*A SEARCH FOR SYMMETRY IN THE CONDITIONAL
DISCRIMINATIONS OF RHESUS MONKEYS,
BABOONS, AND CHILDREN*

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Procedures for generating arbitrary matching-to-sample performances may generate only conditional discriminations. Rational grounds for this distinction are proposed, based on the properties that any equivalence relation must possess. Empirical tests are described for determining whether subjects trained on conditional discriminations are also engaged in true matching to sample. A series of studies then leads to the conclusion that proof of true matching to sample by monkeys, pigeons, or baboons is yet to be provided. Whether the absence of such proof reflects experiential factors or species-defined limitations is not presently clear.

Key words: conditional discrimination, matching to sample, stimulus equivalence, stimulus classes, stimulus control, key press, monkeys, baboons, children

A commonly used experimental arrangement presents a subject with two discriminative stimuli simultaneously, perhaps a vertical and a horizontal line, while a third stimulus, perhaps a green or red hue, determines the positive or negative function of each line. Proce-

durally, the relation of the hues to the lines is that of conditionality, or "if . . . then . . ." (for example, if green, then vertical; if red, then horizontal). The line discriminations are conditional; hues are the conditional stimuli.

Assumptions that extend the relations between stimuli beyond the procedurally defined conditionality reveal themselves when we call the behavior generated by the procedure "matching to sample." An important special case is identity matching. The vertical discriminative stimulus (comparison) may be positive when the conditional stimulus (sample) is also vertical, with the discrimination reversing when the sample changes to horizontal. Experimenters often assume that for their subjects, too, these stimuli bear a relation to each other not only of conditionality but of sameness, or identity. This need not be so. Carter and Eckerman (1975) have presented data which suggest that "identity matching" can be a misnomer. For pigeons, a red sample and comparison may be as different from each other as a red sample and a vertical comparison. For experimenters working with pigeons, then, matching to sample may be a case of mistaken identity.

The distinction between conditional discrimination and matching holds also when all the stimuli are different—to subjects and experimenter. By adding the qualifiers, "non-identity," "arbitrary," or "symbolic" to the term, "matching to sample," investigators re-

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veal their assumption that the procedure generates another stimulus relation besides conditionality. Although the assumed relation cannot be identity, it can be equivalence. Matching to sample, therefore, sometimes refers not simply to the identity relation between a conditional and a correlated positive stimulus, but to the more general equivalence relation. (Identity itself can be shown to be an equivalence relation.)

An example may suggest why many of us have overlooked the possibility that the conditional-discrimination procedure may generate nothing more than conditional relations, assuming instead that the procedure also generates equivalence relations. Suppose the conditional stimuli, hues, control discriminations not just among simple tilted lines but among lines of greater complexity—the printed words *red*, *green*, and their like. By calling a subject's performance "matching," we imply that each color and its correlated word comprise a class of equivalent stimuli, permitting us to say, "The words are symbols for the colors," or "The colors are the meanings of the words," and to include such tasks in tests of simple reading comprehension. Equivalence is a tempting assumption, transforming a conditional discrimination into a semantic process and supporting the notion that arbitrary matching to sample is a linguistic performance. If the assumption were valid, it would permit us to adopt conditional discrimination as a procedural model for studying aspects of language even in nonhuman animals.

The Equivalence Relation

We cannot tell by looking at a subject's conditional-discrimination performance whether or not it involves true matching to sample. Although conditionality is directly inferable from current behavior, additional tests are necessary to validate an inference of equivalence.

Suppose conditional stimulus *a* controls a discrimination in which *b* is positive. The procedurally defined relation *R* between stimuli *a* and *b* is the conditional relation *aRb*. If *aRb* also satisfies the properties of an equivalence relation, the stimuli will be members of a class of equivalent elements, and we can call the subject's performance "matching to sample." Table 1 summarizes the mathematical definition of the equivalence relation. A relation *R*

Table 1
The Equivalence Relation

<i>Equivalence Relations must be:</i>
1. Reflexive: <i>aRa</i>
2. Symmetric: If <i>aRb</i> , then <i>bRa</i>
3. Transitive: If <i>aRb</i> and <i>bRc</i> , then <i>aRc</i>

must possess all three listed properties—reflexivity, symmetry, and transitivity—in order to fulfill the definition of an equivalence relation.

The reflexive property requires the relation *R* to hold between each stimulus and itself. If *R* were the relation "larger than," reflexivity could not be satisfied; a stimulus cannot be larger than itself. If *R* is the conditional relation, reflexivity requires "if *a*, then *a*," "if *b*, then *b*," etc. to hold true. Successful identity matching is a necessary consequence of reflexivity, which therefore conveys the notion of sameness.

The identity-matching procedure, however, does not definitively test reflexivity unless we have correctly identified the stimuli that control the subject's behavior. If, for example, control by the lines depended on their location on the left or the right key (given the usual arrangement in which the conditional stimulus is on the center key, and the others are on the outer keys), the subject might not match vertical to vertical, and horizontal to horizontal, but rather, vertical/center to vertical/left and vertical/right, and horizontal/center to horizontal/left and horizontal/right. The experimenter's presumption of identical stimuli would then be incorrect, and a performance that looked like identity matching would not be; to conclude that one was testing the relation *R* for reflexivity would be invalid. A definitive indicator of true identity matching, and therefore of reflexivity, is generalized identity matching. Successful generalized matching confirms reflexivity for each relation that is tested.

Symmetry requires the relation *R* to hold bidirectionally between two different stimuli. If sample *a* bears a conditional relation to comparison *b* (*aRb*), the relation must also hold when *b* is the sample and *a* is the comparison (*bRa*); symmetry requires sample and comparison to be interchangeable. A subject who has learned to select vertical when the sample is green should, given the opportunity, select green when the sample is vertical.

The final requirement, the transitive property, must hold for the relation among three stimuli. Before one can test R for transitivity, the subject must acquire a second conditional discrimination in addition to aRb ; the former comparison b , now a sample, must control a discrimination in which a third stimulus c is positive (bRc). If the relation R is transitive, a subject who has learned, for example, to select vertical (v) when given a green (g) sample (gRv), and to select a triangle (t) when the sample is vertical (vRt), should, when given the opportunity, also select the triangle when the sample is green (gRt).

A subject's failure in any one of these tests—generalized identity matching (reflexivity), sample-comparison interchangeability (symmetry), or appropriate sample-comparison recombination (transitivity)—would force a conclusion that the conditional-discrimination procedures did not generate matching-to-sample performances; R would not be an equivalence relation. If the tests verified all three properties, the conditional relation R would have met the requirements for an equivalence relation, thereby justifying the matching-to-sample terminology. One could then regard each sample and its matching comparison stimulus as equivalent members of a class, and the procedure as a model for studying the development, relevance, and other aspects of such classes.

With human subjects, generalized matching tests for reflexivity, along with a test that permits symmetry and transitivity to be evaluated simultaneously, have demonstrated equivalence relations in conditional discriminations (see Sidman & Tailby, 1982, for the rationale underlying this combined test). Retarded youths became able to match pictures to their printed names after being taught to select each picture and its printed name (separately) conditionally upon the corresponding dictated name (Sidman, 1971; Sidman & Cresson, 1973). The emergence of new relations between printed words and pictures attested to the formation of three-member stimulus classes, each containing an equivalent dictated word, picture, and printed word. Numerous experiments in this laboratory (e.g., Lazar & Kotlarchyk, Note 2; Sidman & Tailby, 1982; unpublished data) have systematically replicated this finding with normal children also.

