Journal of Comparative Psychology
2000, Vol. 114, No. 4, 335-346

0735-7036/00/$5.00 DOI: 10.1037//0735-7036.114.4.335

Interactive Use of Sign Language by Cross-Fostered Chimpanzees (*Pan troglodytes*)

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Cross-fostered as infants in Reno, Nevada, chimpanzees (*Pan troglodytes*) Washoe, Moja, Tatu, and Dar freely converse in signs of American Sign Language with each other as well as with humans in Ellensburg, Washington. In this experiment, a human interlocutor waited for a chimpanzee to initiate conversations with her and then responded with 1 of 4 types of probes: general requests for more information, on-topic questions, off-topic questions, or negative statements. The responses of the chimpanzees to the probes depended on the type of probe and the particular signs in the probes. They reiterated, adjusted, and shifted the signs in their utterances in conversationally appropriate rejoinders. Their reactions to and interactions with a conversational partner resembled patterns of conversation found in similar studies of human children.

In cross-fostering, adults of one species rear the young of another species. Sign language studies of cross-fostered chimpanzees are a tool for studying the fuzzy overlap between human behavior and the behavior of other animals and between verbal behavior and other intelligent behavior (B. T. Gardner & Gardner, 1989, 1998; R. A. Gardner & Gardner, 1998; R. A. Gardner, Gardner, & Van Cantfort, 1989; Goodall, 1967, 1986; Hayes & Nissen, 1971; Plooij, 1984). The cross-fosterlings acquired and used the signs of American Sign Language (ASL), a naturally occurring human language, under nursery and conversational conditions. Comparable conditions and comparable measures reveal similar patterns of development in human infants and cross-fostered chimpanzees (Bloom, Rocissano, & Hood, 1976; Braine, 1976; Brown, 1968; De Villiers & De Villiers, 1986; Ervin-Tripp, 1970; D. H. Fouts, 1994; B. T. Gardner & Gardner, 1998; B. T. Gardner, Gardner, & Nichols, 1989; Krause & Fouts, 1997; Leonard, 1976; Nelson, 1973; Reich, 1986; Wells, 1974). This article reports an experimental study of patterns of conversational interaction between cross-fostered chimpanzees and a human interlocutor.

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We thank Washoe, Moja, Tatu, and Dar for their participation in this research; Mary Radeke, Michelle Haislip, Kimberly Williams, and Mark Krause for serving as camera operators; and Heidi Shaw, Crickette Sanz, Jill Unger, and Mark Bodamer for their assistance as second observers. This article is in memory of Beatrix T. Gardner, who participated in the conception of the study and its design.

This study was based on a doctoral dissertation submitted by Mary Lee A. Jensvold to the University of Nevada, Reno in partial fulfillment of the requirements of a doctoral degree.

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Method

Subjects

The 4 chimpanzee subjects (*Pan troglodytes*) of this experiment were Washoe, Moja, Tatu, and Dar. Washoe was captured wild in Africa. She arrived in the Gardner laboratory in Reno on June 21, 1966, when she was about 10 months old and lived as a cross-fosterling until October 1, 1970, when she left to become the first chimpanzee in the Fouts laboratory in Oklahoma. Moja, Pili, Tatu, and Dar were born in U.S. laboratories, and each arrived in Reno within a few days of birth. Moja was born at the Laboratory for Experimental Medicine and Surgery in Primates, New York, on November 18, 1972, and arrived in Reno on the following day. Cross-fostering continued for Moja until winter 1979 when she left for the Fouts laboratory in Oklahoma. In 1980, Washoe and Moja moved to the Fouts laboratory in Ellensburg where the present study took place. Tatu was born at the Institute for Primate Studies, Oklahoma, on December 30, 1975, and arrived in Reno on January 2, 1976. Dar, a male, was born at Albany Medical College, Holloman Air Force Base, New Mexico, on August 2, 1976, and arrived in Reno on August 6, 1976. Cross-fostering continued for Tatu and Dar until May, 1981, when they left to join Washoe and Moja in Ellensburg.

The objective of the procedure was to sample conversational interactions between Washoe, Moja, Tatu, and Dar and a familiar human interlocutor under typical daily conditions in this laboratory (R. S. Fouts, Abshire, Bodamer, & Fouts, 1989). A video camera recorded the sign language responses of the chimpanzees to four distinct types of sign language probes presented by the human interlocutor.

Interlocutor

The first author of this article, Mary Lee A. Jensvold (MLJ), served as the interlocutor. At the time of data collection, she had 8 years of experience caring for and interacting with this group of chimpanzees and 10 years of experience communicating in ASL. Figure 1 shows MLJ and Washoe in a typical trial.

Procedure

When she arrived at the interaction area, MLJ either approached a chimpanzee or waited for a chimpanzee to approach her as she normally

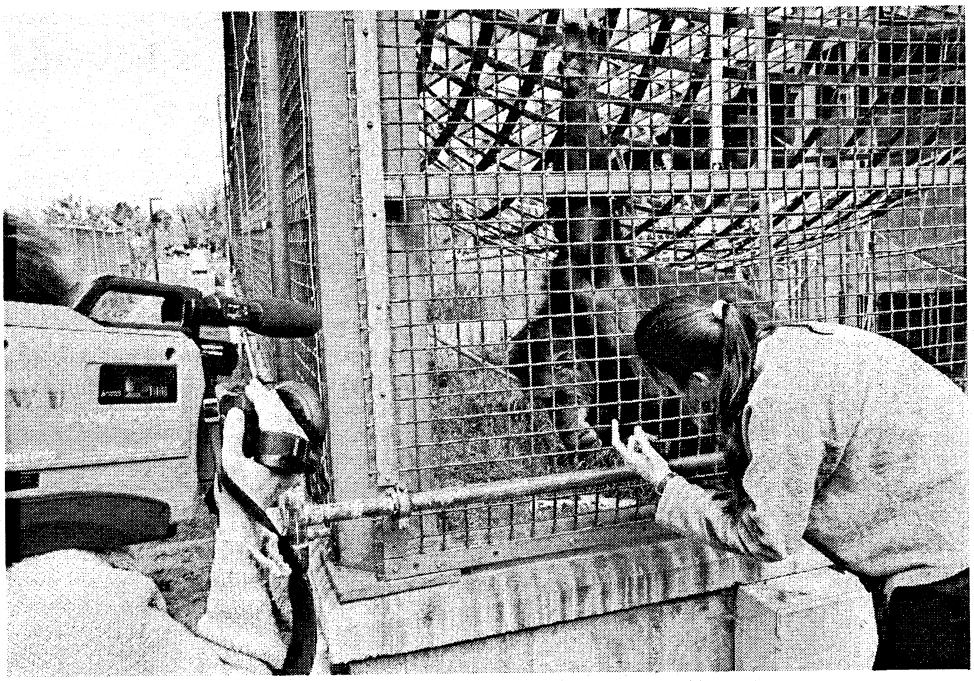

Figure 1. An example of a trial. The camera operator on the left is recording Washoe, and the interlocutor is signing NOT UNDERSTAND?/

did in the course of a day. The interlocutor then attempted to engage the chimpanzee in a typical conversational interaction on a subject such as looking at a book, eating a meal, playing a game, or some other common activity (R. S. Fouts et al., 1989). The chimpanzees were free to interact with the interlocutor or to ignore her. As the participants settled down during this pretrial period, the camera operator positioned the camera and started the tape record.

