1992).

The work of Tomasello and colleagues posits *ontogenetic ritualization*, a process of fading or shaping frequently performed actions in repeated interactions with another individual, as the main process through which ape gesture is created (Tomasello, Kruger, Farrar, & Evans, 1985; Tomasello, Gust, & Frost, 1989; Tomasello, Savage-Rumbaugh, & Kruger, 1993; Tomasello, Call, Nagell, Olguin, & Carpenter, 1994; Tomasello, 1999 for an overview). The adaptive explanation of action mapping is a simpler one than ontogenetic ritualization, which as a process has been deduced but never actually observed in full. In the experience of the present authors, ontogenetic ritualization is not a completely satisfying explanation of all inventions by zoo gorillas or by signing gorillas. Instead, much invention appears to begin not with shaping of a functional action directed toward another gorilla, but with one of these two processes: (1) a spontaneous natural body movement (perhaps a sign or gesture such as *armshake*) is expanded or altered when re-used in varying situations of social interaction, eventually gaining meaning through repeated interactions, or (2), an iconic movement is produced by putting into manual motion an action mentally anticipated or desired. For Koko, this, with manual reproduction of shapes of objects as well as actions, was the primary method of invention. Such gestures or signs, generated by either process, may vary in scope, size, and dynamic according to context, as do signs in human sign languages. Type (1) invention is not entirely removed from the idea of ontogenetic ritualization though it need not begin with a functional action; type (2), however, would be generated by action mapping without any need for a ritualization process. Koko's gestures, *above*, *below* and *browse*, discussed earlier in this paper were all spontaneously used by the gorilla well before human companions understood them, thus no shaping process could exist. In the zoo, Barney's usage of *armshake* appeared to develop from spontaneous use of an idiosyncratic, but anatomically feasible movement, used at first in a solitary context and only later developed in social contexts. It is also not impossible that the two kinds of gesture creation described above could both be used in forming one meaningful gestural motion, though an example has not been found at present.

Pointing and other deictic gesture is not well explained by ontogenetic ritualization. There are too many variations in size, scope, location, and orientation of gestures indicating locations for each gesture to be likely to be individually ritualized. Likewise, though zoo gorillas' tactile iconic gestures may appear to be "faded" from forceful actions, new gestures constantly appear in different directions and dimensions, with no two exactly alike. It is unlikely that each gesture would be individually faded. Many untaught gorilla gestures combine action mapping with the deictic principle of locating a sign appropriately in a certain location, on one's own body or on another's body. An example from zoo gorilla Kubie, *come shoulders*, involved patting both his shoulders with his palms, to which play partner Zura responded by approaching and placing her hands on his shoulders (Tanner & Ernest, 1989). Koko also early generated an untaught "pointing" sign. The taught sign "bird," used by her instructor to point out a bird seen through the window was co-opted by Koko as a sign for various animals and novel objects on the other side of the window. Koko used both index fingers to point in a configuration similar to the original sign performed by the instructor, an extended thumb and index finger.

At the San Francisco Zoo, Kubie used his established repertoire of gestures with several gorillas and was later understood by new individuals. He used most of the same repertoire of gestures he used with Zura in his interactions with two other females in the group during other time periods years apart. His most frequent gestures were all used regularly over a period of more than seven years, though proportions of the different gesture types used with each female varied. Apparently different recipients were able to interpret his actions and the resulting interactions were favorable often enough that it benefited each new pair to establish such communication. Action mapping as a cognitive ability shared by apes explains this mutual understanding of iconic gesture between different partners without any need for re-shaping.

Thus, though gorillas in the zoo group varied in their repertoires of gestures, with some gestures being shared with other gorillas, and others unique to individuals, the gorillas still seemed to have developed a mutually *understood* system of communication. This was particularly striking in Kubie and Zura's interactions; their gestures often alternated in a turn-taking conversational manner and seemed to be used to make decisions about type, timing, and location of play as well as simply promoting contact (Tanner, 2004).

Koko's untaught signs for objects are unlikely to be explained as "faded" from action, but they can be understood as formed by an ability to map and mirror visual input with the hands. Ontogenetic ritualization "takes two" to shape gestures for mutual interaction, but originating a sign for an object does not require interaction for its invention, only to establish it as a mutual communicative element. Shared cognition and shared backgrounds along with shared interaction with objects, make understanding of such signs possible. Koko's newly untaught iconic signs thus eventually make good sense, once decoded by human companions.