We have, however, been unable to demon-

strate to our satisfaction that monkeys' conditional discriminations can properly be called matching to sample. The major purpose of this paper is to describe some experiments that failed to reveal equivalence relations in the conditional-discrimination performance of rhesus monkeys—a failure that was confirmed with baboons. The experiments to be described represented our first approach to this problem; we asked whether the animals' performances satisfied the symmetric property of an equivalence relation. In the course of these experiments, we also obtained some data on transitivity. Although Hogan and Zentall (1977), Holmes (1979), and Rodewald (1974) have reported failures to find symmetric relations between the stimuli in pigeons' conditional discriminations, several variables that might have contributed to the absence of symmetry still require investigation. The present experiments, in addition to testing for symmetry with other species of subjects, will provide some of the information needed for a more definitive judgment.

GENERAL METHODS

The general subject, apparatus, and procedure specifications will apply to all experiments unless specific exceptions are noted.

Subjects

In all but two experiments the subjects were adult rhesus monkeys, *Macaca mulatta*. Before becoming experimental subjects, and later, when nearing the end of "vacations" from experimental regimens, the animals were fed, at fixed times, enough to maintain their weights as close as possible to free-feeding levels. With any remaining food being removed one hour later, the animals learned to take their full ration. An animal that did not obtain its full ration in an experimental session received the remainder one-half hour after returning to its home cage. Up to Experiment 4, the monkeys underwent five experimental sessions, each no more than two hours long, in successive two-week periods; one week, sessions took place on Monday, Wednesday, and Friday, and the monkey received its daily ration in the home cage on Sunday; the next week, sessions took place on Tuesday and Thursday, with a home-cage feeding on Saturday. During Experiment 4 the animals had a 1.5-hr session every weekday.

Both schedules maintained sufficient deprivation to ensure several hundred trials per session and at the same time kept the animals' weights close to free-feeding levels. In the event of excessive pausing or high error rates late in training sessions, the daily ration was reduced slightly until the performance became more stable.

Apparatus

The animals' experimental environment, a sound-attenuating, fan-ventilated chamber, was in the same room as the programming and recording equipment. The portion of the chamber that held the monkey was 63 cm high, 61 cm wide, and 59 cm deep. One stainless-steel inner wall, opposite the access door, contained a five-key touch-sensitive stimulus-response matrix, a trial-initiation key that operated a limit switch, two pellet dispenser trays, and a houselight. Figure 1 diagrams the keys and feeder tray. The trial-initiation key, 3.2 cm in diameter, was mounted on the vertical midline, its center 16 cm above the grating floor. The five stimulus-response keys were each 3.0 cm in diameter. Four were located at the corners of a 9-cm square (measured from the centers of the keys), with the fifth in the square's center. The matrix, on a circular black Plexiglas surround, was mounted with the center of the middle key at the vertical midline, 35.5 cm above the floor. Pellet trays on each side of the matrix, 22 cm above the floor and 19 cm to the

Fig. 1. Diagram (not to scale) of keys and feeder trays in the monkey chamber. The trial-initiation key (TI) was located below the matrix of stimulus-response keys (1-5). Sample stimuli always appeared on Key 3, and comparison stimuli on Keys 1, 2, 4, and 5 (two per trial). If the correct stimulus was on Key 1 or 4, the pellet was delivered to the left tray (FL); if the correct stimulus was on Key 2 or 5, the pellet was delivered to the right tray (FR).

left and right of the vertical midline, received Noyes 1-g banana pellets. A 60-W Sylvania Lumiline houselight, protected by an aluminum grill, was mounted above the key matrix, its top 55 cm above the floor.

An IEE projector (Grason-Stadler #A509-2A, Stimulus Pattern 156) behind each key of the matrix provided the stimuli, red or green patches filling the key, or a vertical or horizontal white line, .3 by 1.8 cm, on a black background. The trial-initiation key could be illuminated from the rear by two clear 7.5-W bulbs. A punched-tape reader programmed sequences of stimuli and trial types; solid-state equipment programmed the procedures. Events of interest were recorded on electromechanical and electronic counters, with temporal relations and other details being preserved by an Esterline 20-pen event recorder.

Procedures

Five minutes after an animal entered the experimental chamber the houselight signaled the start of a session and remained on until the session ended. The animal stayed in the darkened chamber for an additional five minutes before being taken back to its home cage.

Preliminary training. Animals first received magazine training, with pellets delivered unpredictably to either the left or the right tray. An autoshaping procedure (Brown & Jenkins, 1968; Sidman & Fletcher, 1968) then taught them to press the keys. All stimuli to be used later appeared on each key in a mixed sequence, one stimulus and one key per trial. If the stimulus appeared on the center key, the pellet was delivered alternately to the left or the right tray; on other trials the pellet dropped into the tray on the same side as the lit key. Once the animal reliably pressed the lit key, and only the lit key, within eight seconds, autoshaping contingencies ceased.

Each trial in the next stage began with a stimulus on the center key. By pressing the center key, the animal produced a stimulus on one of the four outer keys of the matrix but no pellet. The center key stayed on. Pressing the outer key then produced a pellet and a five-second intertrial interval. Only one comparison key had a stimulus on it, the stimulus that was to be correct for the sample during conditional-discrimination training. In this and all subsequent training and testing procedures, pressing a dark key during a trial had

no consequence except to activate a recorder pen.

The next stage required the animal to press the illuminated trial-initiation key to produce a sample; when the sample came on, the trial-initiation key became dark. Pressing the center key then produced a comparison, and pressing that key produced a pellet and the intertrial interval. The animals then learned to press the trial-initiation key five times to produce a sample and thereby initiate a trial. The trial-initiation key permitted animals to pace their own trials.

The final step introduced one incorrect stimulus along with the correct comparison after the animal pressed the sample key. This marked the start of conditional-discrimination training. The sample remained on Key 3 (Figure 1). Comparisons, only two per trial, appeared on outer Keys 1, 2, 4, and 5; on any conditional-discrimination trial, two outer keys had stimuli projected on them and the other two were dark.

Each combination of stimuli and keys occurred equally often. With only two kinds of trials, as in the green/red identity-matching procedure, no more than three of the same type could occur consecutively. With more than two kinds of trials, all sample-comparison combinations had to occur before any could repeat. Also, all four comparison keys had to be scheduled as correct before any could be correct again. With those exceptions, all trial types and correct keys were equally probable on successive trials. Tape loops programmed sequences of 192 to 640 trials, depending on the number of trial types. Each session began with the trial that would have come up next at the end of an animal's previous session. Session durations and trials per session varied from animal to animal and in different stages of the experiments. Fewer trials had to be scheduled in sessions when a food pellet followed each correct trial than when leaner reinforcement schedules prevailed (see below).

When an animal pressed the correct comparison key a pellet dropped into the tray on the same side of the matrix as the correct key, all keys became dark, and the intertrial interval began. Except for the pellet, the same consequences followed an incorrect response. The procedure was noncorrection; errors did not cause trials to be repeated. Intertrial intervals lasted at least five seconds, but could not

terminate sooner than five seconds after the animal pressed any dark key.

Conditional-discrimination training. Monkeys R46 and R47 first had line-line training (line sample and line comparisons). The animal received a pellet if it pressed the vertical comparison when the sample was also vertical, and the horizontal comparison when the sample was horizontal. Because Monkeys R46 and R47 had great difficulty learning the line-line task, they were taught to respond differentially to each sample line. Five responses (FR) were required to vertical samples, and a pair of responses spaced two seconds apart (DRL) was required to horizontal samples before the comparison stimuli would be presented. The animals' accuracy quickly rose above 90%, confirming the facilitative effect of sample schedules reported by Cohen, Looney, Brady, and Aucella (1976), who used pigeons. Both monkeys then learned hue-hue (hue sample and hue comparisons) without differential sample schedules, pressing the green comparison when the sample was also green, and red when the sample was red.

