It would be rash to predict the outcome; not all schemes now being worked on will be adopted, which is the price in technology assessment of keeping options open. Surprises come, not all unpleasant, and a historic parallel occurs to me (*37*). In 1680 Christiaan Hüygens decided to control gunpowder for peaceful purposes, as a perpetual boon to mankind, and set his assistant Denys Papin to invent a controlled gunpowder engine. After 10 years of difficulty, Papin had a different idea, wrote in his diary,

> Since it is a property of water that a small quantity of it turned into vapour by heat has an elastic force like that of air, but upon cold supervening is again resolved into water, so that no trace of the said elastic force remains, I concluded that machines could be constructed wherein water, by the help of no very intense heat, and at little cost, could produce that perfect vacuum which could by no means be obtained by gunpowder.

then invented the expanding and condensing steam cycle, which made possible the industrial revolution.

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# Language in Chimpanzee?


David Premack


Can apes be taught language? Although this question is of biological import, it may ultimately be more important to the fundamental question, What is language? The ape, when properly trained, emerges as the unclear middle case: Neither wholly comparable to man (the clear positive case) nor to parrot (the clear negative), the "talking" ape puts the question of language to its first severe test (*1*).

The approach I have taken to the twofold question of what language is and whether an ape can be taught it can be expressed in terms of two parallel lists. The first is a list of exemplars, things an organism must be able to do in order to give evidence of language. The second is a corresponding list of instructions for training the organism so that it may be taught the exemplars in question.

The exemplars I am dealing with here concern selected aspects of: (i) words; (ii) sentences; (iii) questions; (iv) metalinguistics (using language to teach


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language); (v) class concepts such as *color*, *shape*, and *size*; (vi) the copula; (vii) the quantifiers all, none, one, and several; and (viii) the logical connective if-then. This list is in no sense exhaustive, nor are the items on it of comparable logical order. They are simply topics that were chosen to illustrate the present approach.

Each word of the language used with the chimp is a piece of plastic, backed with metal, that adheres to a magnetized slate (Fig. 1). Sentences are written on the vertical. The two sentences shown in Fig. 1 can be paraphrased in English as, "No Sarah take honey-cracker" and "Sarah take jam-bread," respectively (*2*). Since the language is written rather than spoken or gestured, words and sentences are permanent. The permanence of the sentence makes it possible to study language without a memory problem. In addition, because the experimenter makes the words, while the chimp merely uses them, the difficulty of any task can be modulated by controlling the number and kind of words available to the chimp at any given time (*3*). There are no phonemes in the language; we have deliberately made the basic unit the word (*4*, *5*).

### Mapping a Social Exchange

The first step in introducing a naive subject to words is to establish a social exchange between subject and trainer. A feeding routine provided an effective transaction with Sarah, an African-born, female chimpanzee about 6 years old when the study began. The trainer began by placing a piece of fruit on the table between Sarah and himself and looking on in a friendly manner while she took it and ate it. After the transaction was well established, the trainer placed a piece of colored plastic from the language system alongside the piece of fruit. The fruit was then placed out of reach, while the plastic chip was easily within reach. Sarah was induced to make a prescribed response with the language element (in this case, to place it on the language board), after which she was given the fruit. The chimp was almost immediately proficient in this act. Causing objects to adhere to a vertical surface was something she did easily, in contrast, for example, to producing human sound.

The rest of the training consisted of making simultaneous changes in some aspect of the transaction and in some aspect of the language system, in order to establish a correspondence between them. We started with the fruits that were offered. When the fruit was a banana, the plastic chip was of one kind; when an apple, of a different kind; when an orange, of still a third kind. On each trial the chimp's task was the same—to place on the board the piece of plastic that was beside the fruit. The chimp was them given the fruit.

Two kinds of tests showed whether or not Sarah had formed an association between elements of the object class and the corresponding elements of the language class. In the first kind, the chimp was given two words and only one piece of fruit. This was done to determine whether she could match the word with the fruit. However, she could know more than such a choice trial would indicate. For example, if she were less interested in the fruit that was offered than in the fruit that was not offered, she could use the "wrong" word as a request for the fruit that she preferred. This possibility was detected by obtaining independent preference orderings on the fruits and on the words.

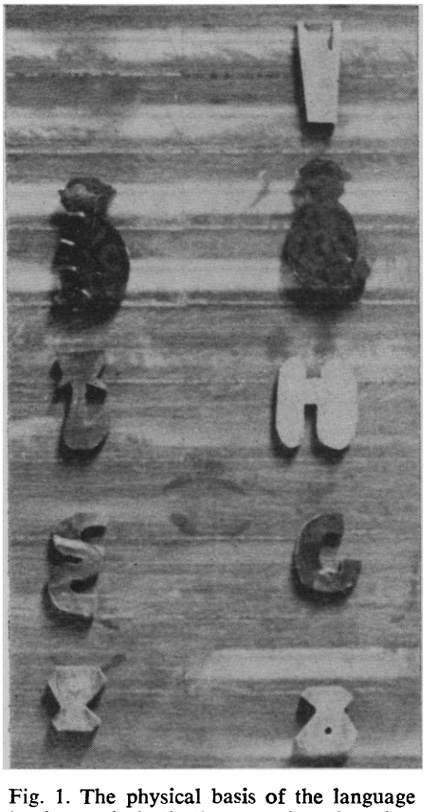


Fig. 1. The physical basis of the language is pieces of plastic that vary in color, size, and shape. Each piece is a word, and each is backed with metal so that it will adhere to magnetized slate. Sentences are written on the vertical.

On one occasion, for example, Sarah chose between all possible pairs of the five different fruits on which she had been trained up to that time; on another occasion, she chose between all possible pairs of the corresponding words. The agreement between her preferences among the words and among the fruits averaged better than 80 percent. In addition, most of her errors occurred on choice trials involving nonpreferred fruit. It was therefore reasonable to conclude that she knew what word went with what fruit, even though her choice sometimes suggested the contrary.

The next perceptual class was mapped in the same fashion. Each change in donor (the person giving the fruit) was accompanied by a change in the second language element. For example, when Mary was present and the fruit was apple, Sarah had to write, "Mary apple" in order to receive the apple; with Randy present, "Randy apple"; and so on. Associations for members of the donor class were tested in the same way that elements of the object class were: when one trainer was present with two or more donor words, the subject matched the word to the trainer. A preference ordering could also have been determined for donors and their names, but it did not prove necessary. She did not appear to attempt to influence donors, perhaps because, typically, only one donor was present in a session, whereas many foods were present.

In addition to being required to place two pieces of plastic on the board, Sarah was required to observe a proper order. "Mary apple" was acceptable but "apple Mary" was not, since the target sentence was "Mary give apple Sarah." The correct order of the words was required from the beginning so that no incorrect orders had to be unlearned. We also observed an antiregression rule. Once Sarah had reached a two-word stage, we rejected one-word fragments, just as we rejected two-word fragments when she had reached a three-word stage, and so on.

The fruit and the donor were easily mapped; the other two classes in this example presented some practical difficulties. For example, the attempt to map the recipient ran into a predictable problem: Sarah was reluctant to produce response sequences calling for a recipient other than herself. Similarly, the attempt to map the operator by varying the action upon the fruit, sometimes cutting it or inserting it in a pail,

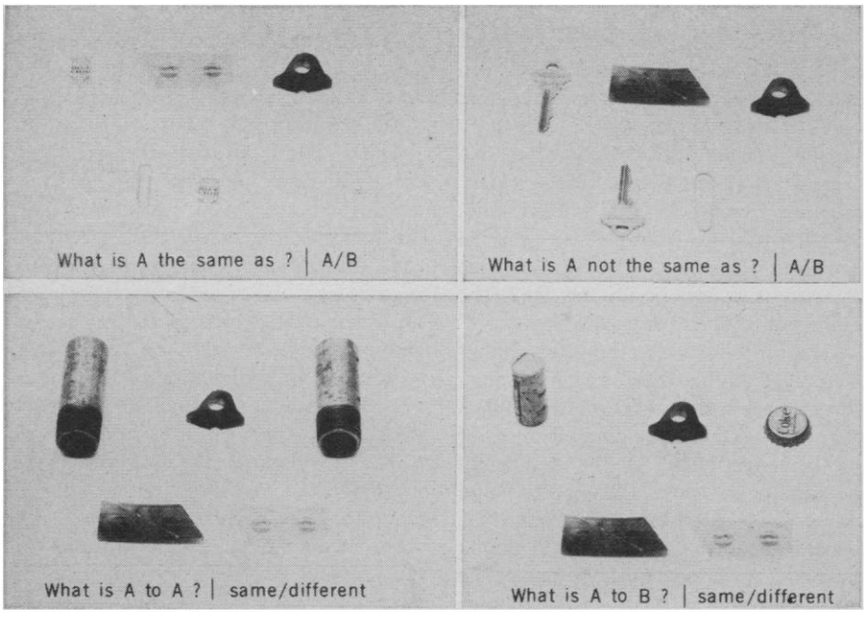



Fig. 2. Four *wh* questions, with English paraphrases.

encountered the same problem. Some of the outcomes were so nonpreferred that, once she had associated the language element with the outcome, she would not form the sentence. However, these were strictly practical problems, and we usually dealt with them by arranging appropriate contingencies. For instance, when Sarah wrote, "Mary give apple Gussie," thereby denying herself the apple, she was given a tidbit she preferred.

In summary, while many variations are yet to be explored, the basic procedure for introducing words to a naive organism was straightforward. A transaction was established between the subject and the trainer. Then a decision was made as to the salient perceptual classes into which the transaction should be divided, a decision which proved to be remarkably easy (5). Each class was then rotated through a series of values such as: apple, banana; Mary, Randy; give, insert; Sarah, Jim; the other classes being held constant. As the value of the perceptual class was changed, a corresponding change was made in the language element; and as each new class was mapped, the language requirement was increased.

