*A TEST OF SYMMETRY AND TRANSITIVITY IN THE
CONDITIONAL DISCRIMINATION
PERFORMANCES OF PIGEONS*

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In a matching-to-sample context, pigeons were taught two conditional discriminations according to one of three equivalence paradigms: train if A, then select B and if B, then select C; train if B, then A and if B, then C; or train if A, then B and if C, then B. Test trials without reinforcement revealed that the conditional relations did not satisfy the symmetrical and transitive properties of an equivalence relation. Apparently, only specific if . . . then relations were learned. Contrary to Kendall's (1983) findings, and probably as a consequence of procedural differences, none of the pigeons in the present experiment were observed to emit mediating behavior during the transitivity probe trials. The absence of symmetry and transitivity may be related to the individual stimuli not being reflexive. Behavioral techniques other than the commonly used matching-to-sample technique might better succeed in avoiding unintended stimulus control in the study of the formation of stimulus classes.

Key words: stimulus control, stimulus definition, arbitrary matching-to-sample, stimulus equivalence, stimulus classes, mediating behavior, key peck, pigeons

One behavioral approach to the study of the formation of stimulus classes that do not have common physical characteristics has been within an arbitrary matching-to-sample context. An arbitrary matching-to-sample task is a conditional discrimination procedure in which the subject is required to select one of a set of comparison stimuli in the presence of a particular sample stimulus, and to select other comparison stimuli in the presence of different samples. The experimenter arbitrarily designates the correct comparison for a given sample. The sample and the comparison stimuli are all physically different.

In a conditional discrimination procedure, the contingencies specify only conditional relations between stimuli. For example, an animal might be trained as follows: if green, then select the square and if red, then select the circle (Sidman, 1986; Sidman & Tailby, 1982). With human subjects, it has been demon-

strated repeatedly that matching-to-sample procedures not only generate conditional relations but also equivalence relations between each sample and its matching comparison stimulus (Devany, Hayes, & Nelson, 1986; Dixon & Spradlin, 1976; Lazar, 1977; Lazar, Davis-Lang, & Sanchez, 1984; Lazar & Kotlarchyk, 1986; Mackay & Sidman, 1984; McDonagh, McIlvane, & Stoddard, 1984; Sidman, 1971; Sidman & Cresson, 1973; Sidman, Cresson, & Willson-Morris, 1974; Sidman & Tailby, 1982; Sidman, Willson-Morris, & Kirk, 1986; Spradlin, Cotter, & Baxley, 1973; Spradlin & Saunders, 1986; Stromer & Osborne, 1982; Wetherby, Karlan, & Spradlin, 1983).

Because the reinforcement contingencies in the conditional discrimination tasks specify only if . . . then relations, we need additional tests to know whether the stimuli, which have been conditionally related during the training, are also equivalent. Sidman and Tailby (1982) define equivalence within a logical framework: a relation must possess three properties—reflexivity, symmetry, and transitivity—in order to fulfill the formal definition of an equivalence relation. They provide a procedural specification of these properties within the matching-to-sample context, thereby allowing these properties to be studied empirically with a convenient laboratory technique. Thus, after being

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taught to select B1 conditionally upon A1 and B2 conditionally upon A2 (AB), reflexivity is demonstrated when the subject, without explicit training, matches each of these stimuli to themselves: A1 to A1, B1 to B1, A2 to A2, and B2 to B2. The original conditional relations may also be symmetrical when the subject, without explicit training, reverses the sample and comparison functions and thus selects A1 when B1 is the sample and A2 when B2 is the sample (BA). After being taught a second conditional discrimination, in which the subject selects C1 and C2 conditionally upon B1 and B2 respectively (BC), transitivity is demonstrated when a new untaught discrimination emerges in which the subject selects C1 when A1 is the sample and C2 when A2 is the sample (AC). If the relations between the stimuli are shown to be reflexive, symmetrical, and transitive, the stimuli A1, B1, and C1 can be referred to as equivalent members of one class and A2, B2, and C2 as the equivalent members of the second class. In that case, each stimulus of a given class may be substituted for each other stimulus of the same class. The formation of such equivalence classes may be essential to the symbolic function of language (Sidman, 1986). In traditional conceptions of language, a word "replaces" or "represents" an object, an event, a property, or a relation and the "referent" is "symbolized" by that word (Devany *et al.*, 1986). The transition from an "associative" to a "representational" or "referential" usage of words has been described as critical in the acquisition of language (Lock, 1980), and can be interpreted behaviorally as a transition from a purely conditional level of responding to the gradual development of responding to stimuli because they are interchangeable members of the equivalence classes.

