5. P. A. Labine, *Evolution* **18**, 335 (1964).
6. ———, *ibid.* **20**, 580 (1966).
7. P. R. Ehrlich, *ibid.* **19**, 327 (1965).
8. L. E. Gilbert and M. C. Singer, *Am. Nat.* **107**, 58 (1973).
9. P. R. Ehrlich and R. R. White, unpublished data.
10. P. Brussard, P. R. Ehrlich, M. C. Singer, *Evolution* **28**, 408 (1974).
11. P. A. Labine, *ibid.* **22**, 799 (1968).
12. P. R. Ehrlich, unpublished data.
13. M. P. Johnson, A. D. Keith, P. R. Ehrlich, *Evolution* **22**, 422 (1968).
14. M. C. Singer, *Science* **176**, 75 (1972).
15. P. Brussard and P. R. Ehrlich, *Ecology* **51**, 119 (1970); *Nature (Lond.)* **227**, 91 (1970); *Ecology* **51**, 880 (1970).
16. M. C. Singer, *Evolution* **25**, 383 (1971).
17. I. L. Brown and P. R. Ehrlich, *Ecology*, in press.
18. R. R. White, thesis, Stanford University (1973).
19. P. R. Ehrlich and R. R. White, unpublished data.
20. P. R. Ehrlich and L. G. Mason, *Evolution* **20**, 165 (1966).
21. L. G. Mason, P. R. Ehrlich, T. C. Emmel, *ibid.* **21**, 85 (1967); *ibid.* **22**, 85 (1968).
22. R. C. Lewontin and J. L. Hubby, *Genetics* **54**, 595 (1966).
23. S. W. McKechnie, P. R. Ehrlich, R. R. White, in preparation.
24. J. C. Avise and M. H. Smith, *Evolution* **28**, 42 (1974); F. J. Ayala, J. R. Powell, M. L. Tracey, C. A. Mauro, S. Perez-Salas, *Genetics* **70**, 113 (1972); S. W. McKechnie, *Biochem. Genet.* **11**, 337 (1974); E. Nevo, Y. J. Kim, C. R. Shaw, C. S. Thaeler, *Evolution* **28**, 1 (1974); R. K. Selander, S. Y. Yang, R. C. Lewontin, W. E. Johnson, *ibid.* **24**, 402 (1970); R. K. Selander and W. E. Johnson, *Annu. Rev. Ecol. Syst.* **4**, 75 (1973).
25. M. Nei, *Am. Nat.* **106**, 283 (1972).
26. The evidence, tests, and other details are discussed elsewhere (*23*).
27. The importance of $4Nm$ originates from the theory of migration and drift. N is the effective size of specific subpopulation and m is the probability that genes in that subpopulation will be exchanged in a given generation by migration. It can then be shown that, at equilibrium, if $4\,Nm$ is much less than 1, there is a high degree of inbreeding in the subpopulation. If $4\,Nm$ is large there is little local inbreeding, migration is overwhelming, and the whole system of subpopulations can be viewed as one panmictic (where mating is random) unit.
28. G. Malecot, *Ann. Univ. Lyon Sci. Section A* **13**, 37 (1950); T. Maruyama, *Theor. Pop. Biol.* **1**, 273 (1970); M. Nei and M. W. Feldman, *ibid.* **3**, 460 (1972).
29. P. R. Ehrlich and P. H. Raven, *Science* **165**, 1228 (1969).
30. M. C. Singer, R. R. White, P. R. Ehrlich, unpublished data.
31. P. R. Ehrlich and L. C. Birch, *Nature (Lond.)* **214**, 349 (1967).
32. R. C. Lewontin, *Evol. Biol.* **6**, 381 (1973).
33. P. R. Ehrlich and P. H. Raven, *Evolution* **18**, 586 (1965).
34. N. G. Hairston, F. E. Smith, L. B. Slobodkin, *Am. Nat.* **94**, 421 (1960); W. W. Murdoch, *ibid.* **100**, 219 (1966).
35. D. E. Breedlove and P. R. Ehrlich, *Science* **162**, 671 (1968); *Oecologia* **10**, 99 (1972); P. R. Ehrlich, D. E. Breedlove, P. F. Brussard, M. A. Sharp, *Ecology* **53**, 243 (1972); L. E. Gilbert, *Science* **172**, 585 (1971); R. R. White and M. C. Singer, *J. Lepid. Soc.* **28**, 103 (1974).
36. P. Dolinger, P. R. Ehrlich, W. L. Fitch, D. E. Breedlove, *Oecologia* **13**, 191 (1973).
37. P. R. Ehrlich and L. E. Gilbert, *Biotropica* **5**, 69 (1973).
38. D. H. Janzen, *Evolution* **20**, 249 (1966).
39. P. P. Feeny, *J. Insect Physiol.* **14**, 805 (1968).
40. R. H. Whittaker and P. P. Feeny, *Science* **171**, 757 (1971).
41. L. E. Gilbert, *Proc. Natl. Acad. Sci. U.S.A.* **69**, 1403 (1972).
42. J. Roughgarden, *Theor. Pop. Biol.* **5**, 163 (1973); G. Barlow, *Am. Zool.* **14**, 9 (1974).
43. We thank M. W. Feldman, R. W. Holm, D. Kennedy, and J. R. Roughgarden for criticism of the manuscript. Supported by a series of NSF grants, the most recent of which is GB 3525 X. Many students working on this project were supported by an NIH training grant in population biology and by a grant from the Ford Foundation.

Putting a Face Together

Chimpanzees and children reconstruct and transform disassembled figures.

David Premack

Chimpanzees do not, so far as is known, construct copies of existing or imaginary figures by any device—drawing, assembling pieces of existing material, or otherwise. In this apparent failure to reproduce or transform parts of the visual world, the ape differs from man no less profoundly than it does in the case of language. Man is never found without reproduction or transformation of his visual world, any more than he is found without language. He decorates his body; draws on walls, in the sand, and elsewhere; throws pots; carves and sculpts statuary; marks tools and other surfaces with calendric inscriptions or other possible forms of protowriting (*1*).

The author is professor of psychology at the University of California, Santa Barbara 93106. This article was written while he was a fellow at the Center for Advanced Study in the Behavioral Sciences, Stanford, California 94305.