Before starting the present experiments, Monkey R44 had learned successive reversals of green/red and vertical/horizontal simultaneous discriminations. Perhaps because of its history, Monkey R44 learned the line-line task without differential sample schedules.

All animals finally had sessions with line-line and hue-hue trials mixed. Before starting the experiments to be reported here, they underwent tests with simultaneous- and delayed-matching procedures in which sample schedules, where used, were removed and reinstated.

Symmetry testing. In symmetry tests, new trial types were inserted as probes into a baseline of previously learned conditional discriminations, with all types of trials occurring equally often. Some experiments provided reinforcement on all correct trials, baseline and probes. Others provided reinforcement only on correct baseline trials, never on probes. In preparation for these extinction tests, before probes were actually inserted, the reinforcement probability on correct baseline trials was gradually reduced from 1.00 to .2. This reduction usually took place in steps of .1, and at least 90% of the trials had to be correct before a change. Occasional decreasing accuracy trends were halted by increasing the reinforcement probability and then using a stricter

criterion while bringing the probability down again. At the final level, .2, at least 90% of each baseline trial type had to be correct in each successive 25-trial block during two consecutive sessions. Then, since no probes would be reinforced, the reinforcement probability on baseline trials during the test was increased sufficiently to maintain the overall probability at .2. The output of a probability gate (BRS/LVE PP-201) was modified to permit no more than nine consecutive correct baseline trials to go unreinforced.

EXPERIMENT 1

In asking whether monkeys' conditional discriminations satisfied the symmetric property of an equivalence relation, we at first simply added a few control features to the basic procedures used in the pigeon experiments (Hogan & Zentall, 1977; Holmes, 1979; Rodewald, 1974). Table 2 summarizes the conditional discriminations. The stimuli in each numbered line—a sample and two comparisons—define a trial type. Each pair of trial types, numbered 1 to 4, is a conditional discrimination with two components, A and B.

The line-hue trial types, 3A and 3B, were of particular concern. Having learned this conditional discrimination, was an animal also doing arbitrary matching to sample? Was the relation between each line sample and its correct hue comparison just "if-then," or was it also equivalence? Had vertical and green be-

come members of one stimulus class, and horizontal and red members of another class?

Trial types 4A and 4B constituted the symmetry test. Hues, formerly comparisons, now became samples; lines, formerly samples, became comparisons. If the sample-comparison relations were symmetric, the animal would now select vertical when given a green sample, and horizontal when given a red sample.

Symmetry might fail to emerge in trial types 4A and 4B simply because a subject lacked experience with lines as comparisons, or hues as samples. Line-line (trial types 1A and 1B) and hue-hue training (2A and 2B) gave subjects experience with lines and hues in a context of conditional discrimination. Then, maintaining conditional discriminations 1, 2, and 3 during the symmetry test provided an ongoing baseline of prerequisite discriminations from which symmetry might emerge, and permitted the experimenters to monitor those discriminations.

Although test procedures differed for each monkey (see below), the general training and testing sequence went as follows: animals first had line-line and hue-hue training, trial types 1A, 1B, 2A, and 2B. This gave them experience with lines and hues as samples and comparisons. They then had line-hue training; 3A and 3B were interspersed among the four previously learned trial types. With vertical samples, animals learned to select green, and with horizontal samples, to select red. Finally, with all six trial types mixed together as a baseline,

Table 2

Conditional discriminations and sample schedules (where used) in Experiments 1, 3, and 5. Where neither FR nor DRL is indicated, a single sample response sufficed to produce the comparisons. (Monkey R44 never had sample schedules, and in Experiment 3, only Subjects J. G. and A. B. had sample schedules.) Trial Types 1A, 1B (line-line), 2A, and 2B (hue-hue) were to provide discriminative prerequisites for the symmetry test. The starred Trial Types 3A and 3B (line-hue) constituted the critical conditional discrimination that was to be tested for symmetry. Trial Types 4A and 4B (hue-line) constituted the symmetry test. Symmetry-test sessions included all eight trial types.

SAMPLE		COMPARISONS	
STIMULUS	SCHEDULE	CORRECT	INCORRECT
1A VERTICAL	FR	VERTICAL	HORIZONTAL
1B HORIZONTAL	DRL	HORIZONTAL	VERTICAL
2A GREEN	—	GREEN	RED
2B RED	—	RED	GREEN
*3A VERTICAL	FR	GREEN	RED
*3B HORIZONTAL	DRL	RED	GREEN
4A GREEN	—	VERTICAL	HORIZONTAL
4B RED	—	HORIZONTAL	VERTICAL

the last two, 4A and 4B, were inserted as symmetry probes. If the line-hue relations in conditional discrimination 3 were symmetric, the animals would now select vertical when the sample was green, and horizontal when the sample was red, although they had never been explicitly trained to do so.

METHOD

Subjects

Monkeys R44, R46, and R47 were subjects. Monkey R44 had a previous symmetry test in Experiment 2 before taking part in Experiment 1.

Training and Testing Procedures

Sample schedules. Table 2 also shows sample schedules, which, as noted earlier, were introduced because of difficulty in training Monkeys R46 and R47 on the line-line conditional

discrimination (1A and 1B). This difficulty persisted for conditional discrimination 3, in which lines again were samples, so schedules were used also in teaching them the line-hue task.

Cohen, Brady, and Lowry (1981) and Urcioli and Honig (1980) have suggested that schedule-generated behavior may actually take over the sample function from stimuli projected on the keys, in a manner reminiscent of coding responses (Lawrence, 1963; Schoenfeld & Cumming, 1963). Before Monkey R47's first symmetry test, therefore, attempts were made to remove the schedule requirements—by turning on the comparisons as soon as the animal pressed the sample key just once. Monkey R47 was unable to maintain both the line-line and the line-hue performances without schedules, but with schedules for line-line only, the line-hue performance eventually met criterion. After the schedules had been used during original acquisition, therefore, they were maintained as shown in Table 2 for Monkey R46 only; Monkey R47 kept the schedules in trial types 1A and 1B, but not in 3A or 3B. Monkey R44 never had differential sample schedules.

In the course of attempts to remove the sample schedules, Monkey R47's comparison keys were permanently reduced from four to two. Samples still appeared on Key 3, but comparisons only on Keys 4 and 5 (Figure 1); Keys 1 and 2 remained dark and without function.

Symmetry tests. After Monkeys R44 and R46 had learned the line-hue conditional discrimination, the reinforcement probability for all six trial types was reduced. Trial types 4A and 4B were then inserted into the sparsely reinforced baseline as unreinforced probes for symmetry. Monkey R47 had two symmetry tests, both of which provided reinforcement on all correct trials, baseline and probe. On probe trials, responses indicative of symmetry were arbitrarily designated as correct.