A second person operated a video camera to record each trial. At the beginning of a trial, the interlocutor stood or knelt to the right of the chimpanzee and positioned herself so that she and the chimpanzee were facing each other at an angle of about 90°. The operator positioned the camera so that the hands and faces of both interlocutor and chimpanzee appeared in the viewfinder of the camera. The camera operator used a list containing the sequence of conditions to prompt the interlocutor in English to present the correct condition on each trial.

Although ASL was virtually the only language that the human members of their foster families used in the Gardner laboratory, Moja, Tatu, and Dar often heard spoken English in the Fouts laboratory and understood spoken English to some extent (Bodamer, Fouts, & Fouts, 1987; Shaw, 1989). To avoid the possibility that the camera operator might prompt the chimpanzee as well as the interlocutor by announcing each upcoming condition, the operator used a numerical code rather than English words to specify conditions and changed the code three times during the course of the study. The prompting of the camera operator was the only English speech heard during these sessions, and this prompting always occurred before the beginning of any trial.

When ready, the camera operator signaled that the camera was ready and prompted the interlocutor by indicating which condition to present on that trial. The next time that the chimpanzee signed to the interlocutor, she replied with the first probe in the series specified by the condition for that trial. When the chimpanzee signed in response to the first probe, the interlocutor probed again, and so on until the interlocutor completed the series of three planned probes specified for that trial.

The interlocutor waited for the end of each chimpanzee turn before presenting the next probe. Signers normally end an utterance by dropping their hands or holding their hands without movement (Covington, 1973; Grosjean & Lane, 1977; Stokoe, 1972). The chimpanzees also use these behaviors at the end of an utterance. In the last third of the film, *Teaching Sign Language to the Chimpanzee, Washoe* (R. A. Gardner & Gardner, 1973, 1974), there are several examples of extended utterances. In one example, Washoe signs the following to Susan Nichols:

Washoe: YOU [hold] ME/ YOU ME WASHOE ME [hold] GO/

Between the phrases YOU ME/ and YOU ME WASHOE ME GO/, Washoe holds her hands in the signing space, but they are relaxed. After the final GO, Washoe drops her hands. These utterance boundary markers are different from the hesitation pauses after the first YOU and the last ME. The hesitation pauses are typical of the halting signing and speech of young children (Stokoe, 1978, pp. 83–85). Utterance boundaries of this type are clear, and judgments yield independent interobserver agreement of 81% to 95% (R. A. Gardner & Gardner, 1998, pp. 194–195; Rimpau, Gardner, & Gardner, 1989, pp. 245–250).[1]

Transcriptions of signs in this article indicate three types of modulation. An "x" following a gloss indicates immediate reiteration of that sign. A question mark (?) following a gloss indicates a questioning inflection. A slash (/) indicates an utterance boundary (see B. T. Gardner & Gardner, 1998, p. 167). B. T. Gardner and Gardner (1998) and Rimpau et al. (1989) describe how cross-fosterlings inflected signs and phrases in the Gardner laboratory.

After each probe, the chimpanzee was free to answer with any signs or phrases in his or her vocabulary, to continue to face the interlocutor, to look

[1] Here and throughout this report, transcriptions of signs appear in all capital letters. Signed utterances are transcribed into word-for-sign English because more literal translations would add words and word endings that lack signed equivalents either in the vocabularies of the chimpanzees or in ASL. This mode of transcription makes the utterances appear to be in a crude or pidgin dialect, but the reader should keep in mind the fact that equally literal word-for-word transcriptions between English and say, Russian or Japanese, appear equally crude.

away, or to leave the scene entirely. If the chimpanzee ended the interaction by leaving the scene, the response to that probe and all remaining probes of that trial were scored as no response. Because the interlocutor never signed to a chimpanzee unless the chimpanzee was facing her, all cases in which she failed to regain the attention of the chimpanzee within 5 s of the last probe or the last chimpanzee response had to be scored as if the chimpanzee had left the scene.

When the chimpanzee failed to respond to a probe in signs within 5 s but continued to face the interlocutor, the interlocutor presented the next probe in the series. Failures to regain attention appeared in two forms. First, when the chimpanzee signed and then looked away, the interlocutor attempted to regain the attention of the chimpanzee by waving her arms or by making a noise such as tongue-clicking noise or kissing noise. If the chimpanzee faced the interlocutor again within 5 s, the interlocutor presented the next probe in the series. If the chimpanzee failed to face the interlocutor for 5 s, the trial ended and the response to the next and to all the remaining probes of that trial were scored as no response. Second, when the chimpanzee looked away before responding to a probe in signs, the interlocutor also attempted to regain the attention of the chimpanzee by waving her arms or by making a noise such as tongue-clicking noise or kissing noise. If the chimpanzee faced the interlocutor again within 5 s without signing, this was scored as a failure to respond, and the interlocutor presented the next probe. If the chimpanzee failed to face the interlocutor for 5 s without responding in signs, the trial ended and the response to that probe and all remaining probes of that trial were scored as no response.

Other chimpanzees near the interaction area were free to observe or to participate in the interactions at any time as usual in daily interactions. If a 2nd chimpanzee interfered with the interaction, then the interlocutor aborted that trial and discarded it from the record. If the 2nd chimpanzee approached without interfering, the interlocutor ignored the 2nd chimpanzee until the end of the trial with the 1st chimpanzee. At the end of the trial with the 1st chimpanzee, the interlocutor was free to begin a new trial with the 2nd chimpanzee.

Conditions

There were four conditions in this experiment; they are listed in Table 1. The probes in the general condition consisted of a series of three general questions. The probes in the on-topic condition consisted of a series of three on-topic questions. The probes in the off-topic condition consisted of a series of three off-topic questions. Finally, the probes in the can't condition consisted of a series of three negative statements.