### Same-Different and the Interrogative

To call two bananas "same" and a banana and an apple "different," neither object need be named. In this sense, same-different has no linguistic prerequisites. It can be contrasted with, for example, "name of" (which is a relation between an item and its name) or the still more demanding if-then (which is a relation between sentences). In addition to being an appropriate starting point, same-different offers possibly the simplest of all contexts in which to introduce the question. Since the question can be of great service in the teaching of further language, it can hardly be introduced too early.

Before attempting to teach Sarah the words "same" and "different," we used a match-to-sample procedure to determine whether or not she was capable of the perceptual judgments that underlie the linguistic distinction. We gave Sarah two cups and a spoon and taught her to put the two cups together; we also gave her two spoons and a cup and taught her to put the two spoons together. Subsequently, we gave her a large assortment of other objects, always in sets of threes, and found that she was capable of matching all the like pairs, not just those on which she had been trained.

If the acquisition of language is the mapping of existing knowledge, as is often suggested (6), then teaching same-different should be easy. We placed two cups before Sarah, gave her a piece of plastic meaning "same," and required her to place it between them. Next, she was given a cup and a spoon and was required to place between them a piece of plastic meaning "different." We tested her associations by requiring her to choose between "same" and "different." Sarah was presented, as before, with either two cups or with a cup and a spoon. This time she was given both the words "same" and "different" and was required to choose between them. She made 4 errors in 26 trials, none on the first 5 trials. Next, she was given extensive transfer tests, which showed that she could apply the words to items not used in training. In principle, Sarah could go about the cage picking up pairs of objects and labeling them "same" or "different." Relations of this kind that she had been capable of recognizing before, she could now label as such. This, rather than any new concept, is what the language training contributed.

In the exercises above, the chimp was already being asked the question. "What is the relation between the two objects—are they the same or different?" However, Sarah was asked this question without an explicit interrogative marker. The only markers she had so far were the implicit one of the space between the objects, into which she was to insert her answer, and the fact that a trial did not end until she had completed the construction by adding the third item.

The question could be made explicit by any of the three standard linguistic devices: inflection, word order, or an interrogative particle. We chose the latter as the simplest, both in the sense of involving the least change for the subject and of being the most compatible with the present physical system. So we simply added an interrogative marker to the schema she was already receiving. For example where we had previously written:

A "same" A "different"

we henceforth wrote:

A "same" ? A "different".

The variation in mechanical devices that languages use to identify a question obscures the basically simple nature of the question. Any completable construction is a potential question. It becomes a question once it suffers one or more missing elements. That is the structural view. From the psychological point of view, we must add that a question arises when a speaker finds himself unable to complete certain constructions and has at hand a listener whom he regards as a probable source of missing elements. If this analysis is correct, then the ontogenetically earliest context in which to introduce the question—and with great didactic benefit to

all subsequent language training—is that offered by the simplest possible completable constructions. Same-different is such a construction, since it can be introduced as a relation between unnamed objects and thus has no linguistic prerequisites.

Since questions rely on missing elements, with a two-term relation such as same-different, two question forms can be generated directly: one by removing the predicate ("same" or "different"), another by removing one, or even both, of the objects instancing the predicate (A or B). A third form can be generated indirectly by appending the interrogative marker, which itself stands for the missing element or elements, to the head of the construction and then requiring that it be replaced by a further element—specifically, either "yes" or "no." Examples of all three questions are shown in Figs. 2 and 3.

An example of two versions of a *wh* question is shown in the upper panel of Fig. 2. These questions can be paraphrased as, "X is what to X?" and "X is what to Y?" The alternatives are "same" or "different," and Sarah's task was to replace the interrogative marker with the appropriate word.

Two versions of a second type of *wh* question are shown in the lower panel of Fig. 2; they can be paraphrased as, "X is the same as what?" and "X is different from what?" Now the alternatives are no longer the words "same" or "different," but the objects themselves. Sarah's task remained the same: that is, to replace the interrogative particle with the proper object and thereby complete the construction.

### The Yes-No Question

The yes-no question, the third form that can be generated in this context, is shown in four versions in Fig. 3. They can be paraphrased as (i) "Is X the same as X?"; (ii) "Is X different from X?"; (iii) "Is X different from Y?"; and (iv) "Is X the same as Y?" These questions were formed not by removing any item from the sentence, but by adding the interrogative marker to the head of the sentence. Three linguistic items were involved in questions of this form: "yes," "no," and the interrogative marker itself. Of the three, Sarah was already familiar with two—the interrogative marker, introduced in the *wh* forms, and "no," the negative particle that was taught her earlier as an injunction against carrying out the action called for by a sentence. An example of the kinds of pairs of sentences used to teach her the negative particle is shown in Fig. 1. The training consisted simply of arresting the chimp's hand whenever she reached for an item referred to in a sentence containing a negative particle. The training was quickly effective. We have considered other ways of introducing negation, but injunction against action seems as basic as any (*7*).

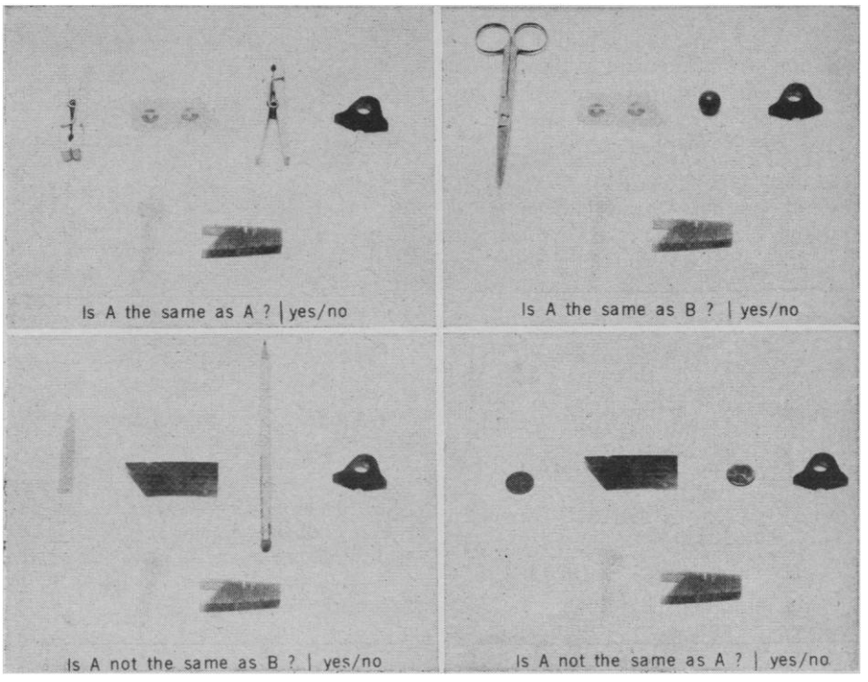



Fig. 3. Four yes-no questions, with English paraphrases. "Different" would be a more suitable paraphrase than "not same," since a negative particle was not used.

Sarah was given explicit training on the first two forms of the yes-no question shown in Fig. 3. She was then tested without prior training on the other two forms. This was designed to find out whether she could transfer from one form to the other. Training started with the question, "? X same X" (Are X and X the same?), where X represents any of the several objects used in the original matching-to-sample. The only alternative given her was "yes," the one word in the yes-no construction that was unknown to her. She displaced the interrogative marker, thus forming the sentence, "Yes, X same X." Next she was given the question, "? X different X" (Are X and X different?). Her one alternative was the word "no." She used it to displace the interrogative marker and form the sentence, "No, X different X." She was given seven trials on each of the two forms.

At step two, she was given the same questions, with both the words "yes" and "no," and was required to choose between them. She made 2 errors in 15 trials, 1 on the first 5 trials. Rather than being given the usual transfer test, with new items substituted for training items, she was tested on the other two forms of the yes-no question. The four forms of the yes-no question were intermingled, and Sarah was asked them in more or less random order. Her alternatives were "yes" and "no," as before, and the objects substituted for X and Y were those used in training.

On the questions in Fig. 3, she made the following number of errors per total number of trials: 6 out of 33; 11 out of 43; 2 out of 27; and 11 out of 51. Errors were concentrated in the forms in which the word "different" appeared. She made 25 errors in 94 trials on "different" questions, only 8 errors in 60 trials on "same" questions. Her error distributions were otherwise about equal. She made approximately the same number of errors on the two forms introduced in the transfer test as on the two old forms (new: 13 out of 78; old: 20 out of 76), and about the same number on questions requiring yes-no answers (yes: 17 out of 78; no: 16 out of 70).

The data suggest that Sarah learned the "different" question simply as a correlation between "different" and "no": that is, write "no" whenever "different" is present. This simple rule failed, how-

ever, when the second form of the question was introduced in the transfer test. There, "different" questions required both "yes" and "no" answers, as did "same" questions. This explains why, after making virtually no errors on the "different" question in the original training, she went on to make numerous errors on this same question when the second version was introduced. Interestingly, although Sarah could just as easily have written "yes" whenever "same" appeared, she apparently did not learn the "same" question in this manner. The introduction of the second form of the "same" question did not occasion a large number of errors: she learned these questions at her usual level of proficiency. Still, the data do not necessarily reflect an inherent difficulty in the yes-no question. They may reflect an unsound training program that allowed an inadequate rule to develop.

How general or abstract was Sarah's conception of "missing item"? Was it specific to the same-different construction, or would she be able to use the interrogative marker as a general particle in any known construction? The evidence favored the latter. This is fortunate, since the ability to define elements of language abstractly is necessary to a creative system of language (*8*).

## Metalinguistics

In contrast to same-different, which can be a relation between unnamed objects, "name of" requires that one of the two terms in the relation be a linguistic one: for example, "X name of Y," where X is the name and Y is the object named. This concept, like the interrogative, has special value for teaching further language and should therefore be introduced early in training.

We placed before Sarah the word "apple" and, at a small distance from it, an actual apple. We then required her to place between them the piece of plastic that meant "name of." On the next trial, we presented the word "banana," an actual banana, and "name of." The procedure was exactly like the one we used to teach same-different.