RESULTS AND DISCUSSION

Figure 2 contains the probe-session results for Monkeys R44 and R46. Individual scores for each trial type make it possible to detect patterns of stimulus control that the customary accuracy measure might obscure (Sidman, 1980). Since each nonoverlapping pair of bars represents a conditional discrimination, averaging the pair would yield the usual accuracy

Fig. 2. Performances by Monkeys R46 and R44 during the symmetry-probe session of Experiment 1. Bars depict the percentage of correct responses for each trial type. Stimuli for each trial type are identified at the bottom of the bars, and a line connects each sample to its correct comparison. The bars, from left to right, correspond to trial types that are listed, from top to bottom, in Table 2. Asterisks denote the line-hue trial types tested for symmetry, and the two righthand bars for each animal depict the hue-line symmetry probes. Probes were unreinforced. Each bar represents approximately 95 trials for Monkey R46, and 65 trials for Monkey R44. Only Monkey R46 had line-sample schedules.

score. The first three pairs of bars for each subject show baseline performances within the test session, and the final two bars the symmetry probes.

All baselines were above 90% correct. Line-line performances (the first two bars for each animal) were nearly perfect, as were hue-hue (the second pair of bars). Bars with asterisks show the maintenance of high line-hue scores—vertical samples matched to green comparisons, and horizontal samples to red comparisons. The final two bars for each animal represent the hue-line probes for symmetry. (Probe-trial responses indicative of symmetry were arbitrarily designated as correct. Subsequent figures will follow this practice.) One animal slightly preferred the vertical comparison, and the other the horizontal; average scores on symmetry trials were 55 and 52% for Monkeys R46 and R44, respectively. The animals did not reverse the sample-comparison roles of lines and hues; they gave no evidence of symmetry.

Monkey R47's first hue-line probes averaged only 56% correct, but line-hue trial type 3A in the baseline also dropped to 76%. After another criterion session of baseline trials alone, summarized in the left side of Figure 3, the animal received a second test. The right side of Figure 3 shows an average of only 49% correct on the probes. Correct probe trials did not become more frequent as the sessions progressed. Again, there was baseline disruption, most severe this time in the hue-hue trials. Even in its second session with reinforcement on correct probe trials, this animal performed no better on symmetry probes than did others in their extinction tests.

Probing in extinction, however, did not affect the other animals' baselines, even though they received only infrequent reinforcement. The left side of Figure 3 shows that all trial types were above 90% during the session before the probes; this typical stability indicates that the baseline deterioration during the next session came about because of the reinforcement on correct probe trials and was not a paradoxical effect of reinforcement on the baseline trials. It seems reasonable to assume that reinforcement on probe trials would not have disrupted the baseline if the conditional relations being tested were symmetric. The significance of the probe performance itself is

somewhat diminished by the poorly maintained baseline, but insofar as the baseline deterioration can be attributed to the probe-trial reinforcement, the test does bolster the evidence against symmetry. Hogan and Zentall (1977) used a similar rationale for the design of some of their symmetry tests.

In line-hue trial types 3A and 3B the animals had apparently learned only a conditional relation between each sample and its correct comparison and gave no evidence for the formation of equivalence relations. They were unable to match the stimuli when the original samples became comparisons, and the original comparisons became samples, and provided no justification for calling their performance matching to sample.

EXPERIMENT 2

Is it sufficient to say that the conditional relation is, "If the sample is vertical, then green is the correct comparison," or must one also specify the incorrect comparison? Would it be more correct to say that the conditional relation is, "If the sample is vertical and the comparisons are green *and* red, then green is the correct comparison"?

Farthing and Opuda (1974) presented pigeon data indicating that the incorrect comparison is irrelevant to the relation between sample and correct comparison. Nevertheless, the problem requires specific resolution in the present context. If a complete definition of the conditional relation had to include incorrect stimuli, then a valid symmetry test would require sample and correct comparison to be interchangeable only when the original incorrect comparison was also present. Experiment 1, however, not only interchanged samples and correct comparisons but also changed the incorrect comparisons from hues to lines (Table 2). In Experiment 2, therefore, the symmetry test substituted samples and correct comparisons for each other, whereas incorrect comparisons remained unchanged.

Table 3 summarizes the conditional discriminations. Trial types 1 and 2 were the same as in Experiment 1. Asterisks mark the relations to be tested for symmetry: in 3A, the sample was vertical and the correct comparison green, as in Experiment 1, but the incorrect comparison was now horizontal instead of red; in 4B

Fig. 3. Monkey R47's performances during Experiment 1's symmetry test (right side) and the preceding baseline session (left side). Bars depict the percentage of correct responses for each trial type (corresponding to Table 2). Stimuli for each trial type are identified at the bottom of the bars, with a line connecting each sample to its correct comparison. Asterisks denote the line-hue trial types tested for symmetry, and the two righthand bars depict the hue-line symmetry probes. All correct trials, including probes, were reinforced. Each bar represents 35 to 40 trials. Only line-line trials had differential sample schedules.

Table 3

Conditional discriminations in Experiment 2. Trial Types 1A, 1B, 2A, and 2B are the same as in Experiment 1. The starred Trial Types 3A and 4B maintain the same line samples and correct hue comparisons as the starred Trial Types in Table 2, but now the incorrect comparisons are lines instead of hues. Trial Types 3B and 4A were included in order to maintain conditionality in the line-hue relations. Trial Types 5A and 5B, the symmetry test, now maintain the same incorrect comparisons as Trial Types 3A and 4B. Symmetry test sessions included all 10 trial types.

SAMPLE	COMPARISONS	
	CORRECT	INCORRECT
1A VERTICAL	VERTICAL	HORIZONTAL
1B HORIZONTAL	HORIZONTAL	VERTICAL
2A GREEN	GREEN	RED
2B RED	RED	GREEN
*3A VERTICAL	GREEN	HORIZONTAL
3B HORIZONTAL	HORIZONTAL	GREEN
4A VERTICAL	VERTICAL	RED
*4B HORIZONTAL	RED	VERTICAL
5A GREEN	VERTICAL	HORIZONTAL
5B RED	HORIZONTAL	VERTICAL

the sample was horizontal and the correct comparison red, but the incorrect comparison was now vertical instead of green. The symmetry test, 5A and 5B, again had former correct comparisons, green and red, as samples, and former samples, vertical and horizontal, as correct comparisons. The incorrect comparisons, horizontal and vertical, remained unchanged from trial types 3A and 4B.

What was the function of trial types 3B and 4A? Without 3B, animals might have learned to respond correctly on 3A even while ignoring the sample simply by selecting green whenever a green and a line comparison were present together. Inclusion of 3B required control by the sample if the animals were consistently to choose correctly between green and horizontal. Similarly, trial type 4A made control by the sample necessary for correct choices between red and vertical.

METHOD

Subjects

Monkey R44 had its first symmetry test in this experiment. The probes, carried out in extinction, will not be described here. Its second test, also in extinction, was reported in Experiment 1. Then came two delayed-matching tests (zero delay), the first in extinction and the next with reinforcement on all correct trials.

These, also, will not be reported here. The baseline for Experiment 2 was then reinstated in preparation for the test to be reported next.

Procedures

The sequence of training and test procedures was similar to Experiment 1. After line-line and hue-hue training, trial types 3A, 3B, 4A, and 4B, with mixed line and hue comparisons, were interspersed among 1A, 1B, 2A, and 2B. Symmetry probes (5A and 5B) were introduced into this baseline of eight different trial types, with reinforcement on all correct trials.

RESULTS AND DISCUSSION

The right side of Figure 4 presents percentages of correct trials of each type during the probe session. Again, asterisks denote baseline trial types that were tested for symmetry. The animal performed no better on the symmetry probes than it did during Experiment 1. (These results were also consistent with the probes in the unreported delayed-matching tests.)