Attempting to account for the ape's lack of visual production revives all of the questions raised by its lack of language. Is the deficiency motor, cognitive, motivational, or some combination of the three? To address these questions I devised a form of visual production which reduced motor demands to a minimum. Then an inability to draw or otherwise fashion visual products would not obscure a possible mental capacity for such tasks. A similar approach in language, eliminating the burden of speech sounds through the use of hand signs or plastic words, revealed an unsuspected linguistic capacity (*2*). Moreover, if evidence of the cognitive factor should be found later on, it could be profitable to return to the motor factor and study rather than simply discard it. But to start with I put the emphasis elsewhere, even as I have bypassed the phonological problem for the time being rather than study it.

An example of the simple visual device used is shown in Fig. 1. An enlarged photograph of a chimpanzee's head (Peony's), with the face blanked out, was mounted on stiff material. The eyes, nose, and mouth were cut out from another identical photograph. Since the pieces did not interlock as in a jigsaw puzzle, placement of an individual piece could not be guided by its conformity to the other pieces. Each piece was mounted on stiff material and was large enough to be easily handled by the chimpanzee. Two sets of facial elements were used, one that preserved normal size relations (Fig. 1, top) and another in which all elements were of the same size (Fig. 1, bottom) (*3*).

The subject's task, deliberately made as simple as possible, was to use all four pieces at least once. The blanked-out face was placed before the subject with the four facial pieces in a scattered arrangement alongside the puzzle, some pieces right side up, others with their blank or white side showing. Once the animal completed the task, it was praised by being told, for example, "That's good, Peony," or the equivalent in an affectionate tone, and given a piece of fruit. At the end of each trial the trainer traced the subject's construction on a translucent grid, removed the pieces from the board, and, after approximately 60 seconds, repeated the trial. Three or four trials were given per session depending upon the subject's willingness to perform. Photography was used on some trials but was disruptive and costly. The facial pieces were large, undetailed, and easily traced; the data recorded by different observers were essentially indistinguishable.

Sarah, Elizabeth, and Peony—African-born females 12, 6, and 5½ years old, respectively—along with Walnut, an 8-year-old African-born male, were the subjects. All four are engaged in a long-term language project (*4*), and were given the visual tests concurrent with the language training at different times of the day.

The test material was notable for the ready agreement it produced between the subjects and trainers as to what constituted an episode, or an act for which praise and fruit were given. After placing all four elements on the board, the subject raised its head, turning its face from the puzzle to the trainer. To this general period marker each subject added an individual flourish that further defined the end. Sarah indicated that she was done in the most explicit way possible: she passed the board out to the trainer. Elizabeth and Walnut leaned back from their hunched working positions. And Peony, least interested of all the subjects in the puzzle per se, looked at the food dish even as her hand added the last piece to the board. Comparable well-defined ends of an episode occur routinely in the language training. But they are not a universal, and sometimes the lack of agreement between the trainer and subject forces the use of a formal period marker. For instance, in attempting to teach the same subjects one-to-one correspondence as a precursor to counting, the animal's indecisiveness forced us to introduce a bell, which the animal is required to ring when through with a given problem. So far the acquisition of quantification skills has lagged far behind the acquisition of language, which suggests that indecision as to what constitutes an episode is an unfavorable prognostic sign (*5*).

The constructions produced on the first three or four trials by each animal are shown in Fig. 2. The animals were both different and consistent. Sarah appeared to make faces or transforms thereof and differed from the other subjects, which did not make faces either in a canonical or transformed sense. The subject's constructions can be described qualitatively as follows: Peony made "lines"; Walnut, "towers"; Sarah, "faces"; while Elizabeth lacked an easily characterized target and her constructions appeared to be attenuated versions of Sarah's. In fact, when given no more characterization than "line," "tower," and "face," human subjects averaged about 90 percent correct in sorting a total of 24 constructions by the three animals; with the addition of Elizabeth's, described simply as "poor face," they were about 79 percent correct in sorting the 32 constructions into four piles.

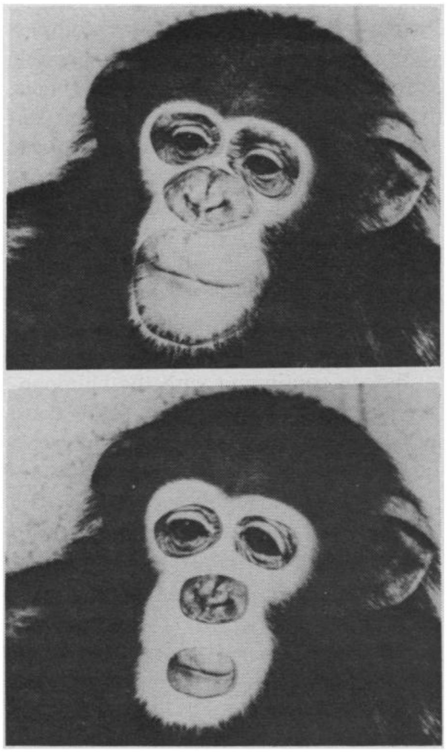

Fig. 1. The main test materials, a blanked out face of the chimpanzee Peony, with normal size (upper) and equal size elements (lower) in veridical positions.

The data can be characterized statistically by defining an ideal face in terms of the grid position of the eyes, nose, and mouth, and then measuring the distance between the actual constructions and the ideal face. Figure 3 shows the results of such analyses for distance measured in terms of two parameters: (i) the sum of the number of grid positions needed to move each of the four pieces from the observed to the ideal position (with a count of one added for every turned-over piece), and (ii) number of pieces that were a quarter or more outside the blanked out or facial area. For purposes of analysis, these two variables were converted into a single distance (D) by the Pythagorean theorem, $D = (X^2 + Y^2)^{1/2}$. The data analyzed are from the six to eight trials for each animal for each of the two conditions (normal size and equal size pieces). The close clustering of the points justified the assumption that the constructions were true replicates under both conditions from session to session and for trials within a session.

The two panels in Fig. 3 differ only in the definition of ideal face. For Fig. 3A a strict definition was used (grid position and identity of piece occupying that position), and for Fig. 3B a relaxed one was used in which the face was defined solely in terms of grid position independent of the piece occupying the position. An analysis of variance for the strict case showed that the between-subject effect was highly significant ($P < .01$), and a Sheffe's test indicated that the differences between pairs of subjects were all significant except for the comparison between Peony and Elizabeth. Analysis of variance for the relaxed case showed that the between-subject effect was highly significant ($P < .01$), but the only significant differences between pairs of animals were those between Sarah and the rest of the subjects.