Contrary to evidence from matching-to-sample research with adults and children as subjects, no convincing proof has been found that matching-to-sample procedures with pigeons (D'Amato, Salmon, Loukas, & Tomie, 1985; Gray, 1966; Hogan & Zentall, 1977; Holmes, 1979; Kendall, 1983; Rodewald, 1974), and with rhesus monkeys and baboons (Sidman *et al.*, 1982) result in equivalence relations. D'Amato and his colleagues (1985) reported some evidence of "associative transitivity" in an experiment with *Cebus apella* monkeys, which had extensive past experience

with identity and symbolic matching. The test procedure, however, does not suffice to allow the conclusion that the stimuli were members of equivalence classes in the sense implied by Sidman's definition. After training on two conditional discriminations (AB and BC), transitivity was assessed across two sets of conditional AC, but not CA, matching tasks. The CA conditional relations require the two baseline conditional discriminations to be symmetrical. Because it was found (Experiment 1, D'Amato *et al.*, 1985), even under conditions of reinforcement, that the monkeys did not respond symmetrically to the stimuli that also constituted the baseline conditional relations for the transitivity test (Experiment 2, D'Amato *et al.*, 1985), the stimulus-control relations that were obtained during the latter test are difficult to interpret as equivalence relations.

The description by Savage-Rumbaugh, McDonald, Sevcik, Hopkins, and Rubert (1986) of the behaviors of two pygmy chimpanzees in a language-acquisition task seems superficially like the formation of equivalence classes. The study by Savage-Rumbaugh *et al.*, however, did not make clear which relations were explicitly trained, and whether symmetrical and transitive relations emerged as a result of this training.

McIntire, Cleary, and Thompson (1987) claim that the conditional discrimination performances of the two cynomolgus macaques in their experiment were based on reflexivity, symmetry, and transitivity. In their study a characteristic response pattern was required during the samples and comparisons that were expected to be members of the same class. During the tests the topographically different responses and not the specific sample stimuli may control the choice over the comparisons (Cohen, Brady, & Lowry, 1981; Paul, 1983; Urcuioli, 1984; Urcuioli & Honig, 1980). McIntire *et al.* (1987) suggested that such response mediation might underlie all instances of reflexive, symmetrical, and transitive relations between stimuli, but there is no evidence yet that such an hypothesis is correct.

In all studies on equivalence relations in nonhuman animals except the one by Kendall (1983), a comparable matching-to-sample procedure is used, with the sample stimulus always presented on the same (usually the center) key and the comparisons on the other (usu-

ally the side) keys. In such an experimental arrangement, the spatial location of the sample and comparison stimuli may become a defining aspect of the controlling stimuli. Indeed, the necessity of including the spatial location of the sample and comparison stimuli in the definition of the controlling stimuli has recently been demonstrated by Iversen, Sidman, and Carrigan (1986). These researchers found that changing from a fixed to a variable location of the sample and comparison stimuli resulted in a deterioration of the conditional line discrimination. Taking into account this finding, the standard matching-to-sample procedure does not provide a problem-free method for testing the reversibility of the samples and comparisons as functional classes (Sidman et al., 1982).