Reinforcement on correct probe trials, however, disrupted the baseline. Each line-line trial type dropped to 89%, trial type 3B (H-HG) dropped to 59%, and 4A (V-VR) to 83%. Although 3A and 4B remained high, the decreases in 3B and 4A indicated considerable change in conditional discriminations 3 and 4 during the test. Probing in extinction had never affected this animal's baseline. Because of the disruption, the left side of Figure 4 shows the preceding baseline session. As with Monkey R47 in Experiment 1, the baseline disruption appeared to be a consequence of reinforcing the symmetry probes and provided additional evidence against symmetry. Baseline performances most severely affected by the reinforcement on correct probe trials involved identical sample and correct comparison lines, but failures to replicate this relation obscured its significance.

Even with incorrect comparisons held constant, a sample and its correct comparison were not substitutable for each other. The revised test was no more successful than the test in Experiment 1 in demonstrating symmetry. The conditional discriminations did not generate classes of equivalent stimuli, and the term *matching to sample* did not appear applicable.

Fig. 4. Performances by Monkey R44 during Experiment 2's symmetry test (right side) and the preceding baseline session (left side). Bars depict the percentage of correct responses for each trial type (corresponding to Table 3). Stimuli for each trial type are identified at the bottom of the bars, and a line connects each sample to its correct comparison. Asterisks denote the line-hue trial types (with lines as incorrect comparisons) tested for symmetry, and the two bars at the extreme right depict the hue-line symmetry probes. All correct trials, including probes, were reinforced. Each bar represents approximately 35 trials.

EXPERIMENT 3

A major justification for stressing the importance of symmetry has been the demonstration that the conditional-discrimination procedure does establish equivalence relations when the subjects are retarded teenagers (Sidman, 1971; Sidman & Cresson, 1973; Sidman, Cresson, & Willson-Morris, 1974; Spradlin, Cotter, & Bax-

ley, 1973), normal children (Lazar & Kotlarchyk, Note 2; Sidman & Tailby, 1982), and normal adults (Lazar, 1977). The human subjects, however, did not learn the same conditional discriminations as the monkeys, nor were the methods of testing for equivalence relations the same. Is it possible that the techniques used with monkeys would have failed to produce symmetry even with humans? Ex-

periment 3 attempted to answer this question by repeating Experiment 1 reasonably closely with children.

METHOD

Subjects

Six normal children, five boys and one girl, participated. Their ages (years-months) at the time of their symmetry tests were: 4-8 (C.H.), 4-8 (J.G.), 4-11 (P.L.), 5-2 (A.B.), 5-2 (J.L.), and 5-9 (K.O.). Each child, recruited by newspaper advertisements, came several days a week with a parent who was paid after each session. The number of sessions, each 15 to 30 minutes long, varied because the children required different amounts of baseline training.

Apparatus and General Procedures

The child sat before a stimulus-response matrix of nine translucent keys onto which stimuli were projected from the rear. The keys, each 7.3 cm in diameter, were arranged in a circle of eight, with the ninth in the center (Figure 5). The display diameter was 32.7 cm; the center-to-center distance was 9.5 cm between adjacent keys on the perimeter, and 12.7 cm between the center key and each of the others. Sample stimuli always appeared in the center, and comparison stimuli for a given trial appeared only on two of the four outer keys that formed the corners of a square (numbered 1, 2, 4, and 5 in Figure 5). A Kodak Carousel projector presented the stimuli, red or green patches filling the key, or a vertical or horizontal black line, .2 by 7.3 cm, on a white background. Solenoid-operated shutters

were mounted between projector and keys. There was no trial-initiation key.

When the subject pressed a key, a limit switch signaled the programming and recording equipment. A response was not defined until the key had been released for .2 sec; this permitted simultaneous pressure on more than one key to be defined as incorrect. Unless a reduced reinforcement probability or an extinction probe precluded reinforcement, correct trials were followed by the sound of chimes, the delivery of a penny into a receptacle below and to the left of the key matrix, and a 1.5-sec intertrial interval. The children kept all pennies they received. Only the intertrial interval followed incorrect responses.

Training and Testing Procedures

Training. Three children (C.H., P.L., and K.O.) had already taken part in an experiment on delayed hue-hue matching and needed no preliminary training for the present study. With the three experimentally naive subjects (J.L., A.B., and J.G.), the delivery of three pennies sufficed to accomplish magazine training. The experimenter then provided nonvocal instruction by pressing the keys appropriately for several trials in which a sample and only a correct comparison stimulus (see below) appeared. Each trial began with a stimulus on the center key. Pressing the center key produced a stimulus on one of the four outer keys while the center-key stimulus remained on. Pressing the outer key then produced chimes, penny, and a 1.5-sec intertrial interval.

The experimenter then ceased all demonstration and the children themselves pressed the keys, with instructions provided only by the reinforcement contingencies. Finally, both an incorrect and a correct comparison came on when the subject pressed the sample key. This marked the start of conditional-discrimination training, which followed the pattern of Experiment 1, as summarized in Table 2. Three children (P.L., A.B., and J.G.) learned hue-hue first, and the others learned line-line first. All four trial types (1A, 1B, 2A, and 2B) were then mixed together. The children then learned the line-hue task that was to be tested for symmetry.

Subject J.G. experienced great difficulty with the line-line conditional discrimination, and Subject A.B. learned line-line but then seemed unable to master line-hue. The sample sched-

Fig. 5. Diagram (not to scale) of the key matrix in Experiment 3. Samples always appeared on Key 3, and comparisons on Keys 1, 2, 4, and 5 (two per trial). The other keys were never used.

ules used with the monkeys (FR 5 and DRL 2-sec) were introduced to help the two children, and these had their intended facilitative effect.

All six trial types were then mixed, providing a baseline for the symmetry test. Subject A.B.'s sample schedules were removed, and he was able to maintain his performance. Reinforcement probability for correct baseline trials was then gradually reduced to .2.

Symmetry testing. Hue-line trials (4A and 4B, Table 2) were interspersed among the six types of baseline trials as unreinforced symmetry probes. Each test contained 72 trials, nine of each type.

At this point, only Subject J.G. still had sample schedules. After his test, reinforcement probability for baseline trials returned to 1.00 and sample schedules were eliminated. When he continued his criterion level of baseline performance, the reinforcement probability was once again reduced, and he had two additional tests.

Subject K.O. also had an additional probe. After her first test, she had baseline training with a delayed-matching (zero-delay) procedure. Reinforcement probability was then reduced once more, and the symmetry probe was repeated at zero delay.

RESULTS AND DISCUSSION

Figure 6 summarizes four of the six children's probe sessions. As before, asterisks mark the trial types being tested for symmetry, and the final two bars for each subject show the symmetry probes. Only Subject J.L. made as many as two errors on any trial type, baseline or probe. Unlike the three monkeys, these four children reversed the sample and comparison roles of lines and hues. Symmetry in the conditional relation between line samples and hue comparisons thereby satisfied one of the requirements for an equivalence relation.

A possibly major difference between the monkeys' and the children's symmetry tests was the smaller number of trials (only nine of each type, for a total of 72) given to the children. Examination of the first 72 trials in the monkeys' probe sessions, however, did not reveal any need to change our conclusion that they had failed to demonstrate symmetry.

The data for two children failed to prove symmetry. Figure 7-A summarizes Subject K.O.'s first symmetry test. Although her baseline remained quite stable, she clearly did not

Fig. 6. Performances by four children during symmetry tests in Experiment 3. Bars depict the percentage of correct responses for each trial type (corresponding to Table 2). Stimuli for each trial type are identified at the bottom of the bars, with a line connecting each sample to its correct comparison. Asterisks denote the line-hue trial types tested for symmetry, and the two right-hand bars for each subject depict the hue-line symmetry probes. Symmetry probes were unreinforced. These subjects had no differential sample schedules during test sessions.

reverse the sample and comparison roles of lines and hues. Her average score of only 17% on probe trials, considerably lower than the 50% "chance" level, might have suggested that the training actually generated strong "anti-symmetry." The score, however, was deceptive; on one-third of the probe trials Subject K.O. did not select the antisymmetric comparison, but instead, pressed both comparisons simultaneously.