Tests were also made to determine whether or not each animal's constructions differed significantly from the ideal face. The hypothesis that a subject produced an ideal face (strict definition) was rejected at the .01 level for all subjects, although the magnitudes of the t values were highly compatible with the visual impression of the data. For example, Sarah has a value of 5.9 compared to those of 10.9, 18.3, and 24.4 for Elizabeth, Peony, and Walnut, respectively, the larger values going with the larger discrepancies between the actual construction and the ideal face. For the relaxed definition, the hypothesis was again rejected at the .01 level for Peony, Elizabeth, and Walnut, and at the .05 level for Sarah. However, Sarah's t value of 2.482 was only slightly larger than $t_{.05} = 2.447$.

The statistical analysis and what the eye sees are in general agreement, although the eye makes a stronger interpretation than the statistics confirm. Statistics and eyes might be brought into better accord by modifying the definition of face. For example, the definition could be further relaxed by accepting facelike configurations that lie outside the facial area. However, it is not a further weakening of the definition that is needed, but a more powerful analysis, one capable of taking into account the possible transformational intentions of the subject. By even the present relaxed definition, a perfect face that was upside down or was rotated 90 degrees would be rejected as nonideal, indeed as highly discrepant. Although transformations of this kind, which conserve the betweenness relations of the elements, could be rather easily incorporated by the present definitions, other more radical ones encountered in the subsequent data could not. Two constructions that are physically identical could deviate from an ideal face for profoundly different reasons: (i) the subject is incapable of producing a face; or (ii) the construction is a transform of a face, made by a subject quite capable of producing faces and substantially more complex figures. Probably it is the possible transformations of an underlying face, which the eye sees but the present statistical analysis is not equipped to see, that leads the eye to make the more accurate prediction of the shape of things to come.

Children's Constructions

Before continuing with the chimpanzee constructions, consider some comparative data from children. Children's constructions with the same test material displayed a number of regularities that simplify the interpretation of more complex data. To enjoy the benefits of these simplifying regularities, it is necessary, however, to use children of appropriate age. When children are too young, their constructions resemble those of Peony, Elizabeth, and Walnut; they are apparently unable to reconstruct the face. When too old, they do nothing but reconstruct the face. It is only children at an intermediate age and only a minority of them who both reconstruct the face and transform it. Indeed, they construct and transform in so orderly a fashion that transformation is not an inference but an observable act.

Twenty-five children, between the ages of 5.2 and 7.0, were tested individually in a manner comparable in its informality to that used with the apes. After being seated on the floor in a familiar room by a familiar person, the

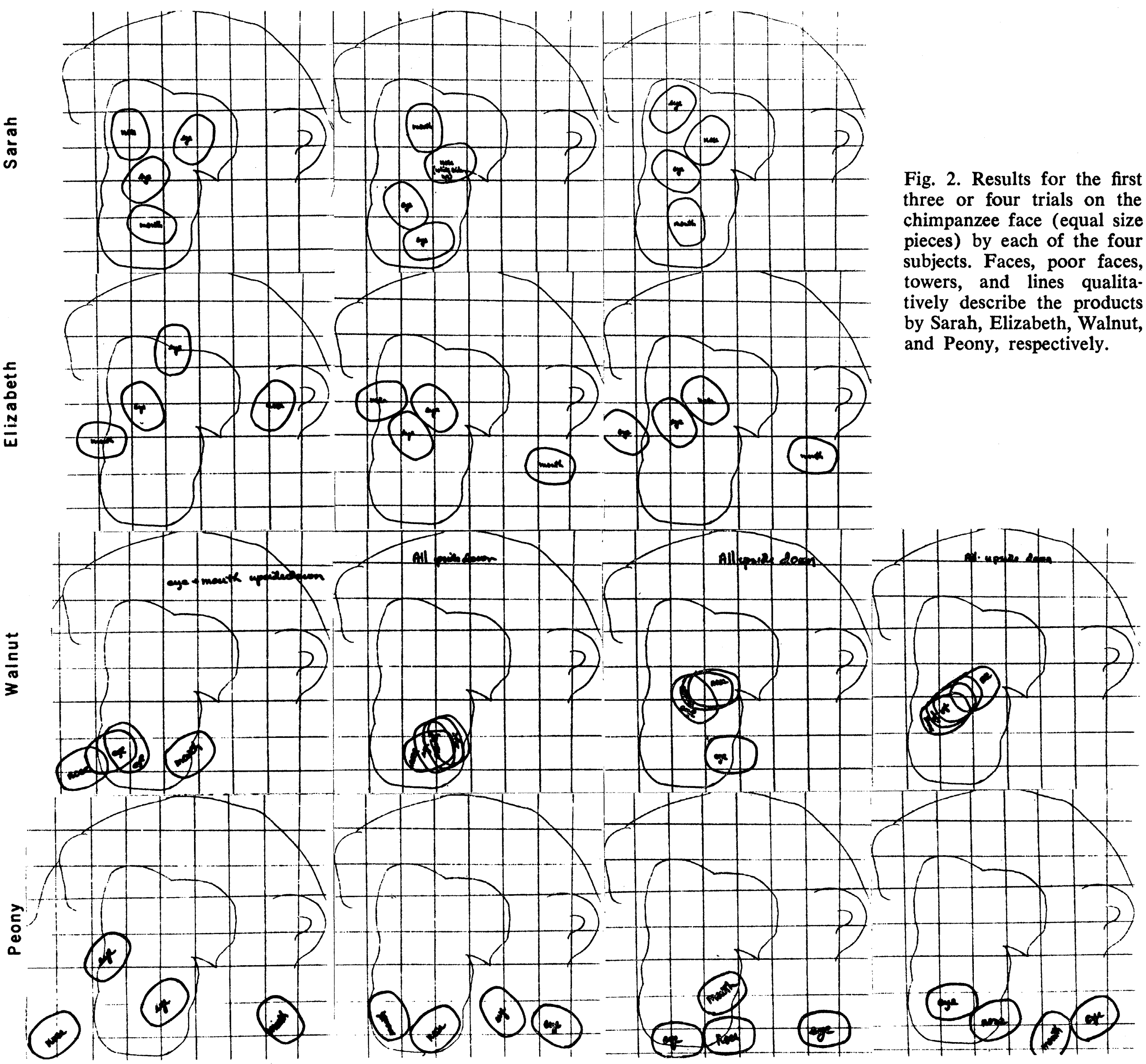

Fig. 2. Results for the first three or four trials on the chimpanzee face (equal size pieces) by each of the four subjects. Faces, poor faces, towers, and lines qualitatively describe the products by Sarah, Elizabeth, Walnut, and Peony, respectively.

child was given the same materials used with the chimps and was addressed with such silence-shunning remarks as, "See what I've got here." Typically the child set to work without further ado. When done they too displayed unequivocal period markers. They pushed the puzzle toward the observer (a gesture reminiscent of Sarah), stood up, looked at the observer, started to leave the room, leaned back in their chair, said, "What's next?" or made some combination of the above. The observer approved of whatever the child had done, for example, by replying, "That's fine, John," or the equivalent, although without providing anything comparable to the fruit given the chimps. To speed the collection of data the child was given another puzzle, a human figure cut into six pieces (an example is shown in Fig. 4).