General trials. For each general trial, the interlocutor asked three general question probes that indicated failure to understand the chimpanzee. The interlocutor always presented the same three general probes in this order: (a) a questioning facial expression without any signs, (b) the sign WHAT?/, and (c) I NOT UNDERSTAND?/ or NOT UNDERSTAND?/, often signed with a negative head shake, which is common usage in ASL (Baker-Shenk, 1985, p. 299; Humphries, Padden, & O'Rourke, 1980). In her questioning facial expressions, the interlocutor pulled her eyebrows together, leaned forward, and held her eye gaze on the chimpanzee. Baker-Shenk describes this as the typical interrogative facial expression of ASL. The only condition in which the sign WHAT?/ appeared alone in a probe was the general condition. An example of a general trial is the following:

Table 1
Conditions Presented During Trials

Condition	Probe type
General	Three general questions
On topic	Three context-appropriate Wh-questions
Off topic	Three context-inappropriate Wh-questions
Can't	Three nonquestion negative probes

Trial #3/1:04:40
1:04:35 Washoe: ME GIMMEX/
1:04:40 Probe 1: questioning expression
1:04:41 Washoe: GIMME/
1:04:49 Probe 2: WHAT?/
1:04:51 Washoe: MEX GIMMEX/
1:04:54 Probe 3: NOT UNDERSTAND?/
1:04:56 Washoe: FOOD GIMME/

Here and throughout this article, each videotaped dialogue between a chimpanzee and a human interlocutor begins with the address of the observation in the videotaped record of this study. In this case, the address "Trial #3/1:04:40" indicates that this dialogue is a transcription from the third videotape and that the interlocutor's first probe began at 1 hr 4 min 40 s from the beginning of the videotape. Note that the address of a trial is the address of Probe 1. Some examples contain a whole trial, and it is easy to see that the address is the address of Probe 1. Other examples only contain part of a trial. These partial cases sometimes include Probe 1 and sometimes begin later, but the address on the tape remains the address of Probe 1.

On-topic trials. In each on-topic trial, the interlocutor asked three Wh-questions that incorporated a relevant sign from the chimpanzee utterance that started the trial and were also appropriate to the context of the interaction. The on-topic condition contained probes such as, WHO WANT FLOWER?/ if the chimpanzee utterance had included FLOWER; WHO EAT?/ if the chimpanzee utterance had included EAT; and WHERE CHASE?/ if the chimpanzee utterance had included CHASE. These were typical questions that human familiars asked the chimpanzees in daily signed interactions. If the chimpanzee's reply to an on-topic probe contained an appropriate sentence constituent (Brown, 1968; B. T. Gardner & Gardner, 1975), then the interlocutor probed again with a different on-topic Wh-question. If the chimpanzee's utterance failed to include an appropriate sentence constituent, then the next probe repeated the previous probe. As is normal in signed interactions of human and nonhuman primates, a questioning facial expression accompanied signed questions.

In the cross-fostering laboratory in Reno, B. T. Gardner and Gardner (1975) and Van Cantfort, Gardner, and Gardner (1989) showed that Washoe, Moja, Tatu, and Dar responded to Wh-questions with appropriate sentence constituents (e.g., names or pronouns in response to WHO?/ questions, names of objects in response to WHAT THAT?/ questions, and so on). In their replies to Wh-questions, the cross-fosterlings developed in patterns that resembled the patterns of human children (Bloom et al., 1976; Brown, 1968; Clancy, 1989; Ervin-Tripp, 1970; Parnell, Patterson, & Harding, 1984; Tyack & Ingram, 1977).

An example of on-topic trial is the following:

Trial #2/0:07:51
0:07:47 Dar: GUMX GOODX GUMX THERE/
0:07:51 Probe 1: WHO WANT GUM?/
0:07:52 Dar: DARX HEIDI DAR THERE/
0:07:56 Probe 2: WHERE GUM?/
0:07:56 Dar: DARX GUM/
0:07:59 Probe 3: WHERE GUM?/
0:08:00 Dar: DARX THERE/

Off-topic trials. For each off-topic trial, the interlocutor asked a series of three Wh-questions that were unrelated to the chimpanzee's first utterance in the trial and inappropriate to the context, as in the following:

Trial #2/0:15:12
0:15:08 Washoe: SHOEX GIMMEX/
0:15:12 Probe: WHERE ROGER?/

Trial #3/0:56:08
0:56:04 Washoe: RED THERE/
0:56:08 Probe: WHO FUNNY?/

As in the on-topic condition, the interlocutor made the characteristic interrogative facial expression, and probes were typical questions that human familiars asked the chimpanzees in daily signed interactions. Indeed, off-topic probes were often identical to probes that the interlocutor presented in the on-topic condition. If the chimpanzee's reply to an off-topic probe contained a sentence constituent that was appropriate to the question, then the next probe contained a different off-topic Wh-question. If the chimpanzee's reply failed to include a sentence constituent that was appropriate to the question, then the next probe repeated the previous probe. An example of an off-topic trial is the following:

Trial #5/0:08:49
0:08:46 Washoe: FRUIT GIMMEX/
0:08:49 Probe 1: WHO FUNNY?/
0:08:51 Washoe: ROGER/
0:08:54 Probe 2: WHERE CAT?/
0:08:56 Washoe: ROGER GIMMEX/
0:09:03 Probe 3: WHERE CAT?/
0:09:05 Washoe: GIMMEX/

Can't trials. For each can't trial, the interlocutor replied with a series of three negative statements indicating that the interlocutor would not or could not comply with the chimpanzee's request or continue the interaction. Typical examples of can't probes were CAN'T/, SORRY CAN'T/, and I MUST GO/. An example of a can't trial is the following:

Trial #1/1:26:13
1:26:06 Tatu: YOUX SMELL YOUX SMELL YOU/
1:26:13 Probe 1: CAN'T/
1:26:14 Tatu: YOU SMELL/
1:26:17 Probe 2: CAN'T NOW/
1:26:18 Tatu: THAT (towards floor)/
1:26:20 Probe 3: CAN'T/ Tatu: No signed response

Design

Each chimpanzee received 20 trials under each of the four conditions, yielding a total of 80 trials for each chimpanzee. The maximum number of trials for 1 chimpanzee in 1 day was three trials. The sequence of conditions was random without replacement, except that the same condition never appeared on two consecutive trials in the same day.

Videotape Transcription

During all trials in this experiment, the interlocutor appeared on the right and the chimpanzee appeared on the left of the television screen. When transcribing the signs of the interlocutor, transcribers occluded the chimpanzee, and when transcribing the signs of the chimpanzee, transcribers occluded the interlocutor.

All of the signs that appeared in the transcription of this experiment appear in Table 3.2 of B. T. Gardner et al. (1989) and in R. S. Fouts (1993). With the exception of a few "home" signs, such as POTTY and PEEKABOO, all of these signs also appear in standard dictionaries of ASL as described and explained in B. T. Gardner et al. We created name signs by the normal procedures for creating name signs in the deaf community. The only pointing sign on this list is the indexical, THAT/THERE, which is also a pointing sign in ASL (see also the sequential analysis of THAT and THERE in B. T. Gardner & Gardner, 1998, pp. 182–184). Two other signs, ME and YOU, are made by pointing to oneself or to an interlocutor in dictionaries of ASL as well as in the vocabularies of Washoe, Moja, Tatu, and Dar. In the published film (R. A. Gardner & Gardner, 1973), Washoe names her image in a mirror signing both ME and ME WASHOE in response to the question WHO THAT? When she points to herself the gloss is ME; when she makes the name sign WASHOE, the gloss is WASHOE. Only when she makes both signs in the same utterance is the gloss ME WASHOE. In any phrase glossed as THAT APPLE or THERE DOG, both the indexical and the object sign must appear.

There were approximately 75 trials on each 120-min videotape. It took approximately 10 weeks to fill a videotape with trials.