After five trials on each of the two positive instances, Sarah was given five trials on each of the two negative instances. The same materials and the same procedure were used in all trials.

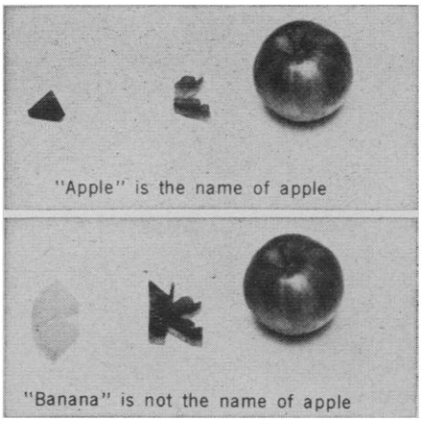



Fig. 4. Examples of the relations "X is the name of Y" and "X is not the name of Y." Note that the name of the negative relation amounts to the negative particle built on to the name for the positive relation (see Fig. 1 for the free form of the negative particle).

We gave her the word "apple" and the object banana on some trials, and the word "banana" and the object apple on other trials. In both cases, we required her to place between the word and the object the piece of plastic meaning "not name of." "Not name of" was formed as a single unit by attaching the negative particle to the name for the positive case (Fig. 4).

Choice trials in which Sarah was given the same materials but was required to choose between "name of" and "not name of" served to establish that she had formed the appropriate associations. In addition, she was tested by being asked questions. For example, she was asked, "? 'banana' name of apple" (Is "banana" the name of the object apple?). The alternatives given her were "yes" and "no." She answered this question correctly, as she did 15 of the 18 comparable questions with the *wh* form (Fig. 2) and other versions of the yes-no form (Fig. 3).

The standard training paradigm, consisting of two positive and two negative instances of the concept, was followed by a transfer test. The transfer test simply replaced the training items with new items and repeated the choice trials and questions. Sarah was asked, for example, "? name of dish" (What is the name of the object dish?). The alternatives given her were "dish," "pail," "apple," and "raisin"—words that had been introduced in the original mapping of the social transaction. She answered correctly about 80 percent of the questions on both the choice and the transfer tests. Her performance indicated that she could apply "name of" to instances other than the ones used in training.

Having introduced "name of," we went on to use it to generate new instances of itself. For example, figs interested Sarah but, like many of the foods she enjoyed, they had not yet been named. We placed before her a fig and a piece of plastic meaning "fig." We then placed the word "name of" between them. Next we placed a second piece of plastic slightly apart from the fig and put the word "not name of" between them. Had Sarah attended to the lesson? In order to answer this question, we resorted to the interrogative, giving her both the *wh* and yes-no forms of the question. She was asked, in effect, "What is the relation between the piece of plastic and the fig?" The alternatives were "name of" and "not name of." We also asked her, in effect, "Is this piece of plastic the name of fig?" In this case, the alternatives were "yes" and "no." Her generally correct answers permitted us to move to the last step, which required her to use the appropriate word in a sentence.

The materials set before Sarah were a fig and a number of words: "fig," the piece of plastic she had been told was not the name of fig, the names of two other fruits, "give," "Sarah," and "Mary." Sarah was given the fig when she produced the sentence, "Mary give fig Sarah," which she did correctly on eight of the first ten trials. She was equally proficient when the same procedure was applied to Cracker Jack, peach, and other items. Notice that the negative trials—in which she is told that X is not the name of Y—serve to rule out the possibility that the name is conferred simply by the physical contiguity between the language element and the object. Both when it is asserted that X is the name of Y and when it is denied, the spatiotemporal relation between the language element and the subject are identical. Yet only in the case of assertion does the subject go on to use the language element as the name of the designated referent.

At a much later stage of training, it was possible to introduce new words in a far less formal way. The trainer simply held up together a piece of plastic and an object and called attention to the pair. Sarah used the piece of plastic as the name of the object with which it was paired no less effectively than names introduced by the formal procedure. This suggests that she recog-

nized the plastic and nonplastic objects as members of classes that took the relation "name of" with respect to one another. This is reasonable, since the plastic was always the name of the other item, never vice versa, and "name of" was the only relation members of the two classes took with respect to each other. The presumptive instructions of the implicit naming procedure could have been made ambiguous if either two pieces of plastic or two objects were held up together. Then it would have been unclear which was to be the name of which, whether they were synonyms, or whether some predicate other than "name of" was intended. We did not give Sarah such tests, since they might have confused her.

### Class Concepts: Color, Shape, Size

"Name of" could not have been introduced until at least some items had been named. Similarly, the class concepts *color*, *shape*, and *size* could not be introduced until names of individual members of each class had first been established. We introduced *color* as the relation between individual colors and the objects that instanced them: for example, "Red color of apple." The names of individual colors were therefore the linguistic prerequisites for the general concept *color*.

Of three possible methods of introducing the names of colors, and of properties in general, I will discuss only the one we found to be highly effective. The procedure is based upon the use of a set of objects having nothing in common except the property to be named. For example, in teaching the names for "red" and "yellow," we used a set of red and a set of yellow objects that, in both cases, were completely dissimilar except for the common property of color. The red set consisted of a ball, toy car, Life Saver, and three comparable items; the yellow set, of a block, crayon, flower, and three comparable items. None of the items in either set was named, although we have no evidence that this is a necessary condition for teaching collective names.

We placed before Sarah one of the red objects; the words "give," "Mary," and "Sarah"; and the piece of plastic that meant "red." Only the latter was unfamiliar to her. Moreover, she had often used the other words to form the sentence, "Mary give Sarah _____." The only word now available to her for completing the sentence was "red." In addition, at this stage of training (only one unfamiliar word) she was always required to use all the words given her. With this convergence of factors, it is not too surprising that she formed the sentence, "Mary give Sarah red," whereupon the red object was handed to her. (It is the outcome that is important here, not the method: if the present method had failed, another one would have been substituted.)

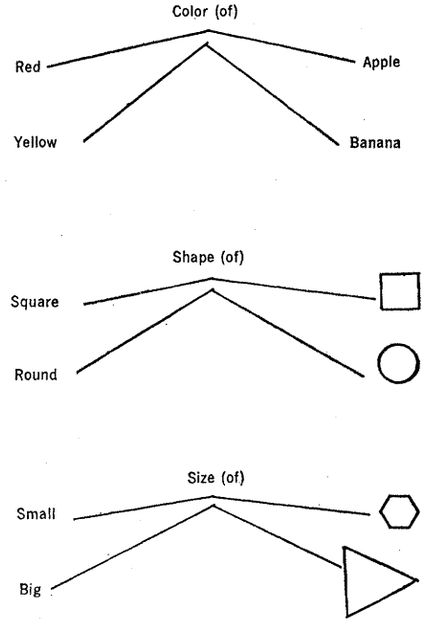



Fig. 5. The cases used to teach the relations "color of," "shape of," and "size of." Words were used in the first case, objects in the other two.

On the next trial, the same conditions obtained, except that Sarah was given a yellow object and the word "yellow." This time she produced, "Mary give Sarah yellow," and was handed the yellow object. Trials of this kind were repeated until the six objects in each set had all been used at least once. She was then advanced to choice trials, where the procedure remained the same except for being required to choose between "red" and "yellow." If a red object were present on a given trial, she was required to produce one sentence; if a yellow object were present, a different sentence. She was correct on eight of the first ten trials and was advanced to the transfer test. In this case, the transfer test included not only new red and yellow objects, but also objects that were indistinguishable except for their color, such as small cards painted red or yellow. She had her customary success on both phases of the transfer test. Exactly the same procedure was used to teach her the words "round" and "square," and later the words "large" and "small" (*9*).

### Property Names Introduce Class Names

Having established "red" and "yellow," "round" and "square," and "large" and "small" (two instances of each of the three main class concepts), we introduced the class concepts *color*, *shape*, and *size*. In each case, the class concept was introduced as the relation between a property and an item instancing that property. As shown in Fig. 5, the items instancing the properties were sometimes actual objects and sometimes names of objects. (The occasional use of objects was forced upon us by limitations in Sarah's vocabulary.) The fact that we could teach Sarah a property by the name of an object no less than by the actual object was, of course, highly encouraging; it was the first unqualified suggestion that the pieces of plastic had the referential function of words.

In teaching class names, we took advantage of the interrogative, which by now was a well-established form for Sarah. "Red ? apple" (What is the relation between red and apple?) was the first question we asked her. We followed this with the same question concerning "yellow" and "banana." On both trials, the only word available to her was "color of." She substituted this word for the interrogative marker, thereby forming the sentences, "Red color of apple" and "Yellow color of banana." The next set of trials comprised questions concerning negative instances of the same concepts. The only word available to her on these trials was "not color of" (see Fig. 4 for an analogy in the case of "name of" and "not name of"). Substituting it for the interrogative particle, Sarah produced "Yellow not color of apple" and "Red not color of banana" (*10*).

The same questions were repeated in step two. Both the words "color of" and "not color of" were available, and she was required to choose between them. She was correct on eight of the first ten trials and was advanced to the transfer tests. There she was required to choose between the same alternatives, but now with items not used in training. For example, she was asked, "red ? cherry," and was required to fill in either "color of" or "not color of." It was not pos-

sible at this stage to test the transfer of the general concept *color* to individual colors other than red and yellow, for these were the only color names she had been taught. In addition, there were few red or yellow objects that had been named at this time; therefore most of the transfer tests were carried out with objects rather than their names. For example, she was asked, "? red color of feather" (Is red the color of the feather?"), where the feather was an actual one, and her alternatives were "yes" and "no." Sentences composed of a mixture of words and objects were written on a work shelf rather than on the magnetic board, since many of the objects that appeared in these sentences would not adhere to the board. We called such strings "hybrid sentences" and used them whenever limitations in vocabulary made them convenient. A language in which words are no less material than the things they map not only makes it easy to form hybrid strings, but also bridges the chasm that some philosophers interpose between words and things.