Most children of this age began in the same way. They made a veridical reconstruction of the face, even to the point of tending to reassemble the face in the same order. The modal pattern was mouth first, followed by nose and eyes; 83 percent of the children started with the mouth. And for most children the matter ended with the veridical reconstruction. They did not return to the face but looked to the observer either for more work or for the signal to leave; a few left without a signal and had to be called back.

Four children of the present group went beyond veridical reconstruction. After a brief pause, they made either of three kinds of responses: (i) a conserving transformation, (ii) a nonconserving transformation, or (iii) a special version of a nonconserving transformation which can be called "changing the topic." By nonconserving transformation I do not mean that no feature was conserved; that would be too formidable a claim in any case. As I am using the terms, conserving and nonconserving transformation can be distinguished by this simple test. When the constructions are removed from the board, if the product of the first episode can be distinguished from that of later episodes, the change is scored as nonconserving.

The most common version of a conserving transformation was to disassemble the face, rotate the board either 90 or 180 degrees, and then reassemble the face as before. Since the child changed the position of the board without changing his own, the face in the latter case would be seen by the child as upside down. In an unusual case of this kind, the child did not rotate the board but turned it over unto its blank side and reconstructed the face there. But whether the board was inverted or rotated, the child made no changes in the internal composition of the face. Thus, if the faces were removed from the board, one could not distinguish the products of the first and second episodes. Four children of the 55 we have so far tested made changes of this kind, either one or two per puzzle.

In the more interesting nonconserving transformation, the child made definite changes in the internal composition of the figure so that constructions from first and later episodes, even if removed from the board, could be readily distinguished. A few of the changes recalled modern art, such as one in which the child moved both eyes to the left side of the face, or another in which the child pushed the elements together, forming a squashed or compressed face. Most of these cases could not be easily characterized. Although nonconserving transformations may yet prove to be summarizable by a few simple principles, it has been hard to do justice to this possibility, for there is a paucity of data. Children who perform in this manner are a decided minority, only 5 in a sample of 55 or about 9 percent of the population tested.

Changing the topic is also a nonconserving transformation but, as the name suggests, differs from the standard variety in that the subject makes a new figure rather than modifying the original one. The resulting figures are rarely interpretable as such; if the subject did not accompany them with such explanatory remarks as, "Now it's a bug," or "snake," and so forth, one might distinguish the previous case from this one by calling the former good transforms and these bad transforms. But this evaluative distinction would be a mistake, for in this case the subject is no longer modifying but making a new figure.

Of the four acts in the present set—veridical reconstruction, conserving transformation, nonconserving trans-

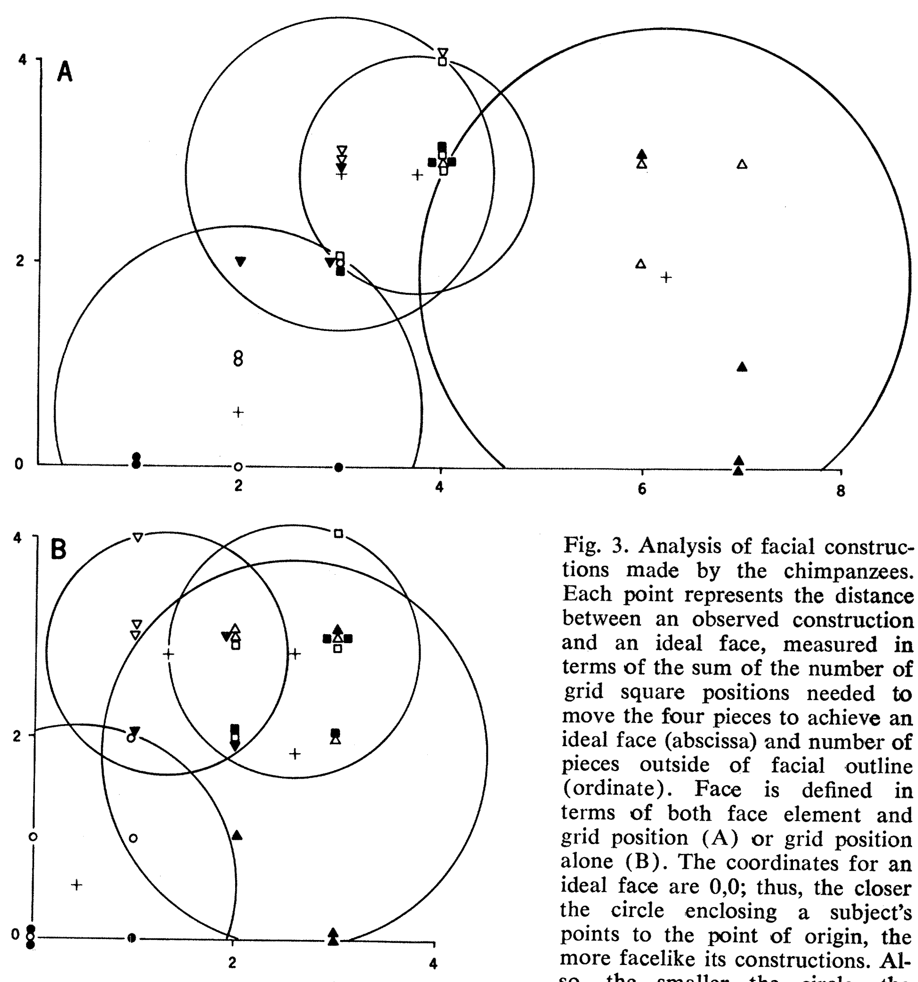

Fig. 3. Analysis of facial constructions made by the chimpanzees. Each point represents the distance between an observed construction and an ideal face, measured in terms of the sum of the number of grid square positions needed to move the four pieces to achieve an ideal face (abscissa) and number of pieces outside of facial outline (ordinate). Face is defined in terms of both face element and grid position (A) or grid position alone (B). The coordinates for an ideal face are 0,0; thus, the closer the circle enclosing a subject's points to the point of origin, the more facelike its constructions. Also, the smaller the circle, the more consistent the constructions. The + is the centroid or center of the circle. Filled and unfilled symbols are for pieces of equal and normal size, respectively; circle, Sarah; triangle, Walnut; inverted triangle, Elizabeth; square, Peony.