Because anatomy and behavior evolve in interaction with the environment, the contexts in which gestures most frequently take place are important in understanding what their ultimate function might be. The gestures observed in zoo gorillas were at their highest frequencies in play and quasi-sexual situations, and pygmy chimpanzees (also known as bonobos) in captivity used iconic gestures to settle on copulatory positioning (Savage & Rumbaugh, 1977). Further, Crawford (1937) saw the spontaneous emergence of much gesturing in an artificial context where two chimpanzees had to cooperate and coordinate their movements in order to receive food rewards. Signing chimpanzees, when observed through remote videotaping with no humans present, conversed with signs and gestures about play, grooming, and other social matters but hardly at all about food and eating or discipline and dominance (Fouts & Fouts, 1989). What all these situations of rich communication have in common is the necessity of *coordination of movement* around the environment, or *cooperation in movement*. The term *co-regulation* in the manner of Alan Fogel's mothers and children could just as well be applied (Fogel, 1993). Visual and tactile gestures proliferate when maintenance of close contact with another, or closely coordinated movement, is necessary for interaction to be successful (King, 2004).

Gestures and signs also obviously thrive when an environment is vested with con-specifics and objects with which interaction is desirable and pleasurable; Greenspan

and Shanker (2004) describe the importance of function and emotion and how complementary they are in the development of communication. In a study of the pragmatic functions of Koko's signing during her first year of instruction (between age 1 and 2 years), the categories found to be used by human children were all used by Koko; these included labeling, repeating, answering, requesting action, requesting an answer, calling, greeting, and protesting (Patterson, Tanner, & Mayer, 1988). A glance at the list of Koko's inventions (Appendix) shows that her untaught signs were for things and activities in her environment that Koko was interested in, but for which she had not been taught a sign. She needed signs in order to maintain shared attention with her companions, and so generated ones of her own invention. In some cases, her signs were emotional comments, such as her *unlisten*, *unattention*, *frown*, and *blew-it* signs.

Koko and her gorilla companion Michael's sign acquisition has been compared to that of signing human children in several studies by Bonvillian and Patterson (1993, 1999). Similarities were found in type of vocabulary content, acquisition of referential signing, and in the generation of various non-sign gestures. Differences were found in rates and patterns of early language and gestural milestones, with gorillas reaching many of these milestones but at a slower rate than children. The same could be said for the zoo gorillas in comparison to the sign-instructed gorillas. Comparison of the untaught signs of Koko, a signing gorilla, and gestures of zoo gorillas shows a continuum of representation, where a signing gorilla moves further than the zoo gorillas along a line that proceeds from behavior directed at immediate goals, to representation of desired action, to representation of objects.

Gesture may well be the structural foundation upon which language is built, and we can find in gesture the thread of evolutionary continuity between animal action and human language (King, 1999; Byrne, in press). The present study shows that it is likely that in the history of our hominoid ancestors, the earliest iconic depictions were of action rather than objects, just as we find in apes. Because such iconic capacity is present in gorillas, and surely in orangutans, given their related ability to imitate and to use human sign language (Russon & Galdikas, 1993; Miles & Harper, 1994; Miles et al., 1996; Shapiro & Galdikas, 1995), it was most likely present 10 million years ago in the common ancestor of hominoids. New means of communication, when they occurred in our ape ancestors, would certainly have achieved increased success for individuals in social, and ultimately, sexual relationships. Such behavior would surely have selective value, and over generations result in gestures becoming increasingly frequent and complex. Through the condensation of real activity to something representing it, in forms progressively more removed from the original, hominid communication have, over millions of years, reached the arbitrariness that is a characteristic of human language. But not all of human language even today is purely arbitrary. We can still see glimpses, particularly in sign languages, of the development of language from the raw materials of action (Armstrong et al., 1995). The creation and usage by gorillas of special repertoires of gestures gives us a window into the developmental processes and environmental pressures that might have led an ancestor ape to further refinement of iconic communication, and its eventual expansion to human gestures of the mouth.

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Appendix

Koko's untaught signs: first 10 years

(Signs from Patterson & Cohn, 1990, analysis of iconic characteristics by first author)

Key:

O: object

A: action

D: deictic

IS: iconic for shape of object

IA: iconic for an action

BL: indicates (self) body location of referent

BLO: on body of other person or gorilla

CMT: cross-modal transfer from English sounds

D: deictic; pointing

U: unknown derivation

FA: functional action

Gloss in English and classification	Physical form of untaught sign	Type of iconicity or other type of reference	Kind of representation
apricot O	"A" hand shape with motion like "peach" sign (hand brushed down cheek)	cross-modal transfer from English sound as well as compounding signs	CMT
barrette O	index finger draws line forward above ear where barrette is usually placed	draws shape of object, also places on body location	IS, BL
bird (notice) D	index fingers, held together at tips, point to location of object of interest that is out of reach	deictic	D
bite A	teeth bite index finger side of hand	iconic for action	IA
blew-it A	loud exhalation: blowing sound directed at offending person	cross-modal transfer from English sound	CMT
blow A	blows on index finger held vertically in front of mouth	iconic for action	IA
body hair O	fluffing up hair on the body by rubbing both hands up and down on body	indicating part of body	BL
bracelet O	cupped hand encircles and pats wrist	iconic for shape of object, placed on body location	IS, BL

