An Explanation of the Language of a Chimpanzee

Abstract. *The language behavior of the chimpanzee Lana, previously described by Rumbaugh (1977), can be simulated by a computer model in which the animal selects, depending upon context, one of six stock sentences with fixed and variable elements.*

We have been studying the LANA Project of Rumbaugh and his colleagues (*1*) with two main objectives: (i) to describe the minimum set of abilities necessary to account for the chimpanzee's use of the Yerkish keyboard language and (ii) to examine the extent to which principles of reinforcement can explain this behavior. We propose that Lana's behavior can, to a large extent, be attributed to two basic processes: paired associate learning and conditional discrimination learning. Lana was capable of rapidly learning a large number of paired associates (that is, lexigrams appropriate for particular objects, people, or events). She was also able to learn to produce one of several "stock sentences" of lexigrams depending upon situational cues, a conditional discrimination. In producing these sentences she was able to insert an appropriate paired associate in an otherwise fixed string of lexigrams.

Table 1 is a decision table of conditions that we propose determine which of six stock sentences is appropriate in a given context. The table shows the circumstances under which each of the sentences was used. These are whether an experimenter has an object, whether it is food, and if so, whether it is placed in a dispensing machine. For example, if food is in the machine, the first stock sentence (S1) is used [for example, (Please machine give milk.)]. In contrast, if a nonfood object is present, then S2 is used [for example, (Please Tim give ball.)]. Table 2 lists paired associates for the people and incentives that are part of a given context.

All of the sentences in Table 1 share the following features: constant elements (for example, the lexigrams for starting and ending a sentence), variable elements (for example, the name and incentive), and finally, an element for the activity (such as "give" or "move"). A prototypical stock sentence can be represented as (Please <name> <activity> <incentive>.). Lexigrams in the same semantic class have the same color, but the sequence of colors is not the same for all sentences. In some cases a stock sentence involves additional lexigrams ("out-of room" and "in machine") whose selection is determined by the particular activity word chosen. For example, in S2 selection of the activity word "move" entails selection of additional words ("into room") to be placed at the end of the string. In Table 1 an activity word and its additional words appear together to show this relationship.

In order to test this analysis of Lana's behavior, we wrote a computer program in BASIC, building into the program the set of skills described above. Input to the program consists of a description of the context as shown in the sample output of the program in Table 3. The data base consists of the six stock sentences listed in Table 1 and the paired associates listed in Table 2.

The program works as follows. The answers to the first three input questions determine which of the six stock sentences is employed; the answers to the last three input questions determine what value the variables of the sentence will take. For example, if a food object is present in the machine, S1 will be chosen (Please machine give <incentive>.). If the object was milk, the appropriate lexigram for milk would be substituted for the variable <incentive>, and the sentence would be (Please machine give milk.). In some cases, more than one stock sentence is possible in a given context. For example, either stock sentence 5 or 6 is appropriate if no object is present. In these cases, the program selects one or the other in a random manner. In some cases, more than one activity word is appropriate to a particular sentence type. This choice is also made probabilistically by the program. For example, the program selects for S5 one of the four possible activity words *tickle, groom, swing*, or *carry out-of room*.

The model that has been presented is

Table 1. On the basis of yes (Y) or no (N) answers to the three questions, a stock sentence is chosen. For example, if food is present but not in the machine S2 (stock sentence 2), S3 or S4 is chosen probabilistically. In these cases one of two activity elements is chosen probabilistically, and a paired associate for the person and incentive present is substituted for the variable ⟨name⟩ and ⟨incentive⟩. See Table 2 for the lists of paired associates.

Queries	Answers			
Object present?	Y	Y	Y	N
Object food?	Y	Y	N	
Object in machine?	Y	N		
Stock sentences				
S1: Please machine give ⟨incentive⟩.	+			
S2: Please ⟨name⟩ {give / move into room} ⟨incentive⟩.		+	+	
S3: Please ⟨name⟩ {move behind room / put in machine} ⟨incentive⟩.		+		
S4: Please Lana {want eat / want drink} ⟨incentive⟩.		+		
S5: Please ⟨name⟩ {tickle / groom / swing / carry out-of room} Lana.				+
S6: Please machine make ⟨event⟩.				+

Table 2. Semantic classes of paired associates.

Names	Incentives					
	Foods*	Unit foods	Liquids	Objects	Unnamed	Events
Tim	Apple	M&M	Coffee	Ball	This which-is ⟨color⟩†	Movie
Beverly	Banana	Nut	Coke	Blanket		Music
Bill	Bread	Raisin	Milk	Bowl		Slide
Visitor	Cabbage		Juice	Box		Television
You	Chow		Water	Can		Door-open
Lana				Cup		Window-open
Me				Feces		
				Shoe		

*In S1, words from this class are always preceded by the lexigram for "piece-of." †Colors: black, blue, green, orange, purple, red, white, and yellow.

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Table 3. Sample results from the BASIC program developed to simulate Lana's behavior.