Kendall's (1983) procedure differs from the common laboratory technique for studying conditional discriminations. In his study on "mediated transfer" Kendall employed three transfer paradigms: (a) train AB and BC, test AC; (b) train AB and AC, test BC; (c) train AB and CB, test AC. For each paradigm pigeons were subjected to two conditional position discriminations in which each stimulus corresponded with a particular key location or with a particular left or right visual display. The A stimuli were two lights mounted on a small panel near the top of the side wall, the B stimuli were projected on the front wall, and the C stimuli on the side wall of the test chamber. This experimental arrangement allowed Kendall to find out whether pigeons would engage in overt mediating behavior during the transfer test. Such mediating behavior would consist of pecking the key that was common to the two baseline conditional discriminations. Kendall found that only the 2 subjects in the first paradigm performed the AC conditional discrimination after learning the AB and BC baseline conditional discriminations. During test trials with reinforcement, one of these pigeons pecked the mediating B stimulus, whereas the other subject made orienting movements towards that stimulus. The performance of these birds may have been based on chaining: when the A stimulus appears as a sample, the correct B stimulus will be chosen, as the birds have learned during the AB training; in turn, the B stimulus sets the occasion for selecting the correct C stimulus. Pigeons trained on the two other paradigms did not show mediating behavior during the transfer

test, and a third new discrimination did not emerge from learning the two baseline conditional discriminations. Mediating behavior of these latter subjects would require that the conditional relations that have been learned are also symmetrical. For example, in the second paradigm—train AB and AC, test BC—the BA relation should exist for the A stimuli to mediate between the B and C stimuli. Kendall, however, did not test these symmetrical relations directly.

If, in Kendall's study, the new conditional relations have been learned by means of chaining the two conditional discriminations trained earlier, equivalence in Sidman's sense might not be involved, because equivalence implies transitivity in cases where the result cannot be due to simple forward chaining. Therefore, the question whether conditional discrimination procedures in animals generate classes of equivalent stimuli can still not be answered in the affirmative.

The perfect correlation of the function of the stimuli and the location of the samples and comparisons in the standard matching-to-sample procedure might lead to control by location. If so, a failure to observe symmetry might be a spurious result of control by location. With an experimental procedure in which the function of the stimuli is not correlated with a particular key location, we wanted to evaluate whether conditional relations of pigeons possess the symmetrical and transitive properties of an equivalence relation. Kendall used the position of the keys as stimuli in his conditional discrimination procedure. Employing other stimulus conditions, we also wanted to investigate whether pigeons engage in overt mediating behavior during the transitivity tests. Thus, besides permitting what might be a more sensitive evaluation of the formation of stimulus classes than is possible with a traditional matching-to-sample technique, the procedure in the present study also allows one to verify and to extend Kendall's findings.

METHOD

Subjects

Nine adult homing pigeons (*Columba livia*) between 6 and 10 years old served as subjects. They were maintained at 80% (± 15 g) of their free-feeding weights throughout the experi-

ment. They were housed in individual home cages with water and grit continuously available under a 12-hr dark-light cycle. The birds were tested for one session per day, 6 days per week. When they did not obtain their full ration in an experimental session, they received the remainder at least 20 min after returning to their home cages. All birds had no prior experience with discrimination procedures.

Apparatus and General Procedure

The experimental environment was a locally constructed pigeon test chamber with the four walls consisting of intelligence panels measuring 36 by 34 by 34 cm each. White noise masked external sounds. Three walls, subsequently referred to as Walls A, B, and C, each contained two pecking keys. Walls A and B and Walls B and C were adjacent to each other. The keys were 2.5 cm in diameter and were aligned horizontally above the chamber floor with a center-to-center distance of 16.5 cm, 9 cm from the vertical edges of the panel and 25.5 cm above the floor. Access to standard mixed pigeon grain was provided through a 5 by 6 cm aperture centered on the fourth wall, 11 cm from the floor of the chamber. A 2.8-W light bulb, centered 30.5 cm above the floor of the fourth wall, served as the houselight. From a three-color lamp, the keys on Wall A could be transilluminated with red or green light and the keys on Wall B with orange light. An Inline Digital Display® cell (model no. 0229-1820) located behind the keys on Wall C provided the stimuli: fully white or three black vertical lines on a white background. A PDP-8/F® minicomputer (Digital Equipment Corporation), located in an adjacent room, and SKED® software (Snapper, Stephens, & Lee, 1974) were used to control the experimental procedures and data collection. All test sessions were videotaped.