Figure 7-B summarizes Subject K.O.'s second symmetry test, with the zero-delay matching procedure. During probe trials, which this time averaged 50% correct, she strongly preferred the vertical comparison. Although Hogan and Zentall (1977) and Gray (1966), who tested pigeons with zero delay, adduced statistical evidence for symmetry, their conclusion was not confirmed by Subject K.O. (or by the data, not presented, of Monkey R44). The zero-delay procedure did not suffice to transform the conditional relation into an equivalence relation.

In Subject J.G.'s first probe session (Figure 8-A), he averaged only 56% on probe trials. In his second test (Figure 8-B), after the sample schedules had been removed, his probe trial performance did not improve, but because of his decreased accuracy (78%) on line-hue baseline trials, he was retrained and tested once more. The third test (Figure 8-C)

Fig. 7. Performances by Subject K. O. during symmetry tests in Experiment 3. Bars depict the percentage of correct responses for each trial type (corresponding to Table 2). Stimuli for each trial type are identified at the bottom of the bars with a line connecting each sample to its correct comparison. Asterisks denote the line-hue trial types tested for symmetry, and the two right-hand bars in each panel depict the hue-line symmetry probes. Symmetry probes were unreinforced.

Fig. 8. Performances by Subject J.G. during symmetry tests in Experiment 3. Bars depict the percentage of correct responses for each trial type (corresponding to Table 2). Stimuli for each trial type are identified at the bottom of the bars, with a line connecting each sample to its correct comparison. Asterisks denote the line-hue trial types tested for symmetry, and the two right-hand bars in each panel depict the hue-line symmetry probes. Line-sample schedules were required only in Panel A.

shows a more adequate baseline but no improvement in the probes. With or without sample schedules, Subject J.G. gave no evidence of symmetry.

Unlike the three monkeys, four children showed symmetry in the relation between lines and hues. To the extent that Experiment 3 replicated the essential features of Experiment 1, one might conclude that the absence of symmetry in the monkeys' performances was not attributable to some procedural artifact. Two children, however, failed to show symmetry under conditions like those of Experiment 1. The possibility remained, therefore, that some aspect of the procedure was still responsible for the absence of symmetry in the performances of Subjects K.O. and J.G., and the monkeys. A reappraisal of the training and test procedures, and their rationale, led to changes in the baseline conditional discriminations, and the two children who had been exceptions joined the other four in yielding positive results in subsequent symmetry tests. Although the absence of controls for repeated testing clouded the relevance of these changes

(Spradlin, Cotter, & Baxley, 1973), the mere possibility that the new baselines might have been responsible for symmetry mandated similar training and test procedures for the monkeys.

EXPERIMENT 4

Among the prerequisites for the symmetry test were a successive discrimination between green and red samples, and simultaneous discriminations between vertical and horizontal comparisons. Experiment 3 brought about a reevaluation of the assumption that hue-hue and line-line training provided subjects with this prerequisite repertoire.

Consider first the successive green-red discrimination (4A and 4B, Figure 2). Probe trials presented either a green or a red sample, and the subject never viewed them together—the hallmark of a successive discrimination. Like the probes, trial types 2A and 2B also presented a separate green or red sample. Unlike the probes, once the comparisons had come on, green and red stimuli were present simultaneously. Although one was a sample and the other a comparison, a subject could view them together. At probe-trial choice points, either a green or a red stimulus was present, but not both; at hue-hue choice points, the subject could compare green with red directly. For this reason, the hue-hue task may not have required the subject to learn the particular successive discrimination that the probes demanded.

To help ensure that the monkeys learned a truly successive green-red discrimination in preparation for the symmetry probes, Experiment 4 changed trial types 2A and 2B from hue-hue to hue-form. Samples remained green and red, but the comparisons were now X and + (Table 4). Because of the change in the comparisons, green and red were no longer present together. Subjects now had to discriminate temporally separate instances of green and red stimuli, the same kind of discrimination that the probe trials required.

Probe trials also required simultaneous discriminations between vertical and horizontal comparisons. Although trial types 1A and 1B (Table 2) were supposed to teach these prerequisites, the discriminations in the line-line trials did not have to be the same as those in the probe trials. The probes required discriminations between lines that were located only on comparison keys, but a subject could learn the line-line performance by discriminating between the line on the sample key and the line on a comparison key. This discrimination would not be available on probe trials, and the subject might fail to show symmetry simply because it had never learned the necessary discriminative repertoire.

To give the monkeys discrimination training more like that required for line comparisons in the probes, Experiment 4 changed trial types 1A and 1B from line-line to form-line. The comparisons remained vertical and horizontal lines, but the samples were X and + (Table 4). Subjects now had to learn the same

Table 4

Conditional discriminations in Experiment 4. Trial Types 1A and 1B, with X and + as samples, were to establish the simultaneous comparison-line discriminations, and Trial Types 2A and 2B, with X and + as comparisons, were to establish the successive sample-hue discriminations required for the symmetry test. The starred Trial Types 3A and 3B (line-hue) constituted the critical conditional discrimination that was to be tested for symmetry. Trial Types 4A and 4B constituted the symmetry test. Test sessions included all eight trial types.

SAMPLE	COMPARISONS	
	CORRECT	INCORRECT
1A X	VERTICAL	HORIZONTAL
1B +	HORIZONTAL	VERTICAL
2A GREEN	X	+
2B RED	+	X
*3A VERTICAL	GREEN	RED
*3B HORIZONTAL	RED	GREEN
4A GREEN	VERTICAL	HORIZONTAL
4B RED	HORIZONTAL	VERTICAL

simultaneous line discriminations that were required during the probe trials; they had to discriminate between lines that were located only on comparison keys.

METHOD

Subjects

Monkeys R44 and R46 were subjects. Although they underwent different training procedures, they yielded similar probe results, and only Monkey R46's experiment will be described.

Procedures

The animal started with the hue-form conditional discrimination (Table 4, 2A and 2B) and learned it rapidly, but then had enormous difficulty with form-line (1A and 1B). Several procedural changes were instituted, both singly and in combination: trial types 1A and 1B were scheduled both with and without other baseline trial types; the sample was permitted to remain present for as long as two seconds after the animal had selected a comparison; and nine responses to the X and + samples were required before the comparison stimuli could appear. None of these had any clear beneficial effect, and all were terminated. A "yes-no" procedure, which Constantine (Note 1) had already analyzed extensively, was then used to teach Monkey R46 the successive discrimination between X and + samples.

In the "yes-no" procedure, trials began as usual with a sample presented on Key 3, but when the animal pressed the sample only one comparison stimulus appeared on Key 4 or Key 5. Sometimes the comparison was positive in relation to the current sample (Figure 9, A and C) and sometimes negative (Figure 9, B and D). The "yes" response, correct for positive and incorrect for negative trials, was to press the comparison stimulus within three seconds of its presentation; the "no" response, correct for negative and incorrect for positive trials, was to refrain from pressing the comparison for three seconds after its presentation. Either a correct "yes" (press within the three-second limited-hold period) or a correct "no" (three seconds without pressing) produced a food pellet; an incorrect press or wait ended the trial without a pellet.

