

EMERGENCE OF SYMMETRY IN A VISUAL CONDITIONAL DISCRIMINATION BY CHIMPANZEES (*PAN TROGLODYTES*)¹

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Summary.—In Exp. 1, three young chimpanzees were trained to match red to a cross and green to a circle in an arbitrary matching-to-sample task. After acquisition of this task, they were tested for the emergence of associative symmetry of these conditional relations using the trials on which shapes were presented as samples and colors as comparisons. One of the three chimpanzees showed statistically significant accuracy on these test trials. This successful subject served in Exp. 2, in which an auditory-visual stimulus appeared contingent upon red and a cross while another auditory-visual stimulus was contingent upon green and a circle. This subject showed higher accuracies in symmetry tests than in Exp. 1, which suggested the facilitative effects of these events common to sample and correct comparison on the development of symmetry. In Exp. 3, subsequent tests in which only these stimuli were presented as samples indicated that these stimuli might have become the members of equivalence classes.

Human subjects were shown to respond to untrained relationships immediately after they learned specific associations in arbitrary matching-to-sample tasks. This ability was shown not only in adults, but also in 2-yr.-old children and in persons with mental retardation (Devany, Hayes, & Nelson, 1986). Sidman and Tailby (1982) called this phenomenon "stimulus equivalence." According to their conceptual framework, a set of stimuli are equivalent if the stimuli have the following three relationships: reflexivity, symmetry, and transitivity.

In matching-to-sample procedures, reflexivity is identified by the formation of "same-different" concept: if the subject is trained to match A to A, then he is able to match B (a novel stimulus) to B without training. Symmetry requires the functional interchangeability between sample and comparison stimuli: if the subject is trained to match A to B, then he is able

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to match B to A. Transitivity is a derived association of stimuli that had no direct association: if the subject matches A to B and B to C, he is able to match A to C. The establishment of these relationships among a class of stimuli are behaviorally analogous to the symbolic functions of "word-referent" relations in human natural languages (Sidman & Tailby, 1982).

In recent years, some investigators examined the establishment of stimulus equivalence in nonhuman animals. Pigeons showed none of these equivalence relations (Lipkens, Kop, & Matthijs, 1988), although some researchers have been able to demonstrate reflexivity (Zentall & Hogan, 1976) and transitivity (Urciuoli, Zentall, Jackson-Smith, & Steirn, 1989). Monkeys sometimes showed reflexivity (Fujita, 1983) and transitivity (D'Amato, Salmon, Loukas, & Tomie, 1985). However, they consistently failed to acquire symmetrical relations (Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982).

Chimpanzees showed more consistent emergence of reflexivity (Oden, Thompson, & Premack, 1988) and transitivity (Yamamoto & Asano, in press), while they failed to show symmetry (Yamamoto & Asano, in press). However, some language-trained chimpanzees showed gradual development of symmetry between names and referents after repeated training to learn symmetrical relationships between them (Kojima, 1984; Premack, 1976).

It is apparent from these previous studies that the most difficult relationship between stimuli is symmetry for animals and that only some language-trained chimpanzees acquire this relationship after a substantial training with a number of stimulus sets. In the first experiment, we questioned if chimpanzees having no history of language-like skills are also capable of acquiring symmetry. Subsequent experiments examined the effects of some procedural variables on the development of symmetry, especially the effects of the differential contingent stimuli following the sample and comparison.

EXPERIMENT 1

In the previous research on symmetry in the language-trained chimpanzees, the subjects had extensive and repeated training with a number of stimulus sets. Such multiple exemplars have been shown to facilitate the various types of concept learning by animals (e.g., Harlow, 1949). By contrast, humans readily formed the symmetry after the training with only one set of stimuli. We first examined whether arbitrary matching-to-sample training with the minimum number of stimuli is enough for chimpanzees to acquire the associative symmetry.

To reduce the novelty of the symmetry tests, we trained the subjects not only on the arbitrary matching from colors to shapes but also on the identity matching of colors and that of shapes. The latter two tasks incorporated all the stimulus configurations that would be presented subsequently on the symmetry test trials from shape to color.