Because *color* was the first class concept taught Sarah, the only relevant alternatives we could ask her to choose between at first were "color of" and "not color of." In the early stages, therefore, we could only ask her whether, in effect, red was or was not the color of apple. But after the class concepts, *shape* and *size*, were introduced, we could require her to choose among various concepts and their negations. Ultimately we asked her whether, for example, "red" was the color, shape, size, or name of the object apple. Her performance was not impaired by the increased alternatives.

### Productive Use of Class Concepts

The productivity that was illustrated earlier, in the generating of new names with the concept "name of," can also be shown with the class concepts *color*, *shape*, and *size*. Productivity, the ability of a concept to generate new instances of itself, is a characteristic of many concepts that express relation, when at least one term in the relation is represented linguistically. Apparently, a class can be introduced on the basis of as few as two values—for example, "red" and "yellow" as the inductive basis for *color*. Afterwards, the class concept can be used to generate new instances of itself indefinitely. For instance, we introduced the color names "brown" and "green" with the sentences, "Brown color of chocolate" and "Green color of grape," where "brown" and "green" were the only words unknown to Sarah. She was asked, "? color of chocolate," and was given "brown" as the only alternative. She replaced the interrogative marker with the only alternative available to her and formed the sentence, "Brown color of chocolate." She did the same with "green." This points up the fact that in a system such as ours, where the subject uses words but cannot make them, one can be certain that, if the subject will work at all, she will form the appropriate sentence from the first opportunity.

To determine whether Sarah could understand "brown" in a sentence structurally different from the training sentence, we gave her the instruction, "Sarah take brown," and at the same time confronted her with four colored wooden disks, only one of which was brown. We followed this with the more complex, "Sarah insert brown (in) red dish," where a red and a green dish were present with the four wooden disks. In both cases, she operated upon the brown disk in the correct manner, thereby showing that her comprehension of the word was not limited by syntactic context. The same point is made by other tests which show the reverse. After learning to use a property name as a noun ("Mary give Sarah red"), she can then understand the word when it is used as a modifier ["Insert apple (in) red dish"]. Although these are early tests rather than final ones, we have yet to find any evidence that Sarah's understanding of a word is restricted to the syntactic context in which it was originally learned (*11*).

### General Functions: Sentence

The subject may produce properly ordered strings of words, yet not be forming a sentence. A sentence differs from a string of words in that it has an internal organization. The organization can be represented by a tree diagram or the application of parentheses, both of which will show the relations between any one word in the sentence and all the others.

One of the simplest relations requiring syntax is the symmetrical two-term relation that can be found in geometrical prepositions. For example, "red on green and green on red." One form of the relation has no edge over the other, unlike, for example, "fly on horse," which is notably more probable than the reverse. The interchangeability in the first case makes it impossible to distinguish physically between the class of items that can take one position in the relation and the class of items that can take the other position. The position of an item in the relation can be determined only by the order of its corresponding word in the sentence or by inflectional differences.

We used four color words that Sarah knew—"red," "green," "blue," and "yellow"—to train her in the preposition "on." Small cards, painted one of the four colors, but indistinguishable otherwise, were used as the objects. One of the two cards was placed on top of the other, the top card offset a bit so that the bottom one could be seen. We trained her in the comprehension mode, requiring her to respond to the trainer's sentences. We then tested her ability to produce the same sentences herself. The training proceeded in three steps, the first restricting her to one pair of colors, the second dealing with her ability to generalize to the other colors, and the last examining her transfer from comprehension to production.

In the first step of the training, the red card was placed on the table before the subject. The trainer wrote on the board, "Green on red," handed Sarah the green card, and then induced her to place it on the one that was already there. Next, the opposite sentence, "Red on green," was presented, with the green card down and the red card handed to Sarah as the one to be placed on top. Subsequently, she was given both cards and was presented first with one form of the sentence and then with the other. Once she was proficient at producing the card arrangement called for by the sentence, she was given sentences using all four color words. She performed as well on the ten new cases as she had on the two training cases.

The last step concerned Sarah's ability to produce sentences appropriate to the trainer's behavior rather than to behave in ways appropriate to the trainer's sentences. On each trial she was given three words—two color words and "on." She was required to place them on the board in a way that corresponded to, or described, the trainer's placement of the cards. Thus, if the trainer put the blue card on the green one, Sarah, who held the words "green," "blue," and "on," was required to write, "Blue on green." She was correct on eight of the first ten trials (*12*).

### Compound Sentence

Consider the sentence, "Sarah insert banana pail apple dish." In English, the sentence instructs Sarah to put the banana in the pail and the apple in the dish. The procedure used to teach Sarah to respond correctly to this sentence was based on three steps, all in the comprehension mode. First, she was trained on each of the four simple sentences which make up the compound sentence: "Sarah insert banana pail"; "Sarah insert apple pail"; "Sarah insert banana dish'; and "Sarah insert apple dish." The trainer wrote each sentence, one at a time, on the board; at the same time, he offered Sarah a choice of fruit and containers and required her to place the designated fruit in the designated container.

Next, Sarah was given all possible pairs of the sentence, side by side, in the manner of a paragraph. For example:

| | |
|---|---|
| Sarah | Sarah |
| insert | insert |
| banana | apple |
| dish | pail |

Since no change was made in the composition of the individual sentences, this step was intended merely to accustom her to carrying out two acts of insertion, as is required by the compound sentence.

In the final step, all possible pairs of sentences were again combined, this time one immediately above the other. This conjunction of two simple sentences was gradually converted into one compound sentence. The procedure generated sentences of the following kind:

| (i) | (ii) | (iii) |
|---|---|---|
| Sarah | Sarah | Sarah |
| insert | insert | insert |
| banana | banana | banana |
| pail | pail | pail |
| Sarah | insert | apple |
| insert | apple | dish |
| apple | dish | |
| dish | | |

Neither the deletion of the second use of "Sarah" nor the subsequent deletion of the second use of "insert" disrupted her performance. Sarah performed correctly 75 to 80 percent of the time (her customary level during this phase of the project), and continued to do so when the changes were made. Nor was her performance impaired in the transfer tests, which included substitutions for both the verbs and the nouns.

### The Copula: Learned as Nonsense Syllable

The concepts of subset or class member, both of which are among the several meanings of "is" ("Red is a color," "Apple is a fruit"), could probably be taught most efficiently by a method analogous to the one we used to teach the names of properties. Using a set of items that had only one common property, we had required her to request each of them by writing the same sentence: for instance, "Give red." This same approach could be adapted to the present concept by temporarily removing the names of the individual fruits and then requiring her to request the items by a class name. For example, where she had previously written, "Give apple," "Give banana," and so on, remove the individual names and require her to request the same set of items by writing, "Give fruit." This would serve to teach the class word "fruit." Repeating the same procedure with "chocolate," "caramel," and "gumdrop" would serve to teach another class word, "candy." Then "is" could be introduced as follows: "Apple, banana is fruit"; "Chocolate, caramel is candy"; "Apple, banana is not candy"; and "Chocolate, caramel is not fruit." These training sentences provide the standard two positive and two negative instances of the concept. More important, they provide strings in which the only unknown is the new predicate itself; both of the arguments, the names of the class members and the names of the classes, are established words.

In fact, we taught Sarah "is" in quite a different way, one that proved to be inefficient. This is interesting because of the suggestion it contains as to what makes a method inefficient. We gave Sarah the question, "red ? color" (What is the relation between red and color?). The only alternative given her was the word "is," which she used to replace the interrogative marker, thereby forming the sentence, "Red is color." We repeated the procedure with "round ? shape." Sarah formed the sentence, "Round is shape" in the same fashion. After being given the usual five trials on each of the two positive instances, she was given the same number of trials on each of two negative instances. She was asked, "red ? shape" (What is the relation between red and shape?) as well as "round ? color" (What is the relation between round and color?). In both instances, the alternative given her was "is not" ("is" and the negative particle). She displaced the interrogative marker, thereby forming "Round is not color" and "Red is not shape."

At step two, she was asked the same questions, was given both the words "is" and "is not," and was required to choose between them. She made 10 errors on the first 22 trials. All of the errors were caused by her failure to use the negative form, resulting in such answers as "Round is color" and "Red is shape." Following this unprecedented failure at step two, she was returned to step one, given five trials on each of the "is not" cases, and advanced again to step two. This time she made 14 errors, 11 of them on "is not." She was returned to step one, given only two trials on each of the negative cases, and retested on step two trials. On this third and final test she made no errors in 18 trials.

On the transfer test, she was asked all of the previous questions, with the words "yellow" and "triangular" substituted for the training words "red" and "round," and was required to choose between "is" and "is not," as before. For example, she was asked, "yellow ? shape." She answered correctly, replacing the interrogative marker with "is not" and forming the sentence, "Yellow is not shape." She made only 3 errors on 26 trials, none on the first 5 trials. Thus, even though "is" was acquired with many errors, it was successfully transferred to nontraining items.

What exactly did "is" mean to Sarah? Unfortunately, we cannot say, because we did not teach her any other concepts with which to contrast "is." Concepts might be said to come in clusters. Only by teaching at least two members of a cluster is it possible to say what either one means. This is not a new point, but a methodological stricture that we adhered to in nearly all previous cases: (i) from the beginning, no class was given only one member—in mapping the original social transaction, "apple" was contrasted with "banana," "orange," and so forth; (ii) we taught not one property class, but "color," "shape," and "size," and for the same purpose; (iii) the logical connectives are an unfinished cluster—the meaning of if-then will remain in doubt until she passes tests on "and" and "or" (*13*). These cases differ somewhat from "is," however, in that what constitutes contrasting alternatives is intuitively clear. It is less clear what con-

stitutes the semantic neighbors of "is." If, when asked the relation between apple and fruit, Sarah wrote, "apple is fruit" rather than, say, "Apple color of fruit," we would not regard this correct reply as especially informative. That is to say, "is" and "color of" do not belong to the same cluster.