A session began with a 10-s illumination of the houselight. Each trial began with a sample stimulus. When the subject pecked the sample key, two comparison stimuli appeared. For some subjects 10 pecks were required on the sample to produce the comparison stimuli. Each sample remained, along with the comparison stimuli, until the subject pecked a comparison key. Pecking the correct comparison key produced 4-s access to the food magazine and the termination of the keylights and the houselight. Removal of the food magazine was fol-

lowed by a 10-s intertrial interval (ITI) during which only the houselight was on. When the bird pecked the incorrect comparison key, a blackout of 8 s followed, during which all keylights as well as the houselight were turned off. The blackout was followed by a 10-s ITI. A noncorrection procedure was used.

The presentation of sample-comparison combinations varied in different stages of the experiment. In the early stages of training, all sample-comparison combinations were equally probable on successive trials, with the following restriction: all possible combinations of samples and comparisons had to occur before any could repeat. In later stages of training and in the test phase, the sample-comparison combinations were presented in blocks of two or three trials that were equally probable, with the restriction that all possible blocks had to occur before any could repeat. Positions of correct and incorrect comparison stimuli were balanced between the keys. There were fewer trials in sessions with a continuous reinforcement schedule (CRF) than with an intermittent reinforcement schedule.

Preliminary Training

All pigeons first received magazine training. They were then taught to peck the keys by the method of successive approximation. They were first trained to peck the left key of Wall A when it was red, then the left key when it was green, then the right key of Wall A when it was red, and so on, until they had learned to peck on all keys with all illuminations used in the experiment. The next phase consisted of the successive presentation of all stimuli on the appropriate keys in a mixed sequence. In the next phase, a trial began with the onset of the sample stimulus on its appropriate wall. When the pigeon pecked the sample key, the comparison stimulus that was to be correct for the sample in the conditional discrimination training appeared. To speed up the conditional discrimination training, Subjects GL1, GL5, GL6, GL7, GL8, and GL9 produced the comparison stimulus by completing a fixed-ratio (FR) 10 sample requirement. In this and all subsequent training and test phases, pecking a dark key had no programmed consequences. Pecking particular dark keys was recorded during the test phases. The final step introduced the incorrect comparison together with the correct one after pecking the sample key.

Fig. 1. A first equivalence paradigm. Each box represents a set of two stimuli. Arrows point from sample to comparison stimuli. For a given sample stimulus, the correct comparison is designated by the same number. The solid arrows (AB and BC) represent conditional relations that are explicitly taught to the subject; the broken arrows (BA, CB, AC, and CA) represent emergent relations.

This determined the start of the conditional discrimination training proper.

Conditional Discrimination Training

This experiment used three equivalence paradigms to determine whether explicitly taught conditional relations were also equivalence relations. In each equivalence paradigm, three sets of stimuli A, B, and C with two stimuli per set (A1A2, B1B2, and C1C2) were used. The A, B, and C stimuli appeared on Walls A, B, and C, respectively. The A1 and A2 stimuli (respectively red and green) and the C1 and C2 stimuli (respectively black lines on a white background and fully white) could be presented on the left or right key on their appropriate wall. The B1 (left, orange) and B2 (right, orange) stimuli were presented on the left and right key of Wall B, respectively.

In the first equivalence paradigm, the birds learned to select the B stimuli conditionally upon the A stimuli (AB). Subsequently, they learned to select the C stimuli conditionally upon the B stimuli (BC). These explicitly taught relations are presented by solid arrows in Figure 1. A determination of whether the AB and BC relations involved equivalence as well as conditionality required the subjects, without explicit training, to select the A stimuli conditionally upon the B stimuli (BA), the B stimuli conditionally upon the C stimuli (CB), and to match the A and the C stimuli to each

Fig. 2. A second equivalence paradigm. Each box represents a set of two stimuli. Arrows point from sample to comparison stimuli. For a given sample stimulus, the correct comparison is designated by the same number. The solid arrows (BA and BC) represent conditional relations that are explicitly taught to the subject; the broken arrows (AB, CB, AC, and CA) represent emergent relations.

other (AC and CA). These new untrained relations are represented by broken arrows in Figure 1.