Method

Subjects.—Three young chimpanzees (*Pan troglodytes*, Popo: 6-yr.-old female, Reo: 6-yr.-old male, and Chloe: 7-yr.-old female) served as subjects. They had been trained on an identity and arbitrary matching-to-sample task before the present experiments. However, they had been neither trained on language-like skills nor on symmetrical relationships between stimuli. These chimpanzees were housed according to *Guide for the care and use of laboratory primates (1986 version)* of the Primate Research Institute, Kyoto University. They were not deprived food or water throughout the experiments.

Apparatus.—The experimental cage (2.4 m × 2.0 m × 1.8 m) had a 14-in. CRT color monitor with an optical touch panel (Minato Electronics, Inc. TD-301). The touch to the screen was defined as response. The experimental software divided the screen of the monitor into 12 areas (4 columns and 3 rows). Colored stimuli could be presented in each area. A food tray was installed on the right of the monitor. A universal feeder (Davis Scientific Instruments, UF-100) could deliver a variety of food (apples, pineapple, raisins, peanuts, etc.) into this tray. The equipment was controlled by a personal computer (NEC, PC-9801F2).

Stimuli were two colors in rectangles (red and green, 4 cm × 4 cm in size) and two white shapes [a cross (X) and a filled circle (●), 3 cm × 3 cm in size].

Procedure: matching-to-sample training.—All the subjects were concurrently trained on the following three tasks: an identity matching-to-sample of colors, an identity matching-to-sample of shapes, and an arbitrary matching-to-sample in which the subjects had to match from a red sample to a cross and from a green sample to a circle. These three types of tasks were presented randomly within the sessions. As noted above, the two identity-matching tasks were added to familiarize the subjects with the stimulus configurations that would be presented in the subsequent symmetry test and to establish both successive and simultaneous discriminations among the stimuli.

The left of Fig. 1 illustrates the baseline (left column) and test (right column) trials in Exp. 1. A trial proceeded from top to bottom in the figure. After intertrial intervals, a sample stimulus appeared in one of the four areas in the top row of the monitor. The location of the sample was randomly chosen. The sample disappeared when the subject made three fixed-ratio responses to it, which was defined as observing responses, and two comparison stimuli were immediately presented in two of the four areas in the bottom row on the monitor. The locations of comparison stimuli were also randomly chosen. A choice response to the comparison that corresponded to the sample terminated both comparison stimuli, delivered a piece of food, and sounded

a 1-sec. "correct" chime. A response to the comparison that did not correspond to the sample also terminated both comparisons, but an 0.5-sec. "error" buzzer sounded, followed by a timeout. Intertrial intervals followed reinforcements or timeouts. Intertrial intervals were 3 sec. (or 10 sec. for some sessions) and timeouts were 3 sec. (or 10 sec. for some sessions). A correction procedure in which the same trials were repeated until the subject made a correct response was used in some sessions to reduce positional or stimulus biases.

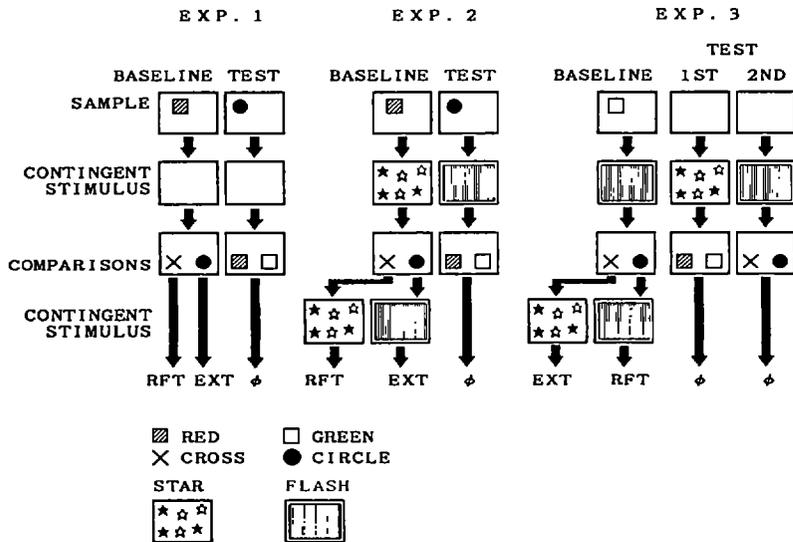


FIG. 1. Schematic diagrams of the baseline and test trials in the present experiments. A trial proceeded from top to bottom. Left, Exp. 1; middle, Exp. 2; right, Exp. 3. RFT indicates the delivery of food with a chime, while EXT the timeouts with a buzzer. ϕ on the test trials indicates no feedback. The blank square indicates no presentation of the sample and contingent stimuli.