Fig. 4. (Left) Unsuccessful attempts by youngest children to reassemble chimpanzee face or human figure. (Right) Transformations on successful reconstructions of same figures by children of intermediate age.

formation, and changing the topic—the last two can be differentiated from the first two by behavioral criteria independent of the visual constructions. Although this judgment is based only on observations, I believe that photographic records will confirm the observations. There is a decided heightening of affect when the child carries out a nonconserving transformation or changes the topic, the two acts that alter composition of the existing face. Facial expression and affective tone are like those found in humor or wit. In addition to laughter or more subdued giggles and smiles, there is an increased frequency of eye contact, as though the child were saying to the observer, "We both know that I can do better than this and that I'm now playing." Of course, I want to confirm the observations before inventing theories, but there is a strong temptation to relate especially the nonconserving transformation to a theory of wit, of humor expressing itself in the visual domain. Incidentally, either comparable affective changes are not made by the chimpanzees or are not recognized when they are made.

Can Transformation Be Increased?

How can we increase the frequency of behavior that goes beyond the simple veridical reconstruction found in most of the children? The direction in which one turns to find more transformations will be guided by whatever tentative theory one adopts as to their nature. Many views are possible, but consider two that are especially divergent. The most common view, I suspect, is that the free or transforming spirit of the child has been quashed by restrictive socialization, pedagogy, or both. All children are creative and would be active transformers if they had not been inhibited by society. From this essentially Rousseauean view one cannot but mourn the 90 percent of children who do not go beyond veridical reconstruction.

A quite different view suggests that one should not mourn the lack of transforming children, but rather be surprised that there are any at all. It, too, reflects dissatisfaction with current pedagogy but for altogether different reasons, specifically for failing to teach transformations. Normal perception supplies only veridical models—intact faces, bodies, trees, and so forth. The few disfigured bodies and the like which the child experiences accidentally are insufficient to teach the possibility of transformations; they must be taught explicitly. I describe these positions not to decide between them at this time, but to adumbrate some of the theoretical issues raised by the present data.

In an effort to obtain more transformational data I tried (i) younger children—their playfulness might take the form of visual transformation; (ii) older children—in being bored by this too easy material, they might transform to overcome monotony; and (iii) more fanciful stimulus material, the structural ambiguity of which might increase transformations. Each attempt failed in its primary aim but generated some secondary results of interest.

First, the ten older children (average age, 9.2 years; range, 8.0 to 10.10 years), tested in the same way as the two previous groups, produced ten perfect chimp faces, ten perfect human bodies, and nothing else. At this age there was only veridical reconstruction. Second, the ten youngest children (average age, 3.0 years; range, 2.4 to 3.9 years) were largely unable to reconstruct either the ape face or the human body. Three children made a veridical face, none made a veridical body. One child made a conserving transformation; he rotated the board 180 degrees and reproduced the same face upside down relative to himself.

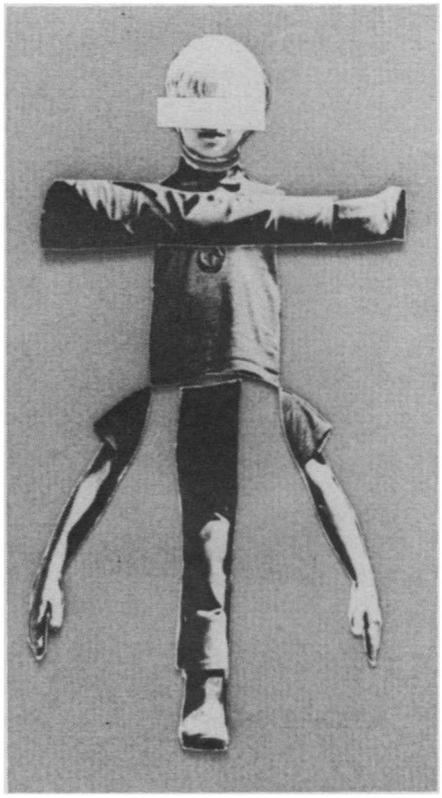

Fig. 5. A nonconserving transformation on a veridical reconstruction of a human figure by a 7.2-year-old child. The child made an adroit sexual improvisation that did not sacrifice other appendages. Sexual improvisations by other children were less adroit, resulting in either one-armed or one-legged figures.

Six of the ten youngest children made constructions like Peony's lines and Walnut's towers, four of the six making both lines and towers.

Some of the construction produced by children who did not make veridical reconstructions were indistinguishable from constructions made by children in the intermediate age group. Figure 4 shows three such pairs, those in the left panel by youngest children, those in the right panel by children of an intermediate age. As though the "mistakes" of the young child equaled the "art" of the older child, constructions of the youngest child were indistinguishable from the transformations of the intermediate children. That is, although alike in form the constructions had different histories. Those on the left were the product of the first episode, the child's initial act; those on the right were the product of the second episode, the child's transform of its veridical reconstruction. In addition, heightened affect was a concomitant of those on the right but not those on the left (*6*).

The fanciful stimuli—commercial puzzles involving would-be comical figures—did not bring out more transformers but tended to increase the amount of transformation engaged in by already known transformers. The five known transformers had produced an average of 1.2 transformations per chimp face and human body, compared to an average of 2.4 with the fanciful stimuli. However, a far more effective device for increasing the amount of transformation in known transformers was found in self-puzzles, that is, photographs of the child mounted on stiff material and cut into pieces. Three of the five known transformers (two having left the school) were tested in a counterbalanced order on puzzles of themselves and of a school friend. The average numbers of transformations for puzzles of self and of the other child were 5.4 and 5.2, respectively. Several of the nonconserving transformations were sexual improvisations, either an arm or leg placed in the pubic region and explicitly labeled by the child as "penis" or "wiener." No child carried out a sexual transform on himself but two of the three did so on the puzzle of the other child. The transformation of this kind shown in Fig. 5 was selected because of the nice way in which the child solved the major problem posed by transformations made in the context of nonsurplus resources, that is, of no extra pieces available to the child. In the absence of extra pieces, to improvise a penis therefore required the sacrifice of at least one of the existing pieces. The objective of a transformation is, I assume, not simply to make a change but to do so while at the same time preserving the identity of the original figure. The adroit realization of this objective by a 7.2-year-old boy involved a threefold improvisation: one leg became the penis, one leg became two arms, and the arms became two legs, preserving the customary symmetry of the legs.