Gloss in English and classification	Physical form of untaught sign	Type of iconicity or other type of reference	Kind of representation
clay O	palms together, move back and forth in circular rolling motion	iconic for action, on customary body location	IA, BL
dental floss O	pick index on teeth plus <i>thread</i> sign (two little fingers touch then move apart horizontally)	iconic for shape and action, on body location	IA, IS, BL
drip-chin A	mime with index the action of liquid rolling down chin	iconic for action, on body location	IA, BL
dripping A	index imitates motion of dripping liquid on cheek	iconic for action	IA
earphones O	thumb and index of both hands move down body from ears	iconic for shape of object, placed on body location	IS, BL
eye makeup O	index finger strokes horizontally across eyelid	iconic for action, placed on body location	IA, BL
fake-sneeze A	imitates sound and motion of sneezing	iconic for action	IA
fake-tooth O	taps upper or lower rear tooth with index	body location	BL
fang (Halloween toy) O	tap lower canine teeth with hooked index fingers	iconic for shape of object, placed on body location	IS, BL
filmers, reporters O	thumb and index of both hands move down body where camera straps are located	iconic for shape of object, placed on body location	IS, BL
frown O	lower lip pulled down over chin with fingers	iconic for shape, placed on body location	IS, BL
glasses O	thumb and index pinch at temples	iconic for shape of object, placed on body location	IS, BL
grate A	imitating motion of grating a vegetable; fist moves across palm of other hand	iconic for action	IA
hair bow O	index and thumb of both hands placed on head	iconic for shape of object, placed on body location	IS, BL
inhale A	index from mouth down to stomach	iconic for internal path of an action in body	IA, BL
kiss-hand A	kiss on hand	iconic for action	IA
long hair O	index fingers trace hairline from ears to below shoulder	iconic for shape of object, placed on body location	IS, BL
man, male (<i>foot</i>) O	taps bottom of foot with index	unknown	U
nail file O	tip of bent index moves back and forth across finger of other hand	iconic for action, placed on body location	IA, BL

Gloss in English and classification	Physical form of untaught sign	Type of iconicity or other type of reference	Kind of representation
note (something in environment) D	moves index horizontally across lips before pointing to something	unknown	U
obnoxious QUALITY	knock sharply on wall or floor	cross-modal transfer from English sound "nox" in obnoxious	CMT
pickle O	thumb and index extended from both fists held in space in front of body	outlining shape of object	IS
poke A	jab with index	iconic for action	IA
poke-stomach A	poke stomach with index	iconic for action on body location	IA, BL
puppet O	open hand moves down over fist of other hand	iconic for action (putting hand puppet over hand), placed on body location	IA, BL
runny nose O	index traces path of liquid running from nose	iconic for action	IA, BL
scarf O	palms of open hands down sides of head	iconic for shape, body location	IS, BL
scraper O	fingers of open hand make scraping motion across other hand	iconic for action	IA
sip A	tips of index and thumb touch lips	iconic for action, body location	IA, BL
smooth QUALITY	smoothing motion of open palms up legs	iconic for action	IA
stethoscope O	index fingers in ears	iconic for shape, body location	IS, BL
strangle A	hands grasp neck	iconic for action, on body location	IA, BL
thermometer O	puts extended index finger under arm	iconic for shape, on body location	IS, BL
tickle A	index makes tickling motion under arm	iconic for action, on body location	IA, BL
turn-around A	open hand brought around from one side of waist to other on other's body	iconic for action	IA, BLO
unattention STATE	palms of both open hands placed over face	functional action	FA

Gloss in English and classification	Physical form of untaught sign	Type of iconicity or other type of reference	Kind of representation
under-eye makeup O	index moved horizontally under eye	iconic for action, on body location	IA, BL
unlisten STATE	palms cover ears	functional action	FA
Viewmaster O	one hand open palm like <i>mask</i> , other hand thumb and index at eye like <i>camera</i>	compound sign at body location	BL, IS
walk-up-my-back A	in seated position, hands placed behind back, palms up, and bounced	iconic for action, on body location	IA, BL
walk-up-my- bottom A	arm with open hand swings under body between legs	iconic for action, on body location	IA, BL
woman (<i>lip</i>) O	rubs index horizontally back and forth across lips	iconic for action (applying lip- stick) on body location	IA, BLO

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