Sessions consisted of 144 trials. Of these trials, 48 were identity matching-to-sample of colors, 48 were identity matching of shapes, and the remaining 48 were arbitrary matching from colors to shapes. Training was continued until the subject showed an over-all accuracy of more than 85% correct and more than 80% correct for each of the three types of matching tasks for two successive sessions. The subjects were overtrained for more than 12 sessions after they reached these criteria.

Symmetry tests.—The emergence of associative symmetry was tested for three sessions after the overtraining of the original discriminations. During the test sessions, trials of arbitrary matching from shapes to colors (i.e., sym-

metry test trials) were randomly interspersed among the three baseline matching trials. As shown in the second column at the left of Fig. 1, on the symmetry test trials, reinforcement, chime, buzzer, or timeout did not follow choice responses. A test session consisted of 144 baseline trials and 8 symmetry test trials.

Results

Mean matching accuracies for Reo in the last 12 overtraining sessions were 90.6% for color matching, 96.9% for shape matching, and 89.6% for arbitrary matching. The accuracies for Popo were 92.5%, 95.3%, and 83.0%, respectively, and those for Chloe were 96.2%, 100%, and 88.4%, respectively.

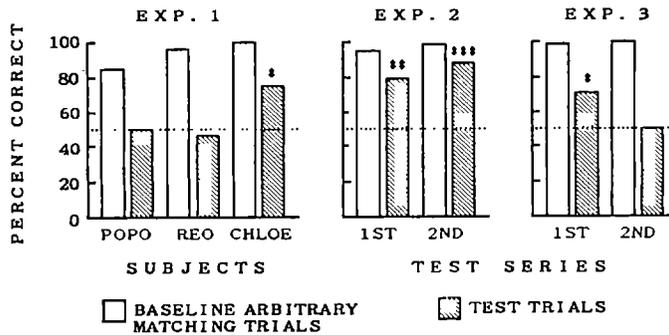


FIG. 2. Mean percent correct choices for baseline arbitrary matching and test trials in the test sessions in the present experiments. Left, the symmetry test for each subject in Exp. 1; middle, the two series of symmetry tests for Chloe in Exp. 2; right, the tests of matching from contingent stimuli to colors (first), and to shapes (second) for Chloe in Exp. 3. Dotted lines at 50% correct indicates chance performance. Asterisks above the bars indicate the significant levels, 5% (*), 1% (**), and 0.1% (***) of the binomial test.

All subjects made more than 90% correct identity-matching on the baseline trials of the test sessions. The left panel of Fig. 2 shows the accuracies of baseline arbitrary matching from colors to shapes and those of symmetry test trials. The data were averaged for three symmetry-test sessions. All subjects showed accuracies higher than 85% correct in the baseline arbitrary matching trials. On the symmetry test trials, two of the three subjects (Popo and Reo) performed at a chance showing no evidence for associative symmetry. One of the unsuccessful subjects (Popo) showed significant preference for the right-sided comparison (binomial test; $p < .05$), and the other (Reo) showed a significant preference for green ($p < .001$). Chloe, on the other hand, was more accurate at 75% correct, which was significantly above chance ($p < .05$), although she also showed significant preference for red

($p < .05$). In her first session, she performed perfectly (100% correct). In the next two sessions, however, she showed stronger preference for red.

EXPERIMENT 2

Recently, it was demonstrated that the relationship between the discriminative stimuli and the other environmental or behavioral events could facilitate the establishment of the equivalence class. One is the relationship between stimuli and the identity of reinforcers. Peterson (1984) showed that the performances of animals on conditional discriminations were improved when different food items were given according to the stimulus class. This is known as the differential outcome effect. Using pigeons as subjects, he also demonstrated that this differential outcome could facilitate the derived associations between the discriminative stimuli. In humans, the differential outcome also facilitates the stimulus class formation (Dube, McIlvane, Mackay, & Stoddard, 1987).