Reducing the Difference between Sarah and the Children

Sarah's constructions had the appearance of nonconserving transformation, but could not be scored as such because she did not first make a normal face. The children were far more obliging: if they transformed at all they did so only after first making a clear veridical reconstruction. Are there conditions

Fig. 6. Elizabeth viewing herself wearing a hat.

that will induce Sarah to separate reconstruction from transformation, or alternately, conditions that will lead the transforming child to mix the two phases? It may be possible to narrow the difference between Sarah and the children who transform, either by bringing the behavior of the children closer to that of Sarah or vice versa.

The children were brought closer to Sarah by a simple step. When the three children known to transform were given the same puzzle on more than one occasion they no longer began with veridical reconstruction. The three transformers were given four sessions on the puzzles of self and the other child, at 48-hour intervals. In all but the first session, they began with nonveridical figures, as though the first act in each of these sessions was a transform on the original veridical reconstruction of the first session. They then further transformed the nonveridical constructions, sometimes as many as six times, and twice ended with a veridical reconstruction. On these occasions the transforming children perfectly reversed the original process order. With unfamiliar material they first assembled a veridical figure and then distorted it one or more times. With familiar material they first assembled a distorted figure, changed it once or twice, and sometimes ended by reinstating the veridical figure.

The conserving transformations seen so far have been of two kinds. Only with the sexual improvisations has it been possible to interpret the new constructions semantically. From what the child said and from the visual evidence itself it is possible to identify the new object. But in all other cases one cannot apply a simple label to the new construction and still less say why the subject made it. Is this because not enough is known about the subject? Or is it possible that not every transformation has a semantic target? Quite possibly only some transformations are of this kind, and even unlimited knowledge would not make it possible to interpret the transformation. Indeed, the special value of unlimited information may lie in the possibility of demonstrating that not every transformation is interpretable, that, as I suspect, many are no more than formal exercises. Nevertheless, those that are interpretable, such as the sexual ones, hold out the hope of teaching something about the general conditions that give rise to transformations, and for that reason they are of special value.

Interpretable Transformations in Sarah

Some semantically interpretable transformations were obtained from Sarah by a bit of good fortune. One of the difficulties in teaching language to a caged subject is finding things to talk about. The cage does not offer much and after a few thousand trials of requesting banana, the subject begins to lose interest in the language. To the uneventful laboratory day, one must add activities in which the animal engages willingly and which can be talked about. On the day preceding a test of the chimpanzee face puzzle, Sarah spent part of the morning trying on women's hats along with the trainer and viewing herself wearing the hats in a mirror. The photograph (Fig. 6) that shows Elizabeth so engaged only poorly conveys the excitement that typically attends this act.

Approximately 36 hours after Sarah had viewed herself wearing a hat, she was given a standard session with the chimpanzee face puzzle. On the fourth trial of that session, she produced the construction shown in Fig. 7. The mouth has been turned over and placed in a hatlike position on the head. Is this a coincidence or can the chimpanzee be attributed with the same dispositions attributed to the children? I said that the child used the leg (or arm) to represent a penis. Can I say that the chimpanzee used the mouth to represent a hat?

In answering this question several kinds of evidence can be used. First, what was the frequency of hatlike configurations in Sarah's base data? Sarah rarely inverted the pieces, rarely placed the mouth on the head, and never did both together, that is, invert a piece (mouth, eyes, or nose) and place it on the head. Thus, her base frequency for the event in question was zero. Second, the perceptual characteristics of the pieces and face can be considered. The mouth is the most hatlike of the pieces and at the same time one that can be sacrificed with minimal loss to the identity of the face. The eyes are the most defining part of the face, perhaps because what one does most with a face is look into its eyes. So long as the face was "anchored" by the eyes, the mouth could be moved without threatening the identity of the face; in fact, the eyes were in position when Sarah moved the mouth. If Sarah never repeated this act, there would be no alternative but to argue from evidence of this kind. Fortunately, there is a more persuasive kind of evidence.

Since the first apparent hatlike transformation was a chance observation, I undertook to replicate the outcome in a controlled way. The morning hat sessions were eliminated and Sarah was given the chimp face puzzle on two daily sessions, four trials a session; the hat sessions were then reinstated on two daily sessions and Sarah was given the chimp face puzzle on the same two days; and the original or base conditions (no hat sessions) were reinstated.

How close in time must the direct experience be to a possible symbolic representation of it for the direct experience to influence the symbolic one? In the chance observation the two experiences were separated by no less than 36 hours; which makes the fact of a possible influence of one experience upon the other all the more impressive. However, it also contributes to the difficulty of controlling the occasions upon which the two experiences may interact. For example, there is no assurance that experience with hats in one week will not influence puzzle behavior in the next week. At this stage, I could only hope that temporal contiguity might maximize the effect. One of the two hat sessions was at the regular morning time, and the puzzle session was about 6 hours later at the regular afternoon time. The other hat session was in the afternoon, immediately before the puzzle session.

The choice of times was effective, for Sarah did not produce any hatlike transformations in either the pre- or posttreatment phases; by hatlike transformation I mean an inverted mouth placed either in a hatlike position or anywhere on the head. In the pretreatment phase she put the nose on top of the head once but did not turn it over; in the posttreatment phase she did not put any piece on top of the head.

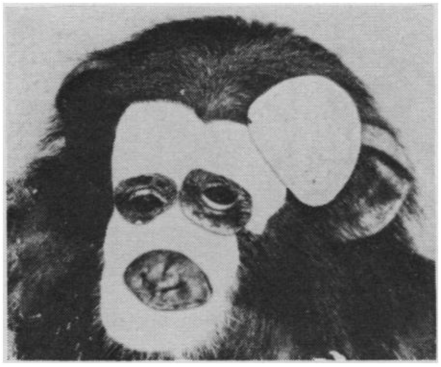

Fig. 7. Sarah's first apparent transformation of the chimpanzee face. Following the opportunity to view herself wearing hats, Sarah inverted the mouth and placed it in a hatlike position on the head.