Moreover, the subject's successful performance on a transfer test cannot substitute for its ability to discriminate between neighboring concepts. Sarah passed the transfer test on "is" by writing, for example, "Yellow is not shape," and "Yellow is color," where "yellow" was a nontraining item. This established that, on her own, she assigned to "yellow" and "color" the same relation that she was taught to assign to "red" and "color." But, unfortunately, it does not tell us what that relation was. That information can come only from the subject's ability to discriminate a word from close alternatives.

### Pluralization

Pluralization, in keeping with the rest of the system, was introduced in the form of a separate particle rather than as an inflectional change. Since we found it mechanically awkward to pluralize both noun and verb, we arbitrarily restricted pluralization to the verb. For example, we wrote, "Red, green is pl color," but not "Red, green is pl color pl," where "pl" after a word is the plural marker. Since this prohibits our studying noun-verb agreement, the restriction is temporary. Ultimately we will pluralize both grammatical classes, though not necessarily with the same particle.

The first sentence given Sarah in her training with the plural was "red, yellow is ? color," which largely defies translation into English. The only alternative given her was the plural marker "pl," with which she displaced the interrogative marker to form the sentence, "Red, yellow is pl color" (Red and yellow are colors). Next she was given the comparable sentence with respect to shapes: namely, "round, square is ? shape," which is no more translatable than its counterpart in colors. Again she displaced the interrogative marker with the only alternative given her, thereby forming the sentence, "Round, square is pl shape," in effect, round and square are shapes.

The two negative instances given her were "red, yellow is not ? shape" and "round, square is not ? color." She displaced the interrogative marker with the only alternative given her, making the sentences, "Red, yellow is not pl shape" and "Round, square is not pl color" (Red and yellow are not shapes; Round and square are not colors). The training departed from the standard procedure in that she was given the same alternative, "pl," on both positive and negative trials. This was done because the negative particle is appended to the verb rather than to the plural marker: that is, "is + pl" equals "are," and "is not + pl" equals "are not." We rejected, as making little sense, the alternative of appending the negative marker to "pl"; that is, "pl not."

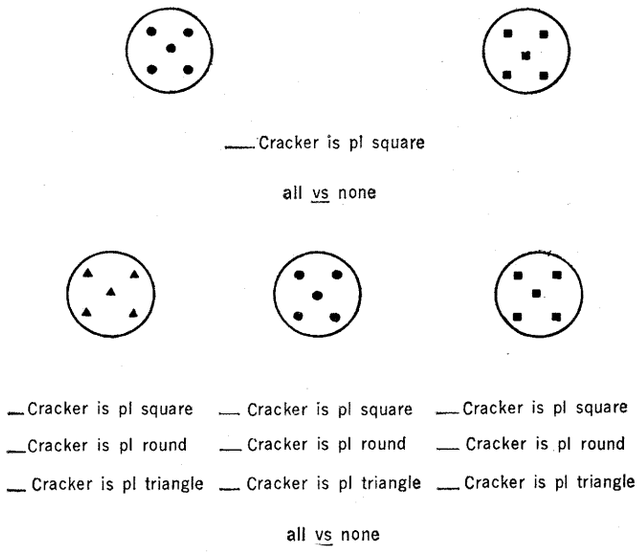
The trials at step two were modified to accommodate the fact that the negative particle was not appended to the new word, as it usually was. We put two interrogative markers in the sentence, indicating a need for two words, and offered three alternatives rather than the usual two. For example, Sarah was asked, "red, yellow ? ? color," and was given the alternatives "is," "is not," and "pl." She displaced the two interrogative markers with the particles "is" and "pl" in the proper order—"Red, yellow is pl color." She was equally successful in displacing the two interrogative markers in the sentence, "round, square ? ? color" with "is not" and "pl," forming the sentence, "Round, square is not pl color." The use of two interrogative markers may have been an unnecessary crutch. After only five trials, we reverted to the use of a single interrogative marker for both words, and she made no errors in 15 such trials. We viewed her successful replacement of one interrogative marker with the appropriate two words as a step toward the eventual achievement of answering questions not with a word, but with a complete sentence (*14*).

The many errors Sarah made in learning the copula are in contrast to the relatively few errors she made in learning most other concepts. Pluralization and the question, for example, map well-defined states of affairs, which is, I think, the main reason they were learned easily. The interrogative marker visually represents the missing item or items in well-learned constructions. Referents are equally clear in the case of the plural marker. In analytic sentences such as "Red, yellow is pl color," "pl" is called for when there are two or more items in the subject (*15*). In synthetic sentences such as "Apple, orange is pl big," "pl" has a double cue—the linguistic one noted above and a nonlinguistic one. The nonlinguistic cue is the state of affairs mapped by the sentence, in this case a large apple and a large orange.

In teaching a two-term predicate such as "is," where the predicate is itself the unknown, both arguments of the predicate must be properly instanced. They were, it would seem, when she was taught the property classes. In teaching "color of" as the relation between "red" and "apple," both "red," as a kind of property, and "apple," as an object instancing that property, had been established by prior training. But in teaching "is" as the relation between "red" and "color," "color" was not properly instanced. Strictly speaking, we had no word for "color," only a word for "color of," having neglected earlier to teach her a genitive particle. Rather than take the time to map the concept "of," such that *color* could then have been taught as a class, I tried to substitute the available "color of." The many errors she made and the drill that was necessary to instill the word "is" suggest that this was a mistake. The pattern of her learning in this case is reminiscent of paired-associate learning, where the subject is required to learn an *arbitrary* association between words or nonsense syllables. If the training method is proper, the predicate will not occur as an arbitrary associate of two words. Instead, it will be the name of a conceptual relation that is instanced by these words. (The new word will be arbitrary in either case, but there will be a relation that is named in one case and not in the other.) I think we may expect different learning patterns in the two cases, drill and numerous errors being far more likely in the one than the other.

### Object Classes

The three object classes we taught Sarah were "fruit," "breadstuff," and "candy," in that order. We started her with the question, "banana is ?" and gave her only one alternative, the word "fruit." She displaced the interrogative marker to form the sentence,



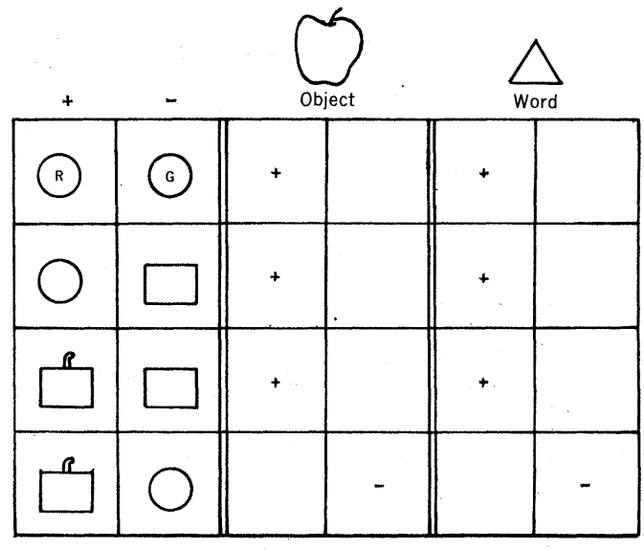




Fig. 6 (left). Exercises used to teach all-none, with the original, unsuccessful version above, and the modified, successful version below. Fig. 7 (right). Features analyses of the object, apple, and the word, "apple."

"Banana is fruit." Next we gave her the same question with respect to cracker and breadstuff, a class invented for the occasion. The usual five trials on each of the two positive instances were followed by an equal number of trials on two negative instances. She was given the question, "banana is not ?" and the word "breadstuff," with which she displaced the interrogative marker. By a corresponding procedure, she was also led to produce the sentence, "Cracker is not fruit."

On trials at step two she was given the same questions, but was required to choose between the words "fruit" and "breadstuff." She made 1 error in 15 trials, none on the first 5 trials. On the transfer tests, the same questions were repeated in the presence of the same alternatives, but with the words "bread," "cookie," "grape," and "peach" substituted for the training words "banana" and "cracker." She made 7 errors in 46 trials, 1 on the first 5 trials.

But what meaning would failure have had in this case? Having been taught that banana is a fruit, suppose Sarah chose not to call peach or grape a fruit. In what sense could she be considered to be in error? In the present exercises, she was not asked yes-no questions, which would have required her to decide whether or not peach, for example, was a fruit. Instead, she was merely asked *wh* questions, which required her to decide only whether a peach was more like a fruit or a breadstuff. Nevertheless, errors are difficult to interpret in the case of object classes. An item cannot partly be and partly not be a color, or a shape, or a size. Yet every object class is subject to this ambiguity. A stone that barks or a dog that never moves—are they animate or inanimate? That is to say, intermediate items can always be proposed in the case of object classes (for example, banana bread in the case of fruit and breadstuff). Notice, however, that there are no intermediate items for colors and shapes, shapes and sizes, sizes and colors. One may waver in deciding whether to call black and white colors, but whatever one decides on that point, he will have no tendency to classify either as a shape or a size.

Because object classes are the victims of intermediate cases, whereas property classes are not, we assigned a higher priority to property classes, used them to map class membership, and then tried to use the mapping to set up object classes. Though logically defensible perhaps, it was tutorially inefficient, and the procedure described at the outset of this section seems clearly preferable.

## Quantifiers: All, None, One, Several

"All" and "none" were the first quantifiers taught Sarah, followed by "one" and "several." Two sets of five crackers each were used in the training. All the crackers in one set were round; in the other, square. The square set was placed before Sarah and she was given the question, "? crackers is pl square" (What or how many crackers are square?). The only word given her was "all," so she used it to displace the interrogative marker. The resulting sentence was "All crackers is pl square" (All crackers are square). We repeated the procedure with the set of round crackers and the word "none." She displaced the interrogative marker and formed the sentence, "None crackers is pl square."