The other relationship is the one between the stimuli and the types of responding for them. McIntire, Cleary, and Thompson (1987) adopted different responding schedules, such as fixed-ratio and low-rate responding, dependent on the identity of the stimulus class. This procedure facilitated the acquisition of the equivalence class.

In the second experiment, we adopted one kind of the differential outcome procedures, in which an auditory-visual compound stimulus was presented after all observing and choice responses. We call these stimuli "differential contingent stimuli." We examined the effects of these contingent stimuli on the development of associative symmetry.

Method

Subject and apparatus.—Chloe, who showed significant emergence of symmetry in Exp. 1, served in Exp. 2. The same equipment used in Exp. 1 was used also in Exp. 2.

Stimulus sets were the same as those in Exp. 1. In this experiment, two types of contingent stimuli followed the completion of observing responses to the sample and choice responses to the comparisons. One was a 2-sec. scrolling of randomly colored stars presented in random locations throughout the screen accompanied by a continuous beep sound (STAR). The other was a three-time flash of yellow screen accompanied by an intermittent beep sound that synchronized the flash (FLASH).

Procedure: matching-to-sample training with differential contingent stimuli.—Following Exp. 1, Chloe was trained on the same three types of baseline matching with differentially contingent stimuli. The middle two columns of Fig. 1 on p. 54 present the baseline and test trials in Exp. 2. Trials were the same as those in Exp. 1, except the STAR or FLASH immediately followed the termination of the sample after the completion of observing re-

sponses to it and the termination of the comparison stimuli after the choice response. The STAR followed only red or cross, while the FLASH followed only green or circle. These auditory-visual stimuli were presented without regard to whether the choice was correct or not. Delivery of food or timeout followed these contingent stimuli. As in Exp. 1, food was accompanied by the 1-sec. correct chime sound, and timeouts were accompanied by the 0.5-sec. error buzzer.

Sessions consisted of 144 trials as in Exp. 1. Training was continued until her over-all accuracy exceeded more than 90% correct for three successive sessions.

Symmetry tests.—After Chloe's performance reached the criterion, the two series of symmetry tests were given to her. Each of the series consisted of three sessions. In the test trials, the contingent stimuli were presented only after observing responses (see the second column of the middle of Fig. 2). The two series of tests were as follows: (1) replication condition: Chloe received the same test as in Exp. 1 for three sessions, with the auditory-visual contingent stimuli. This yielded 24 test trials. (2) Baseline dependent condition: in this condition the test trials appeared (a) if the subject completed at least 18 baseline trials since the last test trials and (b) if the subject's performances during the last 10 baseline trials were perfect. This was to raise the reliability of the test by guarding the test trials from careless changeover of the choice after errors. Each test session terminated after the subject completed eight test trials. The number of over-all trials varied from session to session. Three test sessions were run, yielding 24 test trials.

Results

Chloe reached the criterion during seven sessions of matching-to-sample training with differential contingent stimuli. Mean percent correct for the three types of matching in the last three sessions averaged 90.3% for color matching, 98.6% for shape matching, and 100% for arbitrary matching from colors to shapes, respectively.

The middle panel of Fig. 2 on p. 55 represents the accuracies of baseline arbitrary matching from colors to shapes and of those of the symmetry test trials of the two series of tests. On the first test, the replication condition, Chloe showed an accuracy of 79.2% correct in the test trials (significantly above chance, binomial test, $p < .01$). This was higher than that in the corresponding symmetry test of Exp. 1, and stimulus preference shown in Exp. 1 disappeared ($p > .1$). On the second test, the baseline dependent condition, her symmetry-test accuracy (87.5% correct, $p < .001$) was the highest among the three symmetry tests conducted in the present experiments.

EXPERIMENT 3

In the experiments with differential responding or outcome, it was

known that associations between discriminative stimuli and responses or reinforcers could be established. Thus, responses and reinforcers would become the members of equivalence classes. However, this possibility has received few systematic tests (cf. Dube, *et al.*, 1987; Eckerman, 1970). In Exp. 3, the query was whether the contingent stimuli were associated with discriminative stimuli as a result of the training with the differentially contingent stimuli.

Method

Subject and apparatus.—As in Exp. 2, Chloe served in Exp. 3. The same equipment used in Exps. 1 and 2 was again used in Exp. 3. Stimulus sets and auditory-visual contingent stimuli were the same as those in Exp. 2.