Interlocutor. After a videotape was filled, MLJ assigned glosses to each sign in each probe on the entire videotape using the place, configuration, and movement (PCM) system. The PCM system (R. S. Fouts, 1993; B. T. Gardner et al., 1989) is a description of how the sign is formed using the place where the sign is made, the configuration of the hand, and the movement of the hand.

Chimpanzee. Next, MLJ assigned glosses to each sign in each chimpanzee utterance on the entire videotape using the PCM system.

Reliability. A second observer independently scored a randomly selected sample of 20% of the videotapes for interlocutor and chimpanzee glosses using the same PCM system (R. S. Fouts, 1993; B. T. Gardner et al., 1989) as MLJ. These comparisons yielded agreements ranging from 87% to 95%.

Modulation. B. Gardner and Gardner (1998) describe modulation as follows:

> Dictionaries of ASL, like dictionaries of spoken languages, show signs in citation form—the form that is seen when an informant responds to the question "What is the sign for X?" In normal conversation, fluent signers inflect their signs in a variety of ways. The sign, GIVE, for example, may start near the signer's body and move out toward the addressee to indicate, "I give you". The same sign with the direction of the movement reversed, indicates, "You give me". Inflection makes signs more versatile and more expressive; a single lexical item can become several different signs. Typical inflections have parallel effects on many different signs. At least 20 different types of inflection appear in the field records [of the Reno laboratory]. Each type can be characterized by an aspect of sign form—e.g., Place or Movement—and by the way in which this aspect differs from citation form. (p. 167)

In this study, the cross-fosterlings modulated their signs as they did in most casual interchanges. As she glossed each utterance, MLJ also reported two prominent types of modulation: reiteration, in which the signer repeats a sign one or more times, and placement, in which the signer forms a sign on a place that differs from the citation form (Rimpau et al., 1989).

A chimpanzee could reiterate the sign APPLE by signing APPLE APPLE APPLE APPLE instead of a single APPLE. Both human children (Hoffmeister, Moores, & Ellenberger, 1975, p. 123; Keenan, 1977; Keenan & Klein, 1975; Nelson, 1980; Scollon, 1979) and cross-fostered chimpanzees (B. T. Gardner & Gardner, 1998, p. 168; R. A. Gardner, Gardner, & Drumm, 1989, p. 47; Rimpau et al., 1989, p. 249; Van Cantfort et al., 1989, pp. 210–211) commonly reiterate words or signs within an utterance. R. A. Gardner, Gardner, and Drumm found that Tatu and Dar, like the human children studied by Keenan and Keenan and Klein, were likely to reiterate signs in their response to positive announcements and unlikely to reiterate signs in responding to neutral or negative announcements. This indicates that reiteration within an utterance serves as a pragmatic device expressing emphasis or assent. We use reiteration here rather than repetition following R. A. Gardner, Gardner, and Drumm:

> When used in this context, the term repetition leads to confusion since it is also used to refer to incorporation (Keenan, 1977, p. 125). This confusion is compounded by the practice of classifying some incorporations as repetitions and some as imitations, depending upon adult inferences about the intention of the child. Terminological confusion is still further compounded by the widespread disagreement as to the criteria that might distinguish repetition from imitation in human children's replies (Keenan, 1977, pp. 125–129). It is for this reason that we recommend the terms *incorporation*, for items also found in the preceding utterance of an interlocutor, and *reiteration*, for items that recurred within a single utterance. (p. 47)

Both human signers (Wilbur, 1980) and cross-fostered chimpanzees vary the place of a sign to express person, place, and instrument (Rimpau et al., 1989). For example, in its citation form, the place for TICKLE is the back of the hand. In the Gardner laboratory, Rimpau et al. found that Dar also signed TICKLE on the addressee to indicate that the addressee should tickle him and on objects to indicate that the addressee should tickle Dar with the object (p. 257).

Results

Sign language studies of cross-fostered chimpanzees simulate the natural conditions in which human children engage in interactive conversations. This must be distinguished from laboratory experiments that measure success and failure on arbitrary tests. Typically, such experiments present subjects with a series of forced-choice tests, sometimes with as many as four alternatives, but usually with only two alternatives. When the proportion of correct choices exceeds chance estimates in such studies, the result is interpreted as confirming a particular theoretical hypothesis about the cognition of a particular species.

By contrast, sign language studies of cross-fostered chimpanzees, like developmental studies of human children, typically use productive tests in which subjects are free to use any word or sign in their vocabulary and any number of words or signs in any given utterance. Moreover, as in studies of human subjects, utterances are relatively appropriate or inappropriate rather than precisely correct or incorrect. Many different utterances can be appropriate in any given conversational context, and different utterances are appropriate in different conversational contexts. Appropriateness is judged by patterns of responses rather than by high or low scores.

Before we could analyze appropriateness in an objective fashion, we first transcribed the utterances of the chimpanzees and the probes of the interlocutor separately and independently according to the procedures described in the Method section of this article. Next, we classified the utterances into a fixed number of categories to analyze the distribution of the categories in response to the four different types of probes.

Because the appropriate data of this experiment consist of patterns of frequency distributions, the appropriate statistic is chi-square. With the chi-square, we could evaluate the most important contrasts that normally appear in an analysis of variance (ANOVA). We could compare different patterns evoked by different probes within chimpanzees, and we could compare common patterns and individual differences among chimpanzees (Wickens, 1989). Finding both common patterns and individual differences is important for two reasons. First, cross-fostered chimpanzees are like human children in that they exhibit both commonalities and individual differences. Second, demonstrable individual differences show that the patterns originate with the individual chimpanzees rather than from artificial experimental constraints.

This section presents the scheme of classification followed by analyses of the distribution of the classified responses to the four types of probe. Later sections present the distributions and their analysis.

For convenience, this analysis designates each chimpanzee utterance as C_n, where the chimpanzee utterance that initiated each trial is C_0, and the sequence of replies to the interlocutor is C_1, C_2, and C_3. Similarly, this analysis designates each interlocutor probe as P_n, where the sequence of three probes is P_1, P_2, and P_3. The first analysis measures the *reaction* of the chimpanzees to each probe by comparing the signs in each chimpanzee utterance with the signs in the immediately preceding chimpanzee utterance, that is, C_1:C_0, C_2:C_1, and C_3:C_2. The second analysis measures the *interaction* of the chimpanzees with each probe of the interlocutor by comparing the signs in each reply with the signs in the immediately preceding probe, that is, C_1:P_1, C_2:P_2, and C_3:P_3.

Classification Into Categories

Using the gloss transcriptions, MLJ classified the reaction of each chimpanzee utterance, C_1:C_0, C_2:C_1, and C_3:C_2, according to the scheme in Table 2 and the interaction of each chimpanzee utterance, C_1:P_1, C_2:P_2, and C_3:P_3, according to the scheme in Table 3.