In the case of all-none, we arbitrarily elected to pluralize both forms: "All is pl round" and "None is pl round." The same questions were repeated, with Sarah choosing between "all" and "none." She quit after only eight trials, which was not uncommon; but she made three errors in the eight trials, which was uncommon. She was given 20 more choice trials of the same kind on the next lesson. She made 12 errors, 6 on "none" and 6 on "all."

The lessons were modified by adding a third set of crackers (all triangular) and two further questions. The original and modified lessons are diagramed in Fig. 6. The top portion of the figure shows the original form of the lesson, and the bottom portion, the revised form. A sense of the task confronting Sarah can be gained by covering up all the material in each lesson except for one question and one set of crackers. Notice that in the first lesson only one question was asked—it was simply asked in the presence of two different sets of crackers. In the revised lesson, however, three different questions were asked, each one in the presence of three different sets of crackers. Her

alternatives on both lessons were the same: namely, "all" and "none." On the revised lesson she made 4 errors in 15 trials; the errors were divided almost evenly among the possibilities. Sarah's 74 percent correct is still below criterion, but it is an improvement over the preceding lessons.

The original lesson in all-none was atypical in that it provided Sarah with less information than the standard lesson does. Sarah is given two pieces of positive and two pieces of negative information in the standard lesson. However, in the first version of the present lesson, Sarah was given only half the usual information. Only one sentence was associated with each set: "All crackers are square" with the square set; and "None of the crackers is square" with the round set. Usually, "All crackers are round" would have been associated with the round set, and "None of the crackers is round" with the square set. The revised lesson, in which three sentences were associated with each set, provided the missing information. Two sets of crackers would have been sufficient to convey the standard amount of information, but we added a third set for emphasis. In doing so, we may actually have provided too much information.

What is the optimal amount of information for teaching the various concepts? We have relied heavily on two positive and two negative instances of each concept, and the present failure suggests that they may actually be necessary. But it will be some time before we really know. Systematic changes in training procedures, of a kind needed to answer such questions, have been deferred. At this stage, we have concentrated on teaching as many exemplars of language as possible and have not changed training programs unless forced to do so by failure.

A number of set arrangements are possible in teaching the distinction between "one" and "several." In the approach we used, there was no overlap between the sets. Six sets were used to teach "one," and six different sets to teach "several." All sets consisted of five crackers of two different shapes. The sets used to teach "one" contained one cracker of a different shape from the other four. The sets used to teach "several" contained two or three crackers of one shape, and the remainder (up to five) of a different shape. "Several" could thus mean either two or three crackers of the same shape. This condition was fulfilled for each shape by four sets. For instance, "Several crackers are round" could be applied to the following four sets: two round and three square, two round and three triangular, three round and two square, three round and two triangular.

Each of the 12 training sets was placed before her and she was asked a question appropriate to it. For example, in the presence of the set containing only one square cracker, she was asked the question, "? cracker is square" (What or how many crackers are square?). The only alternative given her was "one," with which she replaced the interrogative marker to form the sentence, "One cracker is square." On other occasions, a set containing two round and three square crackers was placed before her and she was asked the question, "? cracker is pl square" (What or how many crackers are square?). Since the only alternative given her was "several," she made the sentence, "Several cracker is pl square."

On trials at step two, she was presented with the same sets and questions as on step one, but she was now given both "one" and "several" and was required to choose between them. She made only one error on the first ten trials. The one-several distinction may be simpler than the all-none distinction, not merely because it was taught later, but also because "one" and "several" correspond with the absence and presence, respectively, of the plural marker. Thus, we say, "One is round" but "Several is pl round."

Because her terminal performance on all-none was substandard (74 percent correct), she was given a review on this distinction. We used ten questions from the revised lesson, with the same three sets shown in Fig. 4; she was correct on eight of the ten trials. Then the sets from the all-none and one-several exercises were combined for the first time. She was asked the same questions as before, but was required to choose among all four alternatives—"all," "none," "one," and "several." She was correct on eight of the first ten trials.

The transfer test presented a special problem. The sets used to instance the quantifiers differed from one another solely in terms of shapes. This is a narrower inductive base than we had used with previous words. Moreover, all the *shape* words Sarah knew had been used in training. Thus, we had either to teach her new *shape* words or to conduct the transfer test with a class concept other than the one used in training. Could she transfer the quantifiers not only to nontraining items, but also to items that differed in properties other than shape?

The class concepts used in the transfer test were *color* and, to a lesser extent, *size*. Sets differing in color were prepared by dyeing pieces of apple red or green, and by leaving the yellow or green peel on slices of ripe or unripe banana. Sets based on size were composed of pieces of bread of two different sizes. Of the 18 sets used in the training of the four quantifiers, 10 were duplicated with either color or size values substituted for the original shape values. For example, color sets consisted of: five red pieces of apple, one red and four green pieces, two red and three green pieces; five yellow pieces of banana, one yellow and four green pieces, and so on. Seven of the sets were based on color and three on size. She was asked the same questions as before, though now they were framed in terms of color and size rather than shape; and she was given all four quantifiers to choose from. For example, in the presence of a set consisting of three green and two pieces of red apple, she was asked, "? apple is pl green" (What or how many apples are green?). She answered correctly by replacing the interrogative marker with "several," thereby forming the sentence, "Several apple is pl green." She was correct on nine of the first ten trials. If she had failed this test, we might then have sought to devise training procedures conducive to cross-dimensional transfer. But she succeeded, and that on the basis of a training program that would seem to make a minimal contribution to cross-dimensional transfer. The success must be attributed to Sarah, not to the training program. Indeed, if an organism were deficient in matters of transfer, it is by no means clear what one would do to overcome the deficiency, though it would be of great interest to try.

A last test concerned Sarah's ability to use the quantifiers in sentences of a grammatical structure different from those used in training. The training sentences had all been descriptive or declarative: All (one, none, several) cracker (apple, banana) is (pl) round (square, red, big, and so on). In the test, the quantifiers occurred in im-

perative sentences. A dish and a large number of both crackers and candies were arrayed before her. She was told, "Sarah insert all the crackers in the dish," and she was allowed to keep whatever she put into the dish. The routine was familiar to her, as was the use of the imperative sentence; the only new element was the application of quantifiers to imperative sentences.

She responded correctly to the first five instructions: (i) "Sarah insert one cracker dish," (ii) "Sarah insert some cracker dish," (iii) "Sarah insert one candy dish," (iv) "Sarah insert all candy dish," and (v) "Sarah insert several candy dish." On the next two instructions, when told to insert "none" cracker and "several" cracker, she obeyed insofar as the crackers were concerned, but supplemented the instructions a little with candy, inserting one piece in the first case and all in the second. The trainer decided to allow the performances to pass on the grounds that (i) the action on the candy was not specifically interdicted and (ii) the explicit instructions dealing with crackers were, in fact, carried out. The trainer gave one more instruction, "Sarah insert one candy dish." At this point Sarah took all the candy, and the lesson was terminated. The first five instructions, and even the next two to some extent, point to the same conclusion: Sarah's grasp of the quantifiers was not limited by a syntactic factor; she understood them in sentences of a grammatical form different from those used in training.

### Logical Connective: If-then

With concepts such as same-different, it is possible to perform a few simple tests, before any language training is started, to determine whether or not the subject is capable of making the perceptual judgments upon which the concept depends. Thus we either (i) find knowledge to be present, (ii) attempt to devise a means of instilling it if it is not, or (iii) give up the idea of mapping it with words. Unfortunately, this procedure is based on the assumption that one can both state and assess the perceptual judgment underlying the linguistic distinction. Consider if-then, the conditional relation, as exemplified by the simple instruction, "If Mary take red then Sarah take green." What tests will reveal beforehand whether or not it is sensible to attempt to teach Sarah to map the relation with words?

Failing to answer that question, we applied a contingency training procedure to Sarah. We exposed her to differential reinforcement, a standard procedure for training animals, in which the subject is rewarded for doing one thing but not for doing another. If a subject cannot be influenced by such experience, it seems unlikely that it could be taught to recognize if-then relations. On the other hand, the fact that a subject's behavior can be influenced by such procedures is no guarantee that the subject can recognize relations of this kind and learn to label them as such (*16*). We began by allowing Sarah to choose freely between a piece of apple and a piece of banana, simply to confirm that she still had no particular preference. Next, she was given a piece of chocolate when she chose apple, but not when she chose banana. She soon ceased to choose banana, since it was not followed by chocolate, which she preferred to both fruits.

The particular contingency used with Sarah was carefully chosen—all of the words used to describe it were familiar to her, except those concerning the conditional relation itself. For example, the following sentences would accurately describe the contingency training she received: (i) "If Sarah take apple then Mary give Sarah chocolate" and (ii) "If Sarah take banana then Mary no give Sarah chocolate." Notice that "if" and "then" are the only unfamiliar words. In addition, the sentences that are combined to form the conditional sentences are familiar. Thus we have progressed from same-different, where the known terms were nonlinguistic items (actual cups and spoons); through "name of," where one of the known terms was a word; to the present point, where the known terms are sentences. Sentences (i) and (ii) above are, thus, strict training procedures in that they require the introduction of only one new term.

In English, the conditional relation is marked by discontinuous constituents (if-then). This poses an interesting problem, but not one that we need grapple with at this time. Therefore, we marked the conditional with a single particle, as in symbolic logic: "Sarah take apple ⊃ Mary give Sarah chocolate." We began the language training by giving Sarah the question, "Sarah take apple ? Mary give Sarah chocolate" (What is the relation between Sarah's taking apple and Mary's giving chocolate?). She used her one alternative, the conditional particle, to displace the interrogative marker and form the sentence, "Sarah take apple ⊃ Mary give Sarah chocolate." She was then given a piece of apple, followed by a piece of chocolate, both of which she ate. Next she was given the question, "Sarah take banana ? Mary no give Sarah chocolate" (What is the relation between Sarah's taking banana and Mary's not giving chocolate?). Again her only alternative was the conditional particle, which she used to form the sentence, "Sarah take banana ⊃ Mary no give Sarah chocolate." This time she was given a piece of banana (which she sometimes ate), but it was not followed by a piece of chocolate. We gave Sarah five trials on each of the two questions. Then we moved to a series of trials in which we gave her one of two pairs of sentences: (i) "Sarah take apple ⊃ Mary give Sarah chocolate" and "Sarah take banana ⊃ Mary no give Sarah chocolate;" or (ii) "Sarah take apple ⊃ Mary no give Sarah chocolate" and "Sarah take banana ⊃ Mary give Sarah chocolate."