In a second equivalence paradigm (see Figure 2), the subjects learned to select the A and C stimuli conditionally upon the B stimuli (BA and BC). If these conditional relations were also equivalence relations, the subjects should match A to C and C to A. In this case, they should also match B to A and B to C because, according to the derivation paradigm of Sidman and Tailby (1982), these two symmetrical relations form the basis for the formation of the transitive relations AC and CA.

In a third equivalence paradigm (see Figure 3), the BA, BC, AC, and CA conditional relations would emerge after learning the AB and CB relations if the matching-to-sample procedure generated stimulus equivalence. The development of equivalence should thus create in each of the paradigms two three-member classes of equivalent stimuli, A1B1C1 and A2B2C2. In each paradigm, the B stimuli are the common stimuli that link the two conditional discriminations. The function of the B stimuli (as sample and/or as comparison) differs in the three paradigms, but only in the first paradigm can "transitivity" be obtained by chaining of the two baseline conditional discriminations. The position stimuli on Wall B were used precisely because they allowed us to observe mediating behavior of the pigeons

Fig. 3. A third equivalence paradigm. Each box represents a set of two stimuli. Arrows point from sample to comparison stimuli. For a given sample stimulus, the correct comparison is designated by the same number. The solid arrows (AB and CB) represent conditional relations that are explicitly taught to the subject; the broken arrows (BA, BC, AC, and CA) represent emergent relations.

during the AC transitivity test, during which the B keys were unlit.

A separate group of three pigeons served in each of the equivalence paradigms. Teaching of the two baseline conditional discriminations proceeded according to the sequence summarized in Table 1. To advance from one training phase to another, subjects had to meet the accuracy criterion of 90% correct for each baseline trial type. A trial type is a specific sample-comparison combination (e.g., A1 on the left

key as sample with B1 and B2 as comparisons is a different trial type than A1 on the right key as sample with B1 and B2 as comparisons).

Increasing the number of required sample responses may facilitate the acquisition of a conditional discrimination (Sacks, Kamil, & Mack, 1972). For Birds GL1, GL5, GL6, GL7, GL8, and GL9, 10 observing responses on the sample key produced the comparison stimuli. For some of these birds a clearly differentiated pecking on the sample key was observed. For example, Bird GL6 systematically pecked softly and with a closed beak on green; her pecking responses on the red key were with an open beak and were so vigorous that they could be heard in the adjacent room. It has been reported that with different sample behaviors the comparison choices are primarily controlled by their sample-specific behavior, rather than by the stimuli projected on the keys (Cohen *et al.*, 1981; Paul, 1983; Urcuioli, 1984; Urcuioli & Honig, 1980). To obtain proper stimulus control, the FR-10 sample requirement was reduced to FR 1 after a few sessions. For each bird except GL9, this schedule change resulted in an initial disruption of performance. For the remaining birds, the CRF schedule was used from the beginning of the experiment.

For the first conditional discrimination, Subjects GL1, GL5, GL7, and GL9 met the accuracy criterion of 90% correct for each base-

Table 1

Sequences in which the subjects were taught the baseline conditional relations and were tested for the symmetrical and transitive properties of these conditional relations.

	Subject								
	GL1	GL2	GL3	GL4	GL5	GL6	GL7	GL8	GL9
Conditional relations trained									
AB	1	1	1	1	—	1	—	1	—
BA	—	—	—	—	1	—	1	—	1
BC	2	2	2	—	2	—	2	—	2
CB	—	—	—	2	—	2	—	2	—
AB, BC	3	—	3	—	—	—	—	—	—
BA, BC	—	—	—	—	—	—	3	—	3
AB, CB	—	—	—	—	—	—	—	—	—
Conditional relations tested									
BA	4; 8	3	4; 8	3	—	3	—	3	—
AB	—	—	—	—	3	—	4; 8	—	4; 8
CB	5; 9	—	5; 9	—	—	—	5; 9	—	5; 9
BC	—	—	—	—	—	—	—	—	—
AC	6; 10	—	6; 10	—	—	—	6; 10	—	6; 10
CA	7; 11	—	7; 11	—	—	—	7; 11	—	7; 11

Table 2

The sample and the correct and incorrect comparisons in the baseline conditional relations used in each of the three equivalence paradigms.