The yes-no procedure was introduced in three steps, starting with trial types A and B (Figure 9), then adding the C-types, and finally the D-types. These steps also included temporary variations in the durations of the limited-hold and the waiting periods, and in the proportion of trials of each type given during a session. A correction procedure was also used for a few sessions. When the performance met the usual criteria, form-line training with the yes-no procedure was complete; the animal successfully learned the intended sample discrimination.

Fig. 9. Representations of stimulus displays in the "yes-no" procedure after a subject had responded to the sample and brought on a comparison stimulus. Samples ($\times$ or $+$) are depicted in the center, and comparisons (vertical or horizontal lines) on either side. Shading indicates a blank key.

Normal form-line trials (Table 4, 1A and 1B) were then interspersed among the yes-no trials. Although the animal had not learned trial types 1A and 1B in 130 previous sessions, it now exceeded the learning criteria almost immediately, and maintained excellent form-line performances even after yes-no trials were no longer presented. This positive transfer from the yes-no to the two-choice conditional discrimination confirmed Constantine's earlier finding with harbor seals (Note 1).

The other trial types were then added, and the animal met the performance criteria relatively rapidly on the full form-line, hue-form, and line-hue baseline (Table 4). Monkey R46 then had great difficulty maintaining its performance at reduced reinforcement probabilities, meeting the criteria only after the maximum number of consecutive unreinforced correct trials was limited to nine for each trial type individually. Symmetry-probe trials were then introduced, first in extinction and then with reinforcement on all correct trials.

RESULTS AND DISCUSSION

On probe trials in both sessions (Figure 10), the animal almost always selected the vertical (incorrect) comparison when the sample was red. A vertical (correct) preference in the presence of the green sample was less pronounced during the extinction test but increased markedly when a pellet was delivered on all correct trials. Baseline error patterns differed during the two tests, with trial type 3B showing some disruption in the extinction test, and trial type 1B slightly below criterion in the test with reinforcement. In neither test did the baseline errors seem severe enough to affect probe trials. Even the new baseline discriminations, therefore, which more explicitly required the kinds of stimulus control that the probe trials called for if symmetry were to emerge, did not bring out symmetry in the line-hue conditional discrimination.

The animals' low scores on hue-line probes also revealed the absence of transitivity (Table 1) in the baseline conditional discriminations. If the stimulus relations in conditional discriminations 1 and 2 were transitive, then, even without line-hue training, hue-form and form-line should have permitted the emergence of hue-line relations in the probe trials.

Fig. 10. Monkey R46's performances during its two symmetry tests in Experiment 4. Bars depict the percentage of correct responses for each trial type (corresponding to Table 4). Stimuli for each trial type are identified at the bottom of the bars, with a line connecting each sample to its correct comparison. Asterisks denote the line-hue trial types tested for symmetry, and the two righthand bars for each session depict the hue-line symmetry probes. In the session shown at the left, symmetry probes were unreinforced (EXT); in the session shown at the right, all correct trials were reinforced (CRF). Each of the lefthand set of bars represents 65 trials; each righthand bar, 23 trials.

EXPERIMENT 5

Whether the different outcomes in the experiments with monkeys and children arose from species-related or experiential factors, or both, is not at all clear at present (see General Discussion). Because tests with other species might help resolve the question, Experiment 5 repeated Experiments 1 and 3 reasonably closely with baboons as subjects.

METHOD

Subjects

Two baboons (*Papio anubis*) were subjects. At the time of their symmetry tests, Subject Bab-Sim was adolescent and Subject Bab-Win was adult. Bab-Sim was experimentally naive; Bab-Win had been confined in a restraint chair during a study that involved hue discriminations but had never been exposed to the chamber or the stimuli used in the present experiment, or to conditional-discrimination

procedures. Experimental sessions took place every weekday and on occasional weekends.

Apparatus

During experimental sessions a cage, like that used in the monkey studies but with dimensions appropriate to the larger animals, held the baboon within a sound-attenuated fan-ventilated chamber. A portion of one chamber wall, accessible to the animal through an opening in the cage, contained a horizontal row of three stimulus-response keys, each operating a limit switch when pressed. The keys were 3.2 cm in diameter, with a center-to-center distance of 4.4 cm between adjacent keys. Samples always appeared on the center key, and comparisons on the outer keys. Line and hue stimuli were the same as those in the monkey experiments. A pellet tray, located immediately below the center key, received Noyes 1-g banana pellets. Except for illumination provided by the projected stimuli, the chamber was always dark. There was no trial-initiation key.

Training

The baboons had preliminary training like the monkeys, but had no trial-initiation key. Conditional discriminations were the same as those in Table 2, but the baboons never had sample schedules.

Subject Bab-Sim learned line-line first. Hue-hue trials were then mixed with line-line. Adding line-hue trials then disrupted the line-line performance, so the animal was trained on line-hue alone before mixing all six trial types again. Reinforcement probability was then gradually reduced, as with the monkeys, and Subject Bab-Sim's first test had no reinforcement on probe trials. A second test on the next day gave reinforcement on all correct trials. Since some baseline disruption occurred during the first two tests, the animal had three more baseline sessions with 100% reinforcement, followed by a third probe like the second (reinforcement on all correct trials). Reinforcement on all eight trial types then continued for 20 more sessions.

Subject Bab-Win started with both line-line and hue-hue trials, then had line-hue alone, and finally had all six trial types mixed together. During this final baseline phase, the intertrial interval was increased to 10 sec and

remained at that duration. Subject Bab-Win had a single test, with reinforcement on all correct trials.

RESULTS AND DISCUSSION

Probe trials during Subject Bab-Sim's first test in extinction (left section of Figure 11) averaged 46% correct, with the animal manifesting a slight preference for the horizontal comparison on both hue-line (probe) and line-line (baseline) trials. In the second test, with reinforcement on all correct trials (center section of Figure 11), probes averaged 44% and the horizontal preference grew larger in both sets of trial types. Criterion baseline performances were then reestablished, in the hope of ruling out loss of the discrimination be-

tween vertical and horizontal comparisons as the source of the animal's difficulty with the probes. During the third test, with all correct trials again reinforced, probes still averaged only 48% (right section of Figure 26). Although the animal's comparison preference had now shifted strongly to vertical, the score of 88% on trial type 1B did not indicate sufficient baseline disruption to implicate a generalized loss of the line-line discrimination as the source of the animal's difficulty with the probes. It seems reasonable to conclude that baseline disruption was not responsible for the probe-trial performances but rather, that unspecified control generated in probe trials was responsible for the baseline disruptions. For example, a comparison-line preference that de-

Fig. 11. Baboon Bab-Sim's performances during its three symmetry tests in Experiment 5. Bars depict the percentage of correct responses for each trial type (corresponding to Table 2, but with no sample schedules). Stimuli for each trial type are identified at the bottom of the bars, with a line connecting each sample to its correct comparison. Asterisks denote the line-hue trial types tested for symmetry, and the two righthand bars for each session depict the hue-line symmetry probes. In the session shown at the left, symmetry probes were unreinforced (EXT); in the sessions shown in the center and at the right, all correct baseline and probe trials were reinforced (CRF). Each bar represents 48 trials.

Fig. 12. Baboon Bab-Sim's performances during its third symmetry test (Session 1) and the subsequent 20 training sessions. All correct baseline and probe trials were reinforced. Hue-hue (G-GR and R-RG), line-line (V-VH and H-HV), and line-hue (V-GR and H-RG) trials appear, respectively, in the topmost, second, and third panels; probe trials (G-VH and R-HV) are in the bottom panel. Each session had 300 to 360 trials.

veloped during probe trials might have caused the animal occasionally to ignore the sample and, instead, to select the preferred comparison even during baseline trials 1A and 1B.