Reaction categories (C_n:C_{n-1}). 1. S (same): The signs in C_n were the same as the signs in C_{n-1} in both gloss and modulation. An example of S is the following:

Trial #3/0:26:03
0:26:07 Moja: CLOTHESx/
0:26:09 Probe: NOT UNDERSTAND?/
0:26:11 Moja: CLOTHESx/

2. S−: The signs in C_n contained some but not all of the same signs in C_{n-1} without additional signs or changes in modulation. An example of S− is the following:

Trial #3/1:39:45
1:39:42 Moja: YOU SHOEx/
1:39:45 Probe: SHOE CAN'T HAVE/
1:38:48 Moja: YOU/

3. S*: The signs in C_n were the same as the signs in C_{n-1} except that the modulation changed either in reiteration or in place. *Reiteration* changes consisted of a shift from a single iteration to one or more reiterations or from one or more reiterations to a single iteration. An example of change in reiteration is the following:

Trial #1/0:47:53
0:47:49 Moja: FLOWER/
0:47:53 Probe: WHAT?/
0:47:54 Moja: FLOWERx/

Table 2
Reaction to Interlocutor Probe

	Relation of signs in turn to signs in previous turn		
Category	Same	Novel	Changed modulation
S	All	None	None
S−	Some	None	None
Sc			
S*	All	None	Some
S+	All	Some	None
S+/−	Some	Some	None
Dc	None	All	–
NR	–	–	–

Note. Modulation was only scored if the glosses in the two replies were exactly the same; see text for definition of terms.

Table 3
Interaction With Interlocutor Probe

Category	Relation of signs in turn to signs in previous probe: Same	Novel
I	All	None
I+	Some	Some
Dp	None	All
NR	–	–

Note. See text for definition of terms.

Place changes consisted of a shift in place modulation. An example of place is the following:

Trial #2/1:12:49
1:12:50 Moja: YOU (toward MLJ's chest)/
1:12:52 Probe: CAN'T/
1:12:52 Moja: YOU (toward MLJ's head)/

Although the configuration and movement were the same, Moja changed the referent by changing the place of the sign.

4. S+: All of the signs in C_{n-1} appeared in C_n together with new signs. An example of S+ is the following:

Trial #3/0:21:29
0:21:23 Washoe: GIMMEX/
0:21:29 Probe: questioning expression
0:21:30 Washoe: FOOD GIMMEX/

5. S+/−: Some but not all of the signs in C_{n-1} appeared in C_n together with new signs. An example of S+/− is the following:

Trial #5/0:07:30
0:07:28 Washoe: HURRYX GIMMEX/
0:07:30 Probe: WHO STUPID?/
0:07:32 Washoe: PERSONX GIMME/

In cases of S+ and S+/−, the chimpanzees expanded on their previous utterances (Bloom et al., 1976; B. T. Gardner & Gardner, 1998, p. 168; Keenan, 1977).

6. Dc: All the signs in C_{n-1} were different from the signs in C_n. An example of Dc is the following:

Trial #5/0:08:24
0:08:33 Washoe: GRASSX GIMME/
0:08:34 Probe: WHO WANT GRASS?/
0:08:35 Washoe: PERSONX HURRYX/

7. NR (no response): The chimpanzee failed to respond within 5 s after the probe (Brinton, Fujiki, Loeb, & Winkler, 1986, p. 77). If the chimpanzee looked away or moved away before the interlocutor could present the next probe, the response was classified as NR.

Interaction categories (C_n:P_n). 1. I (incorporation): All of the signs in C_n appeared in P_n (R. A. Gardner, Gardner, & Drumm, 1989, p. 47). An example of incorporation is the following:

Trial #1/0:15:56
0:16:08–11 Probe: WHOSE BERRY?/
0:16:14 Tatu: BERRYX/

2. I+ (expansion): All of the signs in C_n appeared in P_n together with new signs. In cases of I+, the chimpanzees expanded on the probes of the interlocutor (Bloom et al., 1976; Bohannon & Stanowicz, 1989; B. T. Gardner & Gardner, 1998, p. 168; Keenan, 1977). An example of I+ is the following:

Trial #3/0:49:58
0:49:58 Probe: WHO WANT FLOWER?/
0:49:59 Washoe: FLOWER ME/

3. Dp: All the signs in C_n were different from the signs in P_n. An example of Dp is the following:

Trial #1/0:38:09
0:38:09 Probe: CAN'T/
0:38:09 Moja: YOU BUG/

4. NR (no response): The chimpanzee failed to respond within 5 s after the probe (Brinton, Fujiki, Loeb, & Winkler, 1986, p. 77). If the chimpanzee looked away or moved away before the interlocutor could present the next probe, the response was classified as NR.

Reliability. A second observer independently scored a randomly selected sample of 20% of the videotapes for reiteration and place modulation, and the transcriptions for interaction and reaction categories. These comparisons yielded agreements ranging from 93% to 96%.

Reaction Results

Although MLJ and the second observer agreed on more than 96% of their assignments of reactions to the seven categories of Table 2, we combined S*, S+, and S+/− into a single category, Sc, for statistical analyses.

The effect of each of the three successive probes in each of the 20 trials on the distribution of reactions to each probe condition yielded 16 chi-squares with five categories of reaction versus three probes. Of these 16 chi-squares, 12 probabilities were greater than .50, and the lowest probability was greater than .08. On the basis of this insignificant difference between successive probes within a trial, we treated each probe within a trial as independent. This yielded three times 20, or 60 independent probes for each probe condition in all further analyses of reaction to probe type.

The patterns of reaction to probes for each chimpanzee for each condition appear graphically in Figure 2. A one-way chi-square for each distribution appears below each of the 16 panels of Figure 2, and each of these chi-squares is significant with $p < .006$; there were two exceptions that were significant with $p < .05$. The distribution of reactions among categories was significantly different from chance equality for each chimpanzee and for each condition.

Condition versus condition. The effect of conditions on the pattern of reaction shown in Figure 2 yielded four chi-squares, one for each chimpanzee. With four conditions and five categories of reaction, each test had 12 degrees of freedom. For Washoe, the chi-square for conditions was significant: $\chi^2(12, N = 240) = 55.90$, $p < .0001$. Pairwise comparisons showed significant differences ($p < .02$) between each pair of conditions except the general versus off-topic conditions ($p < .16$). For Dar also, the chi-square between conditions was significant: $\chi^2(12, N =$