Task	Sample	Comparisons	
		Correct	Incorrect
Paradigm 1			
A1B1	Red	Left	Right
B1C1	Left	Lines	White
A2B2	Green	Right	Left
B2C2	Right	White	Lines
Paradigm 2			
B1A1	Left	Red	Green
B1C1	Left	Lines	White
B2A2	Right	Green	Red
B2C2	Right	White	Lines
Paradigm 3			
A1B1	Red	Left	Right
C1B1	Lines	Left	Right
A2B2	Green	Right	Left
C2B2	White	Right	Left

line trial type in six, five, five, and six sessions, respectively. Subjects GL2, GL4, GL6, and GL8 failed to reach the standard accuracy criterion within 27, 28, 29, 29, and 14 sessions, respectively. For these subjects the reinforcement duration was increased to 5 s, followed by the 10-s ITI; the blackout period was increased to 20 s, no longer followed by an ITI. With this procedure Birds GL2, GL3, GL4, GL6, and GL8 learned the conditional discrimination in 2, 2, 5, 12, and 10 sessions, respectively. The original procedure was reinstated before the reinforcement probability was gradually reduced.

When the standard accuracy criterion was maintained for five successive sessions, subjects were submitted to the second conditional discrimination. In this phase, a session began with 20 review trials of the first conditional discrimination. The remaining 60 trials were baseline trials of the second conditional discrimination. When the birds made more than two errors on the review trials, reviews continued for the rest of the session. When they met the 90% accuracy criterion for both baseline discriminations for five successive sessions, both groups of trial types were mixed. The trials were grouped in blocks of two (see Table 2). The first and second trials of a block were a baseline trial type of the first and second

Table 3

The baseline and probe trial types (sample stimulus with correct and incorrect comparisons) used in the symmetry tests in each of the three equivalence paradigms.

			Comparisons	
	Task	Sample	Correct	Incorrect
Paradigm 1				
Baseline	A1B1	Red	Left	Right
Probe	B1A1	Left	Red	Green
Baseline	A2B2	Green	Right	Left
Probe	B2A2	Right	Green	Red
Baseline	B1C1	Left	Lines	White
Probe	C1B1	Lines	Left	Right
Baseline	B2C2	Right	White	Lines
Probe	C2B2	White	Right	Left
Paradigm 2				
Baseline	B1A1	Left	Red	Green
Probe	A1B1	Red	Left	Right
Baseline	B2A2	Right	Green	Red
Probe	A2B2	Green	Right	Left
Baseline	B1C1	Left	Lines	White
Probe	C1B1	Lines	Left	Right
Baseline	B2C2	Right	White	Lines
Probe	C2B2	White	Right	Left
Paradigm 3				
Baseline	A1B1	Red	Left	Right
Probe	B1A1	Left	Red	Green
Baseline	A2B2	Green	Right	Left
Probe	B2A2	Right	Green	Red
Baseline	C1B1	Lines	Left	Right
Probe	B1C1	Left	Lines	White
Baseline	C2B2	White	Right	Left
Probe	B2C2	Right	White	Lines

conditional discrimination, respectively. Given equivalence, the sample and its positive comparison of the conditional relations in one block are expected to be members of the same class. As an example of the first equivalence paradigm, if the first trial was an A1B1 trial, the second trial was then B1C1.

To prepare for unreinforced probe trials during the tests, the baseline reinforcement probability was gradually reduced from 1.0 to .33 given that the accuracy of 90% correct for each baseline sample-comparison combination was met. This reduction took place in steps of approximately .10 and at least 90% of each baseline trial type had to be correct in a particular session before the next reduction took place. When on occasion the accuracy tended to decrease, the reinforcement probability was temporarily increased, and was reduced again when the 90% correct criterion was reached. At the final probability level (.33), a 90% ac-

Table 4

The baseline and probe trials (sample stimulus with correct and incorrect comparisons) used in the transitivity tests in each of the three equivalence paradigms.