The first pair states that the choice of apple, but not the choice of banana, will lead to chocolate; in the second pair, the statement is reversed. Pieces of both banana and apple were set before her on each trial, and she was considered to have responded correctly whenever her choice of fruit led to her being given chocolate. She made over 20 errors, accompanied by emotional outbursts, based on the persistent choice of apple. She then abandoned this approach, only to alternate between the two fruits for about 14 trials. Finally, she took into account the sentences and consistently chose the fruit that led to the chocolate.

Although it took Sarah longer to learn the conditional relation than most of the other concepts, once she had learned it she gave her customary performance on the transfer tests. Extensive changes were made in both the antecedents and the consequents. She was given such pairs of sentences as "Mary take red ⊃ Sarah take apple" and "Mary take green ⊃ Sarah take banana," which required her to observe what object Mary chose, match Mary's action with the antecedent in the appropriate sentence, and then carry out the appropriate consequent.

Sentences such as "Red is on green ⊃ Sarah take apple" and "Green is on red ⊃ Sarah take banana" involved a change of verb in the antecedent. She responded at the same level, approximately 80 percent correct, on both the transfer tests and the final training tests.

Perhaps the complexity of the conditional relation was responsible for her difficulty in understanding the relation. Indeed, how shall we assess the complexity of a concept except through the subject's performance in learning it? But this assumes that the training for all cases is equally effective, which is doubtful. In the prelanguage phase, we had taught her that the choice of apple was always correct. This was a serious error, for it probably gave her little incentive to pay attention to the instructions, except to consistently choose apple. Training in the prelanguage phase should have included at least two correct alternatives. She would not then have entered the language training phase with a fixed response disposition, but would have had to pay attention to the instructions in order to learn which of the two positive items was correct on a given trial (*17*).

### Conjunction: And

It proved possible to obtain an idea of her capacity for understanding the concept of conjunction in advance of introducing a particle for "and." Instead of trying to teach Sarah conjunction-like behavior in a prelanguage phase, we set the stage in such a way as to invite her to engage in such behavior on her own. She essentially took the invitation.

Rather than giving her, in the presence of a single kind of fruit, a set of words from which she could compose, for example, the sentence, "Mary give Sarah apple," we gave her essentially the same set of words, but in the presence of two, and later three, different kinds of fruit. At first, she requested each piece of fruit with a separate sentence. After about eight such invitations, she wrote, "Mary give Sarah apple banana"; still later, "Mary give Sarah apple banana orange," naming all three of the fruits before her. This is already conjunction, it can be argued, even though there is not a particle for "and." Her adding one word to another eliminated the redundant elements that would have been present if the same request had been made with separate sentences. The actual introduction of "and" consisted simply of making the particle available to her and requiring her to use it (*13*).

### Symbolization: When Is a Piece of Plastic a Word?

When does a piece of plastic cease to be a piece of plastic and become a word? We might answer, When it is used as a word: that is, when it occurs along with other words of appropriate grammatical class in sentences and when it occurs as the answer or part of the answer to questions. For example, we consider a small piece of blue plastic to be the word for apple because (i) it is used when, for example, the subject requests apple and (ii) it is used by the subject to answer, "What is the name of apple?" We might add that the piece of plastic is a word when the properties ascribed to it by the subject are not those of the plastic itself, but those of the object it designates.

We can determine whether this condition obtains by using the matching-to-sample procedures again—this time to obtain independent analyses of the features of both the word and its referent. An analysis of the features of the apple was made by giving Sarah a series of trials. On each trial she was given the apple and a pair of alternatives and was required to indicate which of the alternatives she considered to be more like the apple. The alternatives were red versus green; round versus square; square with stemlike protuberance versus plain square; and plain round versus square with protuberances (see Fig. 7). The alternatives could be words or objects instancing the properties named by the words. That is, the subject could be required to decide whether the apple was more like the words "red" versus "green" or more like a red patch versus a green patch. Our use of the latter approach was dictated by Sarah's limited vocabulary.

After obtaining a features analysis of the apple, we repeated the test exactly with the word "apple" (a piece of blue plastic). The subject assigned the same properties to the plastic that she had earlier assigned to the apple (Fig. 7). The properties she assigned to the word "apple" show that her analysis of the word was based not on the physical form of the blue piece of plastic, but on the object that the plastic represents.

Strictly speaking, we do not know the necessary and sufficient conditions for this effect, or even the specific point in training when the effect first becomes demonstrable. There are several intermediate possibilities, but consider the two major alternatives: (i) in the course of acquiring language, the organism learns how to symbolize; (ii) symbolization is an integral property of perhaps all learning and makes language possible. What form would symbolization take in lower organisms if the latter were true? A pigeon exposed to the fact that a vertical line preceded food A, and a horizontal line food B, would ascribe to the vertical line whatever features it ascribed to food A, and to the horizontal line whatever features it ascribed to food B. A nonlaboratory example may make the point still clearer. A dog noses a leash in a hallway. Is a walk into the house or out of it? into the fields or into town? with birds or without? squirrel scent or not? and so forth. When asked these questions of the walk, in one case, and of the leash, in the other, the dog's answers should be the same. We do not know if this is so, but can find out simply by adapting the procedures we used with the chimpanzee to the other species.

Assumption (ii) above seems the more reasonable, since it does not require the further assumption that it is possible to teach an organism that does not symbolize in the first place to symbolize. Of course it may be possible, but I do not see how, any more than I can see how to teach an organism that does not transfer to do so. Symbolization and transfer both lie at the heart of language learning. I suspect they have in common the fact that neither is instilled by the present training procedures, but is a capacity of the organism that is utilized by the training.

### Clever Gretel?

Was Sarah responding to the plastic language or to nonlinguistic cues arising from the trainer's face or body? In principle, this could be tested by eliminating the nonlinguistic cues. Trainers could wear dark glasses, or, after presenting Sarah with a question, station themselves behind an opaque

screen, or simply look away from her. But these measures were practically useless. When the trainer put several questions on Sarah's board and then walked away, leaving her to answer them, Sarah worked erratically or quit altogether, in somewhat the way a conversation falters when one person ceases to pay attention to the other. Social contact may be Sarah's primary motivation. In any case, she did not work under these circumstances.

It was necessary to approach the problem of nonlinguistic cues from the opposite direction. Rather than use a trainer who was competent in the language but who divested himself of normal social behavior, we used a trainer who engaged in normal social behavior but who was not competent in the language. Sarah was adapted to a new trainer who had not been taught the language. Then this "dumb" trainer gave her a series of simple tests involving familiar materials. (Familiar materials were used since the question was whether or not she could respond to old words when the cues were solely linguistic.)

On the production side, she was required to request the object that was present on a trial by writing the simple sentence, "Give Sarah X," where X was either a nut, candy, or one of three fruits. She was given a set of eight words to choose from on these trials: for example, "smoke, eat, give, green, Sarah, Debbie, candy, banana." Also on the production side, she was asked a series of *wh* questions such as "red ? apple." Her alternatives were "color of, size, shape, name, if-then." The only irrelevant word was if-then; all the other words were correct at some time in some sentence.

On the comprehension side, she was given the instruction, "Sarah take blue" (or "yellow" or "green") in the presence of one of the three colored cards. She was also given simple conditional instructions such as "Jon insert yellow ⊃ Sarah take cracker." (Jon, the "dumb" trainer, was identified simply by hanging his name around his neck, which is how all personal names, including Sarah's, were taught in the beginning.) Additional tests, all roughly of this order of complexity, were included in the battery.

The tests were conducted by coding the words with numbers and using a two-way communication system between the "dumb" trainer inside the test area, and a second trainer outside. On a representative production trial, the "dumb" trainer consulted his code sheet (which consisted of a parallel list of numbers and colored pictures of the words), gave Sarah the words called for, and then placed before her the piece of fruit indicated on the trial. After she had arranged her choice of words in a column on the board, he translated her sentence into a sequence of numbers that he read over the microphone to the trainer outside. Depending on whether or not the spoken sequence agreed with the one on the outside trainer's list, the inside trainer heard "yes" or "no" through his headphones, and then either did or did not give Sarah the piece of fruit, along with a bit of praise.

On the first and second production tests described above, Sarah made 6 errors on the first 20 trials and 3 errors on the first 10 trials, respectively. Although this was below her usual performance level, especially for such simple materials, it was well above chance. (She performed at the 70 percent level on both exercises; chance would be approximately 13 percent and 20 percent, respectively, if order were not considered, and still less if it were.) On the first and second comprehension tests described above, she made 4 errors on the first 15 trials and 3 errors on the first 10 trials, respectively. Again, the performance level was above chance, but below her usual level (*18*).

More surprising than the decrement in her accuracy was a deterioration in the form of her behavior. The most striking aspect of this deterioration was a regression to an earlier form of sentence production that was once her dominant form. Early in training she had not produced sentences in their final order: she put correct words on the board in incorrect orders and then made one or two changes before settling on a final order. Although she had abandoned this mode of sentence production at least 10 months earlier, she reverted to it with the "dumb" trainer. In addition, the verticality of her sentences suffered. Ordinarily, words were placed more or less below one another, but with the "dumb" trainer she failed to maintain this orderliness. The sprawling sentence was another characteristic of her early behavior.