Context		Paired associates		Sentence
Query	Answer	Referent	Lexigram	
Is an object present? Is the object food? Is it in the machine?	Yes Yes Yes	Who is the person? What is the object?	Tim Milk	*Please machine give milk.**
Is an object present?	Yes	Who is the person?	Beverly	*Please Beverly move ball into room.*†
Is the object food?	No	What is the object?	Ball	
Is an object present?	Yes	Who is the person?	Tim	*Please Tim move this which-is yellow into room.*‡
Is the object food?	No	What is the object? What is its color?	Pencil Yellow	
Is an object present?	No	Who is the person?	Jane	*Please visitor groom Lana.*§

*When the answer to all three conditional questions is "yes," S1 is selected, with substitution of the paired associate for the incentive present. †When an object is present, but is not food, S2 is selected. In this case, the activity word selected was ⟨move + into room⟩. ‡The context is similar to that above, but no paired associate has been stored for the object present. §When no object is present, S5 or S6 is chosen probabilistically; this is S5. In this example, no paired associate has been stored for the person present.

based upon the 198 sequences that appeared in descriptions of Lana's behavior in Rumbaugh's book (*1*). After the computer program was developed, we were given the data from the appendix of a thesis by Gill (*2*), which contained descriptions of all contexts in situations involving conversations with Lana, as well as complete protocols of Lana's productions during a 3-month period centered about the time of the conversation experiments. We have analyzed all of the data in Lana's protocols for the period of the conversation studies, and selected at random the protocol for 1 day per week for each of 5 weeks preceding and following the thesis period.

The results of the analysis are summarized in Table 4. We have divided Lana's productions into three main classes: (i) stock sentences (one of the six sequences in Table 1), (ii) nonstock sentences (other sequences that were reinforced), and (iii) errors (sequences that were not reinforced).

When no experimenter was present, 91 percent of all productions (5288 of 5830) were one of the six stock sentences, 8 percent were errors, and only 1 percent were nonstock sentences. The model accounts for the stock sentences; it does not attempt to account for Lana's errors. The nonstock sentences, however, are exceptions to the model. Of the 74 nonstock sentences that occurred, 73 were the sequence (Please machine give piano.), which is identical to our S6 except that the activity word for obtaining piano is *give* instead of *make*. This represents no challenge to the model since it could easily be expanded to include one additional stock sentence.

For sequences produced when an experimenter was present, our model is less successful. Of all productions 66 percent were one of the six stock sentences, 19 percent were errors, and 14 percent were nonstock sentences. Again, the nonstock sentences represent exceptions to the model, and therefore we considered them in some detail. Of the 1276 such sequences that Lana produced when an experimenter was present, 776 of these were specifically trained sequences such as (<object> name-of this.). This leaves 500 novel sequences to be accounted for. Twenty-eight of them were fragments such as "box orange" that would normally have been nonreinforced. All of the remaining sequences included the activity words *give*, *put*, *move*, *want*, or *make*. While these sequences constitute exceptions to the six stock sentences as we have presented them, they showed many of the same elements and sequencing relations as the prototypical stock sentences shown earlier and seem to represent extensions of it, rather than departures from it. Presumably, Lana produces such sequences when she has not been able to obtain an incentive in the usual way with a stock sentence.

Table 4. Analysis of Lana's productions.

Type of production	Frequency of occurrence with experimenter	
	Present	Absent
Stock sentences	5725	5288
Trained nonstock sentences	766	73
Novel nonstock sentences	500*	1
Errors	1663	467

*Excluding errors (nonreinforced responses) the model based on 198 sequences in Rumbaugh's book (*1*) fails to account for 6 to 8 percent of the larger sample of 6991 sentences (1 percent confidence interval).

The evaluation of the analysis required complete and accurate records of a large corpus of productions. Such data were collected by Rumbaugh (1977) since the lexigram board was interfaced to an on-line computer. Terrace *et al*. (*3*) also objectively analyzed a large corpus (3.5 hours of videotape) of productions and their contexts of the chimpanzee Nim. The abilities displayed by Nim in the sign-language situation (such as imitation, answering questions, and inserting so-called wild-card signs) were different from the abilities displayed by Lana in the lexigram situation (such as conditional sequence discrimination and variable substitution). Both explanations, however, have emphasized paired-associate learning and the goal-oriented nature of the apes' behavior; the animals were motivated to produce strings of signs or lexigrams in order to obtain a desired object (or event). The approach of these explanations of chimpanzee language behavior may also be useful for understanding some of the abilities involved in human language.

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References and Notes

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2. T. V. Gill, in *ibid*., pp. 225–246; unpublished dissertation, Georgia State University (1977).
3. H. S. Terrace, L. A. Petitto, R. J. Sanders, T. G. Bever, *Science* **206**, 891 (1979).
4. We thank D. M. Rumbaugh for making available to us the complete record of Lana's productions from 29 April 1975 through 29 July 1975, a period that covered the month preceding and the month following research described by Gill (*2*). The LANA Project during this period was supported by PHS research grant HD-06016. This report was facilitated by research fellowship MH 07741 from the National Institute of Mental Health (to R.M.C.).
* Requests for reprints (and/or a listing of the BASIC program used to simulate this behavior) should be sent to Department of Psychology, Brown University, Providence, R.I. 02912.

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