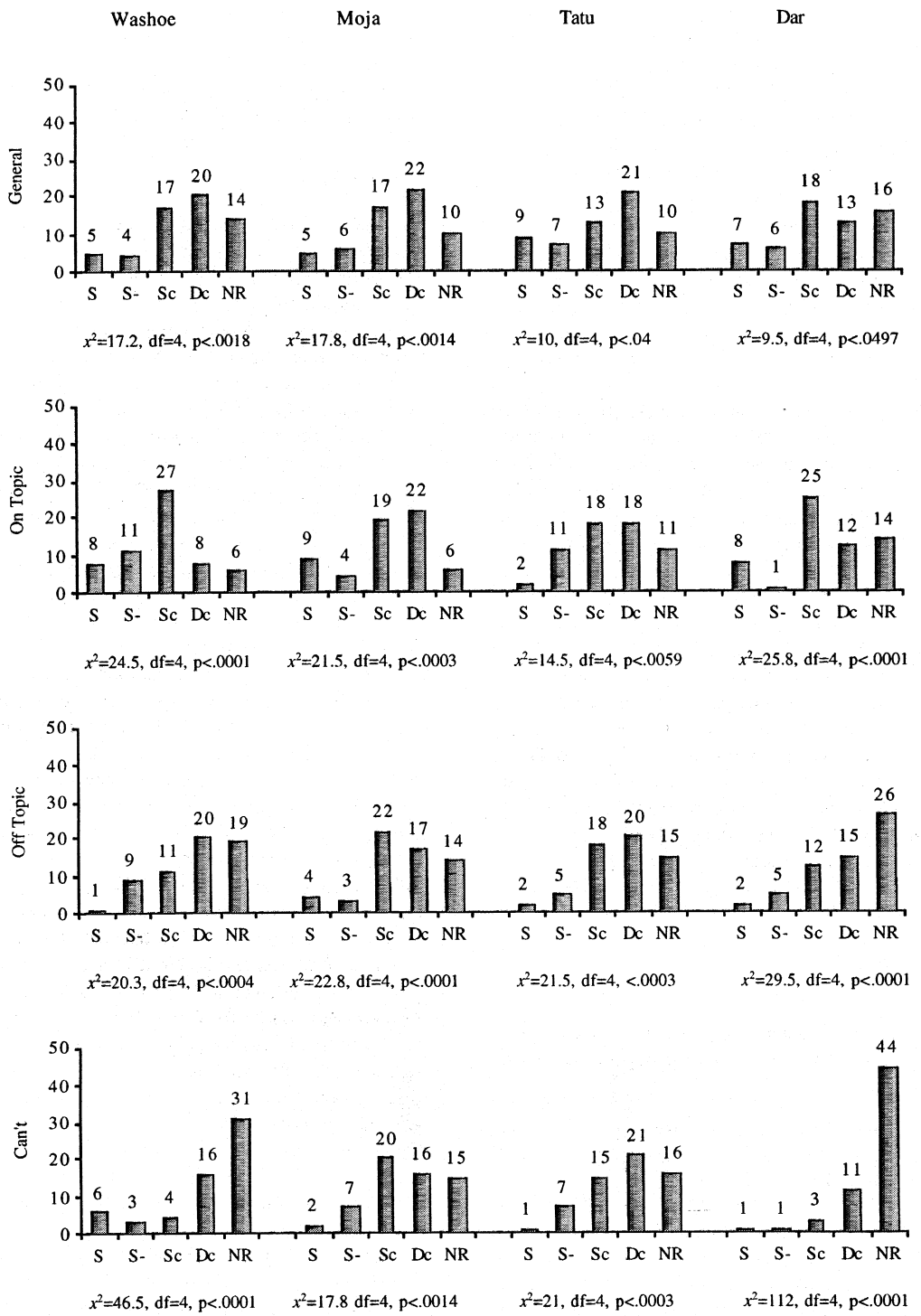

Figure 2. Patterns of reaction to four types of probes; *N*s for all chi-squares appear within the bar graphs. See text for definitions of terms.

240) = 55.85, $p < .0001$. Pairwise comparisons showed significant differences ($p < .005$) between all of the pairs except the general versus on-topic conditions ($p < .30$) and the general versus off-topic conditions ($p < .16$), which only approached significance. The chi-squares for conditions were for Moja, $\chi^2(12, N = 240) = 13.98, p < .3$; and for Tatu, $\chi^2(12, N = 240) = 17.70, p < .125$.

General condition. Figure 2 shows that all 4 chimpanzees had a similar pattern of reaction. The Dc and Sc categories were the most frequent reactions to the general probes. The chi-square for 4

chimpanzees by five categories of reaction was insignificant, $\chi^2(12, N = 240) = 8.22, p = .7679$, indicating that all 4 chimpanzees had a similar distribution of reactions to general probes. Anselmi, Tomasello, and Acunzo (1986); Brinton, Fujiki, Loeb, and Winkler (1986); Brinton, Fujiki, Winkler, and Loeb (1986); and Wilcox and Webster (1980) found that human children often incorporate and expand across turns when asked questions.

On-topic condition. Figure 2 shows two patterns of reaction to on-topic probes: one common to Washoe and Dar and the other common to Moja and Tatu. Washoe's and Dar's distributions peaked in the Sc category. Tatu's and Moja's distributions peaked in the Dc and Sc categories. The chi-square for 4 chimpanzees by five categories of reaction was significant, $\chi^2(12, N = 240) = 31.35, p = .0017$, indicating significant individual differences.

Off-topic condition. Figure 2 shows that all four distributions were similar for all 4 chimpanzees. The chi-square for 4 chimpanzees by five categories of reaction was insignificant, $\chi^2(12, N = 240) = 16.5, p = .169$, indicating that all 4 chimpanzees had a similar distribution of reactions to off-topic probes. The chimpanzees' reactions often fell into the Dc and NR categories and rarely fell into the S and S− categories.

Can't condition. Figure 2 shows two patterns of reaction to can't probes: one common to Washoe and Dar and another common to Moja and Tatu. The chi-square for 4 chimpanzees by five categories of reaction was significant, $\chi^2(12, N = 240) = 57.3, p < .0001$, indicating significant individual differences. Washoe and Dar rarely used S, S−, or Sc in this condition. Instead they used a different sign (Dc) or failed to respond (NR). Moja and Tatu had more Sc responses and more total responses than Dar and Washoe. In the can't condition, Moja and Tatu were more persistent than Washoe and Dar. In the following example, before having a meal, Tatu first had to enter another area:

Trial #1/0:56:18
0:56:14 Tatu: EATx?/
0:56:18 Probe: CAN'T/
0:56:20 Tatu: IN/

Another example of persistence occurred while Moja was outside; she was referring to flowers that were beyond her reach:

Trial #3/0:24:59
0:25:00 Moja: FLOWERx THERE FLOWER THERE/
0:25:09 Probe: FLOWER CAN'Tx/
0:25:10 Moja: FLOWERx YOU/

Moja persisted in the topic she initiated in spite of the negative response of the interlocutor. In contrast, Washoe and Dar usually failed to respond to can't probes, and when they did respond, they mostly reacted with different (Dc) or modified (Sc) utterances.

In summary, in the general condition, all 4 chimpanzees reacted with a similar pattern; their reactions most often fell into the Sc and Dc categories. In the on-topic condition, Washoe and Dar had one pattern of reaction, and Moja and Tatu had a different pattern of reaction. Washoe's and Dar's reactions often fell into the Sc category, whereas Moja's and Tatu's often fell into both the Sc and Dc categories. In the off-topic condition, all 4 chimpanzees reacted similarly; their reactions most often fell into the Dc and NR categories. In the can't condition, as in the on-topic condition, Washoe and Dar had one pattern of reaction, whereas Moja and Tatu had a different pattern. Washoe and Dar often refused to respond, and when they did respond, their responses often fell into the Dc category. Moja and Tatu responded more often to the can't condition, and their responses fell into the Sc and Dc categories.