During the treatment phase, when hat and puzzle sessions occurred in the same time period, she made two constructions different from any she had made before (Fig. 8). In the first of these, not only the mouth but also the nose was inverted and placed in a hatlike position, the nose on top of the mouth. She made this construction in the puzzle session that immediately followed the hat session. In the second case, she added banana peel, which was often available to her in the cage along with orange peel and occasional candy wrappers, in a hatlike position on the head. This construction is of special interest. (i) The face was fully veridical before she added the banana peel, which adds to the conclusion that Sarah can reconstruct faces. (ii) All previous transformations occurred in the context of nonsurplus resources, but with the use of the banana peel Sarah produced an example of transformation in the context of surplus resources. With surplus resources, the face could be (and was) veridical and transformed at the same time; for no part of the face had to be sacrificed in order to represent an item other than itself.

Normal Perception as the Training Program

To examine the possibility of linguistic competence in the ape, human intervention was unavoidable; apes do not acquire language without being trained in one degree or another. The only decision was how to structure the training, whether to simulate the natural case or to devise an artificial approach possibly more efficient than the natural one. In visual production, however, there was at least the possibility that the chimpanzee could reconstruct disassembled figures without human intervention. Thus in this case it was desirable not to train the animal but to set it a task structured only by the decision as to which figures to use and how to divide them into elements. These are inescapable decisions of the most basic kind and cannot be avoided by any approach, structured or unstructured.

In comparing the degree of human intervention in the language and picture-reconstruction cases, we see that not only is the training in the pictorial case weaker than in the verbal case; it approaches an absolute minimum. The strength of a training program can be measured on two dimensions: (i) the input experience given the subject, and (ii) the correction given to the subject's output. Input is considered strong when the exemplars given the subject are identical to those the subject is expected to produce and are introduced in a continuous progression from simple to complex. Output training is considered strong when the subject is not left to observational learning but is corrected for errors.

On the output side the training could not have been weakened. The chimpanzees were given no correction whatever; every construction they made was approved. On the input side there is only one way in which the training could have been attenuated. The subjects were allowed to see one another, themselves in a mirror, their trainers, and occasional nonprimate faces and bodies in the form of dogs and birds. These exemplars could have been eliminated by rearing the subjects in social isolation. But the fact that the input could be weakened only by depriving the subjects of normal visual experience attests to how weak the input experience already was.

For example, compare the chimpanzees' and children's experience with puzzles. Before assembling a puzzle, the child is likely to see the puzzle in its assembled form. It may also see a model—the parent or older sibling—assemble the puzzle, and certainly it will receive correction or assistance, the pedagogical impulse of the contemporary parent being what it is (the correction may not benefit the child so much as it serves the parent in ways that remain to be explicated). The chimpanzees were not given any of these forms of possible assistance—an assembled puzzle to start with, a model who correctly assembled the puzzle, or correction after they began.

How did Sarah and, to some extent, Elizabeth learn to reassemble the face? Doubtless in some sense by matching their constructions to actual chimpanzee faces. But the matching would have to be to the memory of actual faces for, during the time they worked on the puzzles, no mirror or other chimpanzee was present. The possible use of the trainer's face cannot be ruled out, although there was not the faintest suggestion that the animal essayed a tentative face and then corrected it against the trainer's face.

What relation is there, if any, between representational competence and compositional skill? Most 4- to 5-year-old children can not only reconstruct a face from existing elements, but draw a face from memory as well. Children between the ages of 2 and 3, although unable to draw a face, will have matured through some of the stages of nonrepresentational composition which typically precede representational drawing. Kellogg (7) has identified 20 scribbles—lines, dots, loops, and so forth—that a child produces in a first stage. These are combined in a second stage to form crosses, squares, triangles, and the like, followed by a later stage when the child forms crosses within squares, squares within circles, and so on. After four nonrepresentational stages, the child begins to compose representational drawings, of which the face is often the first.

When the appropriate materials are available, the child passes through these stages, but are the stages necessary either for the mature composition of the older child or for the reconstruction of representational elements? If a child were given a series of lines during a stage when lines but not crosses could be produced, he or she might advance to the next stage by combining lines to form crosses. A child at a more advanced stage, who produced circles and squares but did not yet combine them, might place circles within squares if provided with these elements. Reconstruction would precede composition, yet the former would depend on the latter, for the child could reconstruct more than he or she could draw but could not combine elements before being able to compose them.

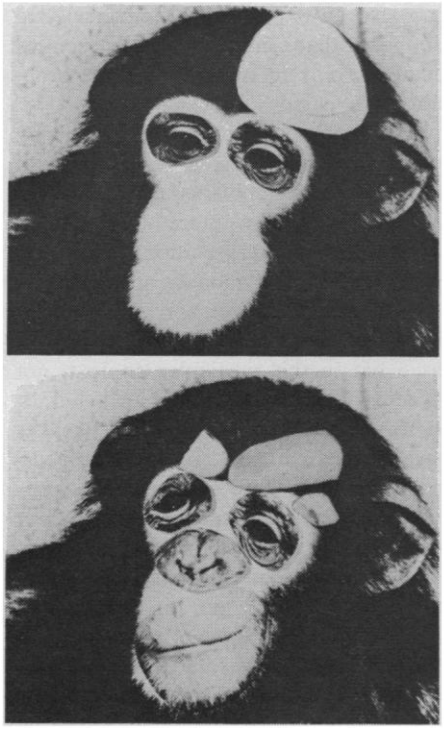

Fig. 8. Two other apparent transformations of the chimpanzee face by Sarah following the opportunity to view herself wearing hats. With the use of banana peel (bottom), the face was both transformed and veridical at the same time.

Sarah's reconstruction of a face shows that not only the above hypothesis, but a class of like hypotheses linking representational competence to compositional skill are probably false. In her 12 years, Sarah received no more than perhaps 50 opportunities to draw, never showing any evidence that she passed through the stages noted among children. Moreover, while Peony and Walnut—5½ and 8 years old compared to Sarah's age of 12—started out by making lines and towers (resembling the child's scribbled horizontal and vertical lines), Sarah never made these constructions. Instead, from the start, she made faces or approximations thereof.

In learning to move the plastic pieces into veridical positions, Sarah acquired visual-motor coordinations analogous in kind to the auditory-motor coordinations of speech. The infant can see the lips of a speaker but not the disposition of the internal speech apparatus, yet learns to produce motor configurations resulting in sounds matching those heard. In both cases the model given the subject supplies only one side of the sensory-motor correlation: the child hears speech sounds and the chimp sees faces. But the child is not shown the motor configurations that produce the sounds nor is the chimp shown the movements that bring the facial pieces into veridical configurations. Although orders of magnitude apart in complexity, these sensory-motor coordinations are analogous in being learned entirely without guidance and indeed without even a complete model. Sarah was not taught how to reconstruct the faces, even less how to transform them.