	Task	Sample	Comparisons	
			Correct	Incorrect
Paradigm 1				
Baseline	A1B1	Red	Left	Right
Baseline	B1C1	Left	Lines	White
Probe	A1C1	Red	Lines	White
Baseline	A2B2	Green	Right	Left
Baseline	B2C2	Right	White	Lines
Probe	A2C2	Green	White	Lines
Baseline	A1B1	Red	Left	Right
Baseline	B1C1	Left	Lines	White
Probe	C1A1	Lines	Red	Green
Baseline	A2B2	Green	Right	Left
Baseline	B2C2	Right	White	Lines
Probe	C2A2	White	Green	Red
Paradigm 2				
Baseline	B1A1	Left	Red	Green
Baseline	B1C1	Left	Lines	White
Probe	A1C1	Red	Lines	White
Baseline	B2A2	Right	Green	Red
Baseline	B2C2	Right	White	Lines
Probe	A2C2	Green	White	Lines
Baseline	B1A1	Left	Red	Green
Baseline	B1C1	Left	Lines	White
Probe	C1A1	Lines	Red	Green
Baseline	B2A2	Right	Green	Red
Baseline	B2C2	Right	White	Lines
Probe	C2A2	White	Green	Red
Paradigm 3				
Baseline	A1B1	Red	Left	Right
Baseline	C1B1	Lines	Left	Right
Probe	A1C1	Red	Lines	White
Baseline	A2B2	Green	Right	Left
Baseline	C2B2	White	Right	Left
Probe	A2C2	Green	White	Lines
Baseline	A1B1	Red	Left	Right
Baseline	C1B1	Lines	Left	Right
Probe	C1A1	Lines	Red	Green
Baseline	A2B2	Green	Right	Left
Baseline	C2B2	White	Right	Left
Probe	C2A2	White	Green	Red

curacy score for each sample-comparison combination had to be maintained for two successive sessions. At that point the test phase was started. In the test phase, the reinforcement probability on baseline trials was increased to maintain the overall probability at .33.

Test Procedure

During test sessions, unreinforced probes were inserted into a baseline of previously learned conditional discriminations. The probe trials were presented in the context of only

those baseline trials required to derive the probed relation. Probe trials were presented directly after the prerequisite baseline trials. Tables 3 and 4 show the trials in the different symmetry and transitivity tests. Only one type of new untrained relation was tested in one session. Table 1 gives the test sequence for each pigeon. Each test consisted of 192 trials. A symmetry test consisted of 96 baseline trials and 96 probe trials: 24 presentations each of the four possible baseline trial types and 24 presentations of the four possible probe trial types. A transitivity test consisted of 128 baseline trials (16 of each of the eight possible trial types) and 64 probe trials (eight of each of the eight possible trial types). When in a test session the 90% criterion for each baseline trial type was no longer maintained, the next session consisted of baseline trials only until the 90% accuracy criterion was again met.

RESULTS

Training

Pigeons GL1, GL3, GL7, and GL9 learned both conditional discriminations. Pigeons GL2, GL4, GL5, GL6, and GL8 did not reach criterion in 66, 64, 63, and 53 sessions, respectively. In the second and following sessions with AB review trials and CB training trials, Bird GL4, for unknown reasons, stopped pecking after a few CB trials but never after AB trials. For Pigeons GL4 and GL8, the second conditional discrimination procedure was changed: After pecking on the sample, only the correct comparison stimulus appeared; after an interval of 1 s the incorrect comparison also appeared. When the standard accuracy of 90% correct was met, the interval was reduced in steps of 0.25 s. This procedure also did not succeed in teaching the second discrimination to these subjects. For the subjects that did not learn both conditional discriminations, only the symmetry test of the first conditional discrimination was given.

Test

Figures 4 and 5 represent the test and baseline scores of the individual subjects that did learn both conditional discriminations. The scores of the baseline trials were combined across all tests. Figure 6 represents the test and baseline scores of the birds that learned only the first conditional discrimination. Baseline

Fig. 4. Performances of Subjects GL1 and GL3 during the symmetry and transitivity tests. The bars under the heading of transitivity and symmetry represent test scores for one test, which is indicated below the bars. Baseline scores are combined for all tests that included these baseline trials.

performances were never lower than 90%. The performances on probe trials reveal that there is no evidence for the establishment of stimulus equivalence. On both symmetry and transitivity tests, the subjects scored at about the 50% accuracy level.