Interaction Results

As in the case of reaction, the effect of each of the three successive probes in each of the 20 trials on the distribution of interactions with each probe condition yielded 16 chi-squares with four categories of reaction versus three probes. Of these 16 chi-squares, nine probabilities were greater than .50, and the lowest probability was greater than .09. On the basis of this insignificant difference between successive probes within a trial, we treated each probe within a trial as independent. This yielded three times 20, or 60 independent probes for each probe condition in all further analyses of interaction with probe type.

The patterns of interaction with probes for each chimpanzee for each condition appear graphically in Figure 3. As in the case of reaction, the effect of repeated probes on the interaction of each utterance with the previous probe yielded 16 chi-squares with four categories of interaction. A one-way chi-square for each distribution appears below each of the 16 panels of Figure 3, and 14 of these chi-squares are significant with $p < .003$. This indicates that the distribution of interactions among categories was significantly different from chance equality for each chimpanzee and for each condition in all but two cases. The exceptions were the interactions with the on-topic probes for Tatu and Dar, which yielded chi-squares of 1.7, $p > .63$ for Tatu, and 0.7, $p > .87$ for Dar. As Figure 3 shows, general probes evoked no incorporations at all. Consequently, the chi-squares for this condition omitted these columns of response and had fewer degrees of freedom.

Condition versus condition. The effect of conditions on the pattern of interaction shown in Figure 3 yielded four chi-squares, one for each chimpanzee. With four conditions and four categories of interaction, each test had nine degrees of freedom. These tests yielded chi-squares of 115.55 for Washoe, 80.13 for Moja, 67.44 for Tatu, and 104.26 for Dar. All four were significant with $p < .0001$. Of the 24 possible pairwise chi-squares, 22 were significant with $p < .05$. The pairwise comparisons between can't and off-topic for both Moja and Tatu were insignificant with $p < .21$ and .75, respectively. In the pairwise comparisons, there were three degrees of freedom for two conditions and four categories of interaction. In pairwise comparisons between the can't and general conditions for Washoe and Dar, however, the I and I+ columns had frequencies of less than three, and these chi-squares were computed as 2×2 contingency tables with one degree of freedom. In the pairwise comparison between the general and off-topic conditions for Moja, the I column had a frequency of zero, and this chi-square was computed as a 2×3 contingency table with two degrees of freedom.

General condition. Figure 3 shows all 4 chimpanzees often responded with different (Dp) signs and never responded with incorporations (I) or expansions (I+). Since there were no responses in the I or I+ categories, the chi-squares for this condition omitted these columns of response and had fewer degrees of freedom. The chi-square for 4 chimpanzees by two categories of interaction was insignificant, $\chi^2(3, N = 240) = 2.73, p = .4354$,

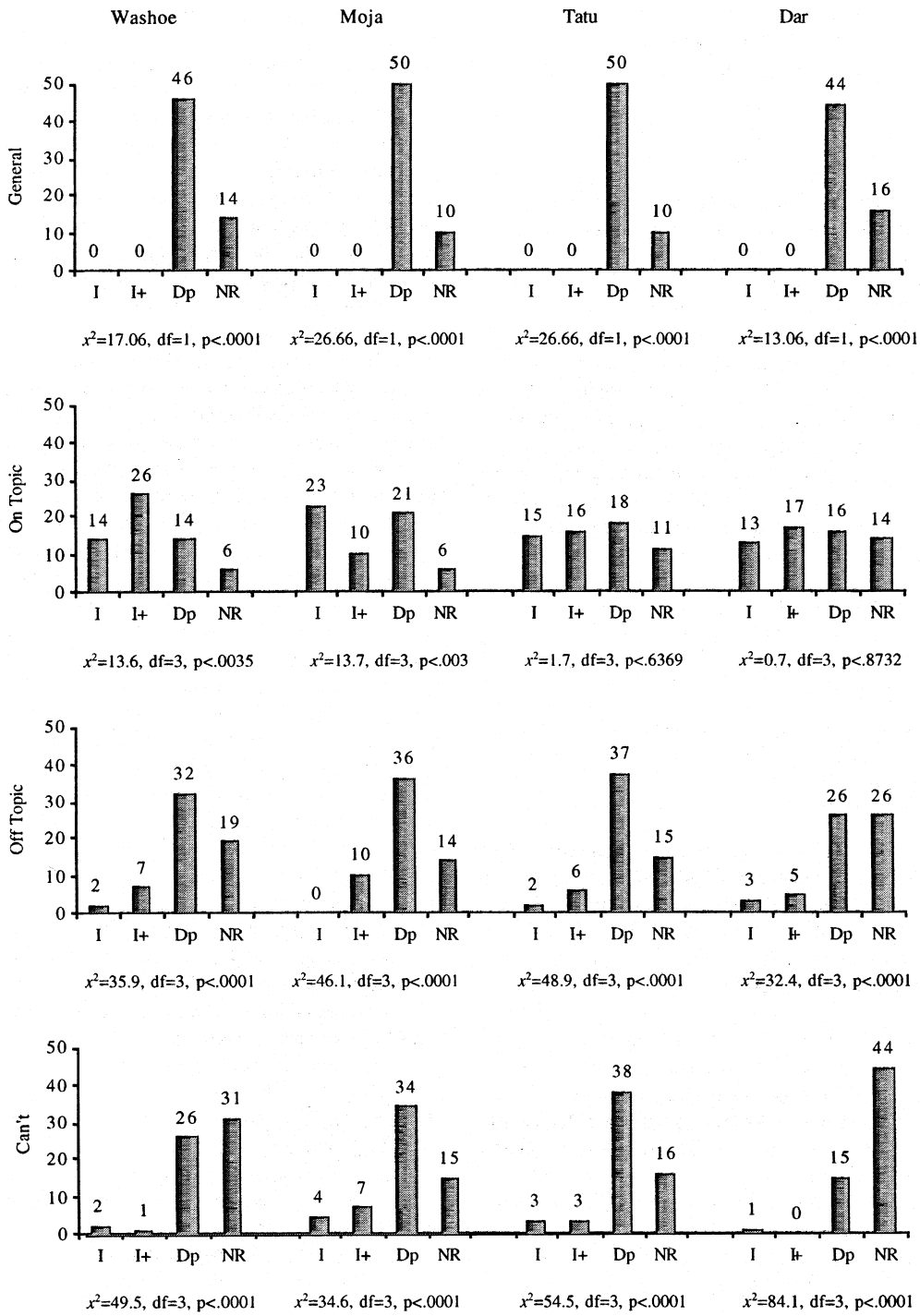

Figure 3. Patterns of interaction with four types of probes; *N*s for all chi-squares appear within the bar graphs. See text for definitions of terms.

indicating that all chimpanzees had a similar distribution of reactions to the general probes. Different signs were the most appropriate response in this condition because incorporations and expansions would be like answering a question with a question and would end the conversation.