Changes of this kind are often ascribed to emotional factors. This is a possibility, even though she was adapted to the new trainer, for the conditions of adaptation differed from those of testing. In addition, she was cut off from her usual trainers. Whatever the proper interpretation of these morphological changes, they accompanied a performance level which, though poorer than usual, was nonetheless substantially above chance. Sarah "talked" to a trainer who did not know the language. She was less accurate in "talking" with him than with trainers who knew the language, but accurate enough to infirm the hypothesis that her performance was based mainly on nonlinguistic cues.

## Training Procedure

The basic operation in the training procedure was one-to-one substitution. Each new word or particle was introduced at a marked location as the only unknown in a string of known elements. At one extreme, the known elements were actual objects, as when same-different was taught; and at the other extreme, sentences, as when if-then was taught. All the strings produced by the act of completion naturally were admissible strings in the language.

One-to-one substitution may be the simplest of all training procedures. When the subject's task is that of completing an admissible string, one-to-one substitution eliminates all of the following possible sources of difficulty: (i) which words to use and how many, (ii) where to put the words in the string, and (iii) which operations to use—simply addition, or rearrangement and deletion as well. The other operations—rearrangement, many-to-one substitution, deletion, and so forth—will occur in the broader use of the language. They may either be taught as such or, as was more nearly the case with Sarah, observed to occur spontaneously (*19*), but they do not seem appropriate to the initial training. There we want the fewest possible operations that are compatible with learning. What constitutes optimal training procedures? Strictly speaking, we do not know, but must find out. Without this information, failure can only be ambiguous. It could indicate an incapacity of the species, or merely that the training was improper. Only when we know what constitutes proper training can we be certain who failed—teacher or "pupil."

## References and Notes


1. Because man is the only creature with natural language, we tend to assign a definitional weight to every aspect of human language. Yet it is equally reasonable to suppose that only certain features are critical, while others are secondary and should not be given definitional weight. The distinction I would like to draw is between language as a general system and the particular form this system takes in its use by man. See R. A. Gardner and B. T. Gardner for another attempt to teach language to chimpanzee [*Science* **165**, 664 (1969)].
2. A literal translation of the sentences in Fig. 1 would be "No Sarah honey-cracker take" and "Sarah jam-bread take." In the beginning, Sarah was taught with the verb in the terminal position, as shown in Fig. 1, but this rule was violated so often by her English-speaking trainers that we had to accept the normal English verb position: for example, "Sarah take jam cracker." The two forms are now generally used interchangeably. However, with the one trainer who has insisted on the terminal verb position, Sarah uses the terminal position; with all other trainers she uses both forms.
3. Notice that in this system, unlike the human one, production need not lag behind comprehension. The subject does not make, but merely uses, the words; and it can do so from the beginning, without having to undergo elaborate motor learning. Thus, the earliest training can occur in the production mode as well as in the comprehension mode. This can be an advantage in training young subjects, since the control of their attention is more certain when they are required to respond rather than merely to observe.
4. Elsewhere we have described an early phonemic system that may be suitable for the chimp [D. Premack and A. Schwartz, in *Genesis of Language*, F. Smith and G. A. Miller, Eds. (M.I.T. Press, Cambridge, Mass., 1966), pp. 295–335] and an intermediate system of words with an implicit phonemic structure that can be made explicit whenever the experimenter wishes (*5*).
5. D. Premack, in *Behavior of Non-human Primates*, A. Schrier and F. Stollnitz, Eds. (Academic Press, New York, in press), vol. 4.
6. L. S. Vygotsky, *Thought and Language*, E. Hanfmann and G. Vakar, Ed. and trans. (M.I.T. Press, Cambridge, Mass., and Wiley, New York, 1962).
7. When the negative particle is introduced in an injunctive fashion, as in the present case, perhaps it should be used to negate a concept before it is used in the yes-no question. Sarah was taught to combine "no" and "same" (when the word "different" was not available to her) as, for example, "A no same B." But this training in a declarative rather than an imperative use of the negative particle followed the yes-no question.
8. N. Chomsky, *Aspects of the Theory of Syntax* (M.I.T. Press, Cambridge, Mass., 1966).
9. Of two procedures that might be used to teach property names, one has failed and the other has not yet been tried. We first tried to teach "red" and "yellow" by dyeing two like pieces of apple red and yellow, respectively, and then requiring Sarah to write, "Give red" or "Give yellow." We also tried to teach her "round" and "square" by offering her two cookies that were identical except for shape and requiring her to write, "Give round" or "Give square." (The two cases differ in that apple was then a named object, whereas cookie was not.) Both failed for reasons that we can only speculate about (*5*). Notice that this method differs from the one described in the text only in the use of two objects that are identical except for the properties to be named, rather than sets of objects that are entirely dissimilar except for the property to be named. The method we have yet to try is simply to introduce the property name as a modifier of an already named object: for example, "Give red apple."
10. The negative of a concept was formed by appending the negative particle to the name of the concept. This was so until relatively late in the project, when we discarded the composite form. But even during early stages of the project, the composite form was only a training device. Once Sarah had passed the transfer test, the negative particle was detached from the name and she was required to negate the concept herself. For example, when she was asked during training, "red ? banana," she was given the single particle "not color of." But when she was asked the same question after having passed the transfer test, she was given the separate particles "not" and "color of" and was required to choose between them or to use both. If she used both, then she had to use them in the proper order. In brief, the appended negative was a training device, discarded during early stages once the transfer test had been passed, and eliminated altogether in later stages of the project.
11. A control is lacking in the present test. It is not sufficient that only one of the four disks be brown: at least some of the other disks must have additional properties that are equally characteristic of chocolate. Suppose that in Sarah's experience chocolate was not only always brown, but always triangular. In this case, one of the disks should be triangular. When given the instruction, "Take brown," her taking the brown rather than the triangular disk would show that she was responding specifically to the color brown. This is but one of several controls which hindsight has recognized the need for, but which the now uncooperative, sexually mature subject has made it difficult to apply.
12. The order of the elements in the sentence and the order of the things referred to by the sentence are the same in the case of "on" —a consequence of the vertical sentence. However, Sarah has since been taught "in front of" by the same procedure used to teach "on," showing that her use of word order does not depend on an isomorphism of this kind.
13. Although we have taught Sarah both "and" and "if-then" and are training her in "or" (A or B, but not both), we have not yet been able to complete tests that would specifically require her to contrast these particles. Until we do, we cannot know what the connectives really mean to her. The tests themselves are not difficult to arrange, but inducing her to take them is another matter. Performing correctly on the following set of instructions would indicate an ability to distinguish one connective from another. "Sarah take: A and B, B and A, A or B, B or A, if A then B, if B then A." Notice that, for the test to discriminate between the conjunction and the conditional, Sarah must not impose an order rule of her own. She must respond in the same way to "A and B" as she does to "B and A."
14. At this stage, Sarah did not ask questions, she only answered them. Moreover, her answers did not consist of sentences composed from scratch. Rather, she inserted into the trainer's questions words which, when appropriate, transformed an interrogative sentence into either a declarative or an imperative one. The trainer's questions were kept on the board before Sarah, not to avoid possible memory problems, but to allow her to answer in this extremely simple form. However, in introducing the question in this way, we neither limit answers to one word, nor rule out answers consisting of sentences composed from scratch. In principle, we can attain sentences composed from scratch in three steps: (i) Teach the subject not to answer the trainer's question, but to copy it and then to insert her answer into the copy; (ii) Take interrogative markers away from the subject so that her copy will be blank where the trainer's question has an interrogative marker, and require her to insert her answer into the blank; and (iii) Erase the trainer's question before allowing the subject to answer.
15. The assumption that Sarah pluralizes when there are two or more items in the subject suggests an important test we have yet to make. This assumption leads us to predict that she will write, "Apple, banana is pl fruit" as well as "Red, yellow is pl color," but that she will *not* write, "Red apple is pl round," for, although "red apple" is two words, it does not refer to two items.
16. Several researchers have used a so-called conditional discrimination problem, in which the subject is required to respond differentially, depending on, typically, a contextual cue. Both chimps and monkeys have solved such problems [H. W. Nissen, *J. Psychol.* **36**, 271 (1953); H. F. Harlow, *Psychol. Rev.* **56**, 51 (1949); A. J. Riopelle and E. L. Copeland, *J. Exp. Psychol.* **48**, 143 (1954)]. Although this type of problem can be made very complex, it seems doubtful that it is any more appropriately described in terms of the conditional relation than is simple reward and punishment. And simple reward and punishment are effective in modifying the behavior of nonprimates. The question of interest is this: If an organism can be modified by a procedure that is reasonably described in terms of the conditional relation, does it follow that the organism can be taught to label the relation? An affirmative answer would make rats and pigeons eligible for such learning; a negative answer would require an account of what must be present, in addition to simple modifiability, to make such learning possible.
17. The conclusion that the procedure was improper need not have been reached in hindsight. The standard training program consists of two positive and two negative instances of the concept, followed by choice trials in which the original material is repeated in the presence of both alternatives—words in production trials and nonlinguistic items in comprehension trials. The actual training did not conform to this format: there were neither two positive nor two negative instances. We are attempting to devise a standard training procedure that, whether it is necessary or not, will be sufficient to teach most language exemplars. But occasionally we stray from our own program. It is embarrassing, on the one hand, to discover that we have strayed; but it is often comforting on the other, for the deviations are typically accompanied by poor learning performances.
18. At the end of the test series, the "dumb" trainer was tested for language comprehension. Although he was ignorant to begin with, he was exposed during testing to conditions that made learning possible. The tests showed that, although he learned certain things correctly, he also mislearned many other things, and that, on balance, his knowledge could not account for Sarah's performance. First, the data reported here came from the first session of each kind, when the trainer was least likely to have learned anything. Second, there was no conformity between Sarah's errors and those of the trainer. Most of the trainer's errors were systematic—words that he had mislearned, whereas none of Sarah's errors were of this kind.
19. D. Premack, in *Cognitive Processes of Nonhuman Primates*, L. E. Jarrard, Ed. (Academic Press, New York, in press).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