Subject Bab-Sim's failure to reverse the sample-comparison roles of lines and hues was confirmed during subsequent training sessions, even with reinforcement on all correct trials (Figure 12). Throughout these sessions the animal maintained scores of 90% or better on hue-hue and line-hue trials (topmost and third panels, respectively). The line-line baseline and the hue-line probes (second and bottom panels, respectively) continued to fluctuate un-

til Session 13, with the probe scores always lower and more variable than the baselines. Generally, the comparison-line preference during line-line trials reflected the probe-trial preference but in reduced magnitude.

Subject Bab-Win's symmetry test, with reinforcement, showed the animal maintaining an excellent baseline while averaging only 49% correct on probes (Figure 13). The baboons, therefore, confirmed the monkeys' data both without and with reinforcement. They gave no evidence that their conditional-discrimination training had established symmetric relations between samples and correct comparisons.

Fig. 13. Subject Bab-Win's performance during its symmetry tests in Experiment 5. Bars depict the percentage of correct trials for each trial type (corresponding to Table 2, but with no sample schedules). Stimuli for each trial type are identified at the bottom of the bars, with a line connecting each sample to its correct comparison. Asterisks denote the line-hue trial types tested for symmetry, and the two righthand bars depict the hue-line symmetry probes. All correct baseline and probe trials were reinforced. Each bar represents 48 trials.

GENERAL DISCUSSION

Procedures that have become more or less standard (e.g., Cumming & Berryman, 1965) generated symmetry in the conditional discriminations of 5-year-old children, but not of monkeys or baboons. The failures confirmed and extended findings with pigeons (Hogan & Zentall, 1977; Holmes, 1979; Rodewald, 1974). Experiment 4 also proved transitivity to be absent in monkeys' conditional discriminations.

Because symmetry and transitivity are necessary properties of equivalence relations (Table 1), the absence of either was sufficient to disprove the inference that each sample and its arbitrarily corresponding comparison stimulus had formed a class of equivalent stimuli. The monkeys', baboons', and pigeons' conditional discriminations could not legitimately be called matching to sample. By extension, any previous interpretations of conditional discriminations (if . . . then relations) as matching to sample (equivalence relations) must be viewed skeptically, particularly, perhaps, if the subjects were not humans.

It is of course impossible to prove by failures alone that conditional-discrimination procedures are incapable of establishing symmetric relations for any organism. Such a conclusion would demand an understanding, which we currently lack, of the prerequisites for symmetry, and an explanation of the organism's inability to meet one or more of the requirements. On the other hand, the data have made it clear that symmetry cannot be taken for granted. This demonstration by means of empirically specifiable behavioral techniques is perhaps the most significant contribution of the present experiments.

If failures to demonstrate symmetry are to be attributed to experiential rather than to genetically related variables, proof that the subjects lacked one or more of the necessary experiences must be provided. Whether or not subsequent investigation succeeds in identifying critical gaps in the subjects' behavioral histories, shifting the burden of proof and thereby provoking the search may prove constructive.

Perhaps the most relevant experience to provide would be additional symmetry tests, with initial test failures being followed by explicit reinforcement of the desired performance, as was done with Subject Bab-Sim (Figure 12). One might argue that pigeons, monkeys, and baboons, unlike humans, do not ordinarily experience enough exemplars for them to appreciate the concept of symmetry. Demonstrations of symmetry with normal 5-year-olds who had not yet started school (Experiment 3), and of equivalence relations with severely retarded, institutionalized, environmentally restricted subjects, who had little language and no constructive academic experience (Sidman, 1971, unpublished data; Sidman & Cresson, 1973),

somewhat blunt the force of this suggestion but do not disprove it. If the animals were taught consecutive pairs of conditional discriminations, with the second of each pair always the symmetric version of the first, would the subjects eventually perform a symmetry test accurately the first time they encountered it? Would they learn the general principle, "Sample and correct comparison are interchangeable"?

Whether or not the provision of enough exemplars would bring about the emergence of symmetry is still an open question. Yet symmetry's very complexity should temper one's optimism. The principle of symmetry, or generalized sample-comparison interchangeability, requires also the existence of the stimulus classes, sample and comparison. Unless these functional classes have been established, so that individual sample stimuli are also members of the sample class, and individual comparison stimuli are also members of the comparison class, no exemplar of symmetry will extend beyond the particular stimuli being tested; the general principle will never emerge. Therefore, subjects who do demonstrate generalized sample-comparison interchangeability (symmetry) should, when tested appropriately (e.g., Mackay, Note 3), also demonstrate equivalence relations among functional samples and among functional comparisons.

Whether the functional classes, sample and comparison, are prerequisites for sample-comparison symmetry remains to be tested empirically. The procedure used here, however, may have obscured the functional classes by confining the potential members of each class to particular locations on the key matrix—samples always in the center and comparisons on the outer keys. Location, perfectly correlated with function, might have become a defining characteristic of the classes. In that event, even if the sample and comparison functions of the experimenter-specified stimuli were exchangeable, the locations correlated with those functions could not be shifted; a symmetry test that attempted to change both the stimulus functions and their locations would not have provided a valid evaluation of functional reversibility. A resolution of this problem may come from a training procedure in which sample and comparison stimuli can appear in any location.

Incorrect specification by the experimenter

of the controlling stimuli in the conditional discriminations may be the most fundamental factor underlying the absence of symmetry. The number of testable differences between the experimenter's specifications and the actual controlling stimuli is limited only by one's ingenuity. One cannot rule out the possibility that continued attempts to sharpen a monkey's training history will succeed in achieving congruence between the experimenter's and the subject's definitions of the controlling stimuli, thereby permitting a valid and successful test for symmetry. Equally difficult to rule out, however, is the possibility that species-related factors will prevent the development of such congruence. It may, for example, not be possible for some species to abstract certain stimulus features from the environment, or to form certain functional classes, or even to separate stimulus features from stimulus functions. Such species differences need not be absolute, but may depend on the ethological validity of the stimuli and functions being examined. The present experiments might have yielded positive evidence of symmetry if they had used monkey odors and monkey sounds as stimuli instead of lines and color patches, or if the functional classes had been "edible" and "safe," or "inedible" and "dangerous" rather than "sample" and "comparison." In that event, the species differences would lie in the arbitrariness or in the variety of the equivalence relations that could develop.

When the conditional-discrimination procedure does generate true matching to sample, the formation of stimulus classes defines a semantic correspondence between each sample and its matching comparison stimulus. The procedure therefore has features that recommend it as a model for the study of complex behavior, and the discovery that children, chimpanzees, monkeys, and pigeons could be taught conditional discriminations fostered the hope that such relatively simple organisms could be used to develop experimental and theoretical models even for language (e.g., Davenport & Rogers, 1970; French, 1965; Nissen, Blum, & Blum, 1948; Riesen & Nissen, 1942; Weinstein, 1941, 1945). If nonhuman species fail to develop true matching performances or prove limited in comparison to humans, then studies with nonhuman subjects take on a somewhat different significance. Rather than accept the nonhuman perfor-

mance as a model, homologous to the human, a thorough analysis of failures of the procedure to generate true matching offers the opportunity to specify the missing components and thereby to identify elements that are unique to the normal human performance. Then, attempts to build into the subjects' repertoires those components that would make nonhuman and human matching-to-sample behavior homologous might yield practical methods applicable to humans with developmental deficiencies.

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