On-topic condition. Figure 3 shows that all 4 chimpanzees used incorporations (I) and expansions (I+) more in the on-topic condition than in the other conditions. The chi-square for 4 chimpanzees by four categories of interaction was significant, $\chi^2(9, N = 240) = 18.05$, $p = .0346$, indicating significant individual

differences. In the following example, Washoe responded with the I category and incorporated the sign of the interlocutor into her utterance without adding any new signs:

Trial #3/0:49:58
0:49:58 Probe: WHO WANT FLOWER?/
0:49:59 Washoe: FLOWER/

In the following example, Tatu responded with the I+ category and incorporated the sign SMELL into an expanded utterance:

Trial #2/0:19:23
0:19:26 Probe: WHO SMELL?/
0:19:27 Tatu: TATU SMELL YOU/

Off-topic condition. Figure 3 shows that off-topic probes also depressed responses but less than can't probes. When the chimpanzees did respond to off-topic probes, most of their utterances contained different (Dp) or added new signs to incorporations (I+). The chi-square for 4 chimpanzees by four categories of interaction was insignificant, $\chi^2(9, N = 240) = 11.81, p = .2244$, indicating that all chimpanzees had a similar distribution of reactions to the off-topic probes.

In this condition, the probes were neither contingent on the chimpanzee's previous utterance nor contingent on the context of the interaction. The interactive effect of off-topic probes on the chimpanzees was to evoke different signs from them. For example, note the following interaction:

Trial #1/0:19:26
0:19:15 Tatu: CRACKERx/
0:19:26 Probe: WHERE DOG?/
0:19:31 Tatu: EATx TIMEX EATx/

Can't condition. Figure 3 shows that can't probes depressed responses; the NR category appeared in this condition more often than in other conditions. Because there were few responses in the I or I+ categories, the chi-squares for this condition omitted these columns of response and had fewer degrees of freedom. The chi-square for 4 chimpanzees by four categories of interaction was significant, $\chi^2(9, N = 240) = 44.86, p < .0001$, indicating significant individual differences. There were two patterns of response: one common to Washoe and Dar and another common to Moja and Tatu. Most of Washoe's and Dar's responses to can't probes fell into the NR category, whereas the remainder fell mostly into the Dp category. Most of Moja's and Tatu's responses to can't probes fell into the Dp category, but most of the rest of their responses to can't probes fell into the no response (NR) category. Incorporations (I) and expansions (I+) did appear in responses to can't probes, but they were rare. Instead, the chimpanzees usually signed something different from the probe (Dp) or failed to respond (NR).

In summary, Washoe's, Moja's, Tatu's, and Dar's responses depended on the probes of their conversational partner. When the interlocutor asked general probes, the chimpanzees responded with different signs. When the interlocutor asked on-topic probes, the chimpanzees responded with incorporations and expansions more than in the other conditions. When the interlocutor asked off-topic probes, the chimpanzees used fewer incorporations and expansions and often refused to respond. In the can't condition, the chimpanzees rarely used incorporations and expansions; instead, they used different signs or failed to respond.

Discussion

Except, perhaps, for the word salad of schizophrenia and the speaking in tongues of religious ecstasy, verbal behavior depends on context. Conversations between two speakers or signers depend on the verbal give-and-take between conversational partners. Conversational contingency appears in utterances of children as young as 2 years old (Anselmi et al., 1986; Bloom et al., 1976; Gallagher, 1977; Marcos & Bernicot, 1994; Wilcox & Webster, 1980). In this experiment, Washoe, Moja, Tatu, and Dar signed to a human familiar whose rejoinders varied according to a systematic experimental design.

The responses of the cross-fosterlings were contingent on the rejoinders of the human interlocutor. The chimpanzees *reacted* to probes appropriately by maintaining or altering the signs in their previous utterance. They *interacted* with probes appropriately by adjusting their signs in relation to the probes.

This experiment varied the conversational input to chimpanzees and showed that systematic variations in input from a familiar conversational partner resulted in systematic variations in the contents and the quality of the responses of 4 cross-fostered chimpanzees. The responses of the chimpanzees were conversational responses that were contingent on the conversational probes of the interlocutor. The responsive, conversational responses of the chimpanzees resembled the conversational responses of human children in similar studies and resembled older children more than very young children. The chimpanzees reacted to general probes by expanding like older hearing children and deaf children (Brinton, Fujiki, Loeb, & Winkler, 1986; Ciocci & Baran, 1998). Like older hearing children, the chimpanzees expanded across turns and were responsive to facial expressions without any signs (Anselmi et al., 1986; Brinton, Fujiki, Loeb, & Winkler, 1986; Pearl, Donahue, & Bryan, 1981). Incorporation and expansion are ways that adult humans and children maintain topic in a conversation (Brinton & Fujiki, 1984; Garvey, 1977; Halliday & Hasan, 1976, p. 278; Wilcox & Webster, 1980), and the chimpanzees incorporated and expanded as well. The effect of on-topic and off-topic probes on the children in Dunham and Dunham's (1995) study was similar to the effects found in the chimpanzees in the present study. In both cases, on-topic probes evoked more incorporations and expansions and fewer failures to respond than did off-topic probes. Marcos and Bernicot (1994) examined reactions of 18- to 30-month-old human children to an interlocutor who refused to cooperate with requests for objects. Like the chimpanzees in this experiment, the children sometimes persisted in their original request, and sometimes they switched to a different topic, but more often they failed to respond. Also, like human children, Washoe, Moja, Tatu, and Dar varied among themselves. They showed patterns of individual differences in their conversational styles.

The cross-fosterlings developed into conversational partners because interlocutors had always treated them as conversational partners. Interactive sign language had always been an integral part of their daily lives, beginning at an infantile level and rising to gradually more sophisticated levels as they matured. The development of human children into conversational partners also depends on their treatment as conversational partners (Singleton, Morford, & Goldin-Meadow, 1993).

The chimpanzee–human dialogues in this experiment were embedded in the casual interactions of daily life in the Ellensburg

laboratory. For experimental purposes, the interlocutor always waited for the chimpanzee to initiate a dialogue, but Washoe, Moja, Tatu, and Dar normally took the lead in chimpanzee–human dialogues in Reno (B. T. Gardner et al., 1989, p. 63) and Ellensburg. In this formal experiment, the interlocutor varied her input according to a systematic experimental design, but this experimental testing blended seamlessly into the social world of the cross-fosterlings. The resulting dialogues have the quality of human conversations because they took place in an appropriate environment. They are comparable to dialogues in similar research with human children because cross-fostered chimpanzees and human children carry on conversations under similar conditions.

In this experiment, the cross-fosterlings showed their conversational skills. When appropriate, they incorporated signs from the interlocutor's responses into their own turns in the conversation and expanded on the signs they incorporated. When appropriate, they also clarified and amplified their own previous responses with suitable expansions. They responded contingently to maintain the interaction and the topic of the interaction. They could keep the conversational ball in the air. They acquired these conversational skills in a conversational environment.

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Received August 27, 1999
Revision received January 25, 2000
Accepted February 25, 2000 ■