Primitive Elements

The wild chimpanzee does not produce either language or pictures, yet with human intervention it produces some degree of both. In both cases man gives to the chimpanzee the primitive elements, words in one case and visual elements (eyes, nose, mouth) in the other. Words, in my approach to language, consist of pieces of plastic made by the experimenter and given to the chimpanzee. But the use of sign language does not change the argument; the trainer spends hundreds of hours molding the animal's hands into the desired signs. Thus the elements are either forged out of chimpanzee behavior by resolute human training, or cut out of stiff material by human hands and given to the chimpanzee. In both cases, it is man, not the ape, who provides the building blocks.

Once given the elements, the chimpanzee learns to arrange them into sentences in one case, pictures in the other. The surprise is that a species that apparently does not itself generate the elements should be so adept in learning to combine the elements once they are provided by another species. In the wild, no species gives the ape those elements upon which the representational systems depend. The remarkable combinatorial capacity of the species thus remains hidden, at least from human eyes, for if the ape's natural behavior manifests representational complexity similar to that demonstrated in the laboratory, humans have not yet learned how to "read" natural behavior.

Could the chimpanzee form its own representational elements? Sarah's use of the banana peel suggests that perhaps it could. The banana peel with which Sarah formed a hatlike adornment was not a preformed element, analogous to those cut out from stiff material or to those trained into the animal's repertory. A piece of chance material, it differed from the elements given the chimpanzee in previous representational systems in two important respects: it was (i) introduced by the animal, not the experimenter, and (ii) assigned a meaning by the animal, not the experimenter. However, even if the chimpanzee could provide its own representational elements, Sarah's use of the banana peel leaves open the question of whether the elements might not have to be iconic. Human language, despite sound symbolism, is predominantly a noniconic representational system. So are the languages that the chimpanzee has been taught with human intervention, the pieces of plastic being even more devoid of iconism than natural language. But in these cases the primitive elements were made by man. Thus the question remains, Could the animal generate primitive elements that were noniconic?

From Icon to Word

The banana peel was not intrinsically hatlike. To interpret it as a hat depends upon contextual factors, its location on the face and its use following experience with hats. If located elsewhere following experiences of different kinds, it could arbitrarily stand for many things, such as glasses if placed across the eyes or a necklace if draped around the neck. The banana peel is like clay, a neutral malleable material that can be indeterminately assigned many meanings. It is also like speech sounds, not in a structural but in a functional sense; they too have no preassigned meanings and can acquire arbitrarily different meanings. To suppose that in Sarah's hands clay could have the semantic potential of speech sounds is too vast an expectation. Conversely, to suppose that she could use neutral material only to represent hats is probably too narrow an expectation.

Whether a symbol is used iconically or noniconically has little to do with the physical resemblance of the symbol and referent, far more to do with whether the interpretation given the symbol depends upon a specific context. The banana peel, for instance, was used iconically because it is interpreted as a hat in this particular context, not because it actually looks like a hat. It is contextual dependence that makes symbols iconic, not physical appearance, and therefore symbols that originate as icons need not remain so. They can advance from their origins to become nonicons or words once we cease to depend upon extralinguistic contextual factors in interpreting them. The distance between iconic and noniconic use is less great than many discussions suggest, and a transition from one to the other is not hard to imagine.

For example, after using banana peel as a hatlike adornment, Sarah might present a trainer with a sequence containing the plastic words *give* and *Sarah*, along with a piece of banana peel. The string *give Sarah* followed by the banana peel might be interpreted by the unknowing trainer as a request for banana. But a more knowledgeable one is more likely to give Sarah a hat than a banana. He could justify his interpretation on the grounds that Sarah did not have a plastic word for hat but did have one for banana and was not using it. His interpretation would be vindicated if Sarah rejected the banana but accepted the hat. In this example the use of banana peel would not be iconic because the interpretation *hat* no longer depends on the facial context. Although it derived its original meaning from a facial context, it loses its iconic character when it is interpreted as *hat* in linguistic strings such as *give Sarah* banana peel, and the vast number of other sentences in which *hat* can occur. It would be a unique word with a special history—it would have started as an icon and been transformed into a word, while ordinary words have the more consistent history of starting and remaining words (*8*).

References and Notes

1. N. Munn, *Walbiri Iconography* (Cornell Univ. Press, Ithaca, N.Y., 1974); A. P. Merriam, in *Horizons of Anthropology*, S. Tax, Ed. (Aldine, Chicago, 1964), pp. 224–236; A. Marshack, *The Roots of Civilization* (McGraw-Hill, New York, 1971); D. Morris, *The Biology of Art* (Knopf, New York, 1962).
2. R. A. Gardner and B. T. Gardner, *Science* **165**, 664 (196[illegible] D. Premack, *J. Exp. Anal. Behav.* **14**, 107 (1970).
3. The equal piece form was intended as a control for the possibility that faces produced with normal sized pieces resulted merely from smaller pieces being stacked on larger ones. In fact, the two forms yielded comparable results, and we have since abandoned the equal size form.
4. D. Premack, *Intelligence in Ape and Man* (Erlbaum, Hillside, N.J., in press).
5. ———, *ibid.*
6. Many of the older child's transformations, like the nonveridical reconstruction of the younger child, appeared to involve the manipulation of symmetry (for lack of a better phrase). In transforming an assembled figure, the older child was probably not attempting to copy actually seen disfigured items, but rather returning to the dispositions of the younger child. It would be premature to claim that the younger child cannot reconstruct the puzzles. They did not reconstruct them but only perhaps because the disposition to do so was less strong than the disposition to "manipulate symmetry." Some children who failed to reconstruct the puzzles nonetheless called the appropriate puzzle "monkey," showing recognition for the object (and the same failure to distinguish monkey from chimpanzee as their parents).
7. R. Kellogg, *What Children Scribble and Why* (published by author, San Francisco, 1955).
8. The chimpanzee data were collected by A. Samuels and D. Barone, and the children's data by E. Arntz; M. Cruise, Center for Advanced Study in the Behavioral Sciences, is responsible for the statistical analysis. The research was supported in part by NIMH grant MH15616 and by NSF grant GV-4377X.