Procedure.—Following the two series of symmetry tests in Exp. 2, Chloe was immediately shifted to the two series of tests for the associations between contingent and discriminative stimuli. As in the normal symmetry tests in Exps. 1 and 2, Chloe was given three sessions, which consisted of 144 baseline and 8 test trials for each test. As shown in the right of Fig. 1, only the auditory-visual contingent stimuli were presented as samples on the test trials. No responses were required during the contingent stimuli. The termination of the contingent stimuli immediately resulted in the presentation of the two comparisons. As in Exp. 2, contingent stimuli did not appear after the choice response.

The two series of tests were as follows: (1) matching from contingent stimuli to colors, in which color comparisons followed the contingent stimuli in the test trials, (2) matching from contingent stimuli to shapes in which shape comparisons followed the contingent stimuli. Each test yielded 24 test trials.

Results

The right of Fig. 2 on p. 55 shows the accuracies of baseline arbitrary matching from colors to shapes and of those of the test trials of the two series of tests. On the first test of matching from contingent stimuli to colors, the subject showed significant choices of the color comparison stimuli that corresponded to the preceding auditory-visual stimuli (70.8%, $p < .05$). On the second test of matching from contingent stimuli to shapes, however, she showed a consistent tendency to choose the circle comparison.

GENERAL DISCUSSION

One of the three young chimpanzees, Chloe, showed statistically significant emergence of associative symmetry in Exp. 1 in which the minimum number of stimuli were employed (i.e., two 2-member classes). This was the first demonstration of symmetry in nonhuman subjects who had no experience with language-like skills. The symmetry shown by Chloe, however, was not as robust as that by humans, because she also showed significant stimu-

lus preference at the same time. Nevertheless, it should be noted that Chloe showed a perfect performance of symmetry in the first test session. It is likely that later decline of this performance in the second and third sessions was due to repeated extinction of her performance on the test trials. The other two subjects, Popo and Reo, however, showed no signs of the formation of associative symmetry. These results agree with other researchers who suggest that the ability to acquire the bidirectional relationships between stimuli would be limited even in chimpanzees (Hayes, 1989; Yamamoto & Asano, in press).

The results of Exp. 2 also suggest that the auditory-visual stimuli contingent to the sample and comparison stimuli may have had some facilitative effects on the development of symmetry. Also, in the second test in the baseline dependent condition, Chloe showed 87.5% correct choices in the trials. This performance is comparable to that of standard symmetry tests in human children (Devany, *et al.*, 1986). In her history of matching-to-sample training, Chloe tended to show emotional "error bursts" after incorrect choices. The baseline-dependent insertion of test trials appears to have reduced such disruption of her performance in the test trials.

Chloe also could use contingent stimuli as the samples to select the appropriate color comparisons on the first test of Exp. 3. In fact, Dube, *et al.* (1987) demonstrated that, when reinforcers were differentiated according to the identity of stimulus classes, the reinforcers themselves became members of the same equivalence classes. The results of the first test of Exp. 3 suggested that the differential contingent stimuli following samples might have similar effects. However, the subject showed no associations between the contingent stimuli and the shapes in the second test of Exp. 3. It is possible that these associations were blocked by a long preceding history of training to match colors to shapes.

In animals, the differentiations among responses, reinforcers, and also contingent stimuli facilitate the formation of stimulus equivalence (Peterson, 1984; McIntire, *et al.*, 1987). In humans, on the other hand, without these explicit differentiations, stimulus equivalence easily emerged (Devany, *et al.*, 1986; Sidman & Tailby, 1982). Research with animals on stimulus equivalence suggests that the implicit mediations between stimuli such as verbal responses or "common codes" with regard to the samples (Urcuioli, *et al.*, 1989) may underlie the processes of the formation of equivalence classes in humans. To study stimulus equivalence in animals with the overt mediating behaviors or events may provide some useful suggestions for understanding humans' stimulus equivalence.

In conclusion, the present experiments showed the results as follows. (a) A chimpanzee had an ability to acquire associative symmetry in the standard arbitrary matching-to-sample discrimination. (b) The differential contingent

stimuli that simply followed each member of the same stimulus class might facilitate the development of associative symmetry. (c) Such contingent stimuli might be enrolled in each equivalence class.

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