A finer analysis of each baseline relation in

its individual trial types (see Table 5) shows that inserting probes between baseline trials resulted in a deterioration of particular baseline trial types. For example, in the test sessions, Birds GL1 and GL3 erred more often in the A1B1 conditional relation when the red sample appeared on the left key (10 and 38

Fig. 5. Performances of Subjects GL7 and GL9 during the symmetry and transitivity tests. The bars under the heading of transitivity and symmetry represent test scores for one test, which is indicated below the bars. Baseline scores are combined for all tests that included these baseline trials.

errors, respectively) than when this sample appeared on the right key (0 and 3 errors, respectively). Also, Birds GL1 and GL7 made errors only in the B1C1 conditional relation when the correct comparison appeared on the left key (23 and 10 errors, respectively). This may mean that the key position is an additional

factor determining the pigeon's conditional discriminations.

Individual scores for each probe trial type allow one to detect patterns of stimulus control that a combined accuracy measure might obscure (Sidman, 1980; Sidman et al., 1982). Table 6 gives the error scores for each probe

trial type for the first session of each test separately. For example, GL3 had a complete right position preference during CA test trials independently of the sample, and all birds preferentially pecked the black vertical lines during the AC test trials. Similar results were observed during the second test sessions.

None of the birds ever pecked on the mediating B keys. Neither did orienting in the direction of these keys occur, as inspection of the videotapes showed. Even the pigeons in the first paradigm did not peck the B keys during the AC transitivity test. The absence of overt mediating behavior may have made it difficult for these subjects to perform correctly on the new conditional discrimination by means of chaining.

During test trials, excessive pecks (range, 1 to 30) on the sample were observed. The time between the first peck on the sample and a peck on one of the comparison stimuli was much longer (1.6 to 6.0 s) during the test trials than during the baseline trials. These longer latencies are partially correlated with the excessive pecking on the sample. We observed that in test trials, some pigeons went to the comparison stimuli after pecking the sample but returned to the sample and stayed for a long time in front of the wall on which the sample appeared.

DISCUSSION

Starting from a logical definition of equivalence relations based on its three defining properties—reflexivity, symmetry, and transitivity—our discrimination procedure failed

Fig. 6. Performances of Subjects GL2, GL4, GL5, GL6, and GL8 during the symmetry test. Bars depict the percentage of correct responses on baseline trials and symmetry probes.

to provide evidence for the emergence of classes of equivalent stimuli. This result is in contrast with conclusions from human experimentation, but it confirms and extends the findings obtained from nonhuman animal research (Sidman et al., 1982). In contrast with Kendall (1983), we did not find any evidence of mediating behavior in the performance of the subjects during the test.

An explanation of the difference between Kendall's (1983) and our findings might involve the following: During the transitivity tests in our experiment, the keys on which the previous B stimuli had been projected were present but not illuminated. Pecking unlit keys was never reinforced during any phase of the training procedure. Although key color could not be a discriminative stimulus because both keys

Table 5

Number of errors in each baseline trial type during the symmetry test for Subjects GL2, GL4, GL5, GL6, and GL8 and during the symmetry and transitivity tests for Subjects GL1, GL3, GL7, and GL9.

Subjects	Baseline trial types											
	A1 _L B1	A1 _R B1	A2 _L B2	A2 _R B2	B1A1 _L	B1A1 _R	B2A2 _L	B2A2 _R	B1C1 _L	B1C1 _R	B2C2 _L	B2C2 _R
GL1	10/112	0/112	10/112	23/112	—	—	—	—	23/112	0/112	1/112	0/112
GL2	5/20	2/19	0/20	0/20	—	—	—	—	—	—	—	—
GL3	38/112	3/112	3/112	9/112	—	—	—	—	5/112	1/112	3/112	2/112
GL4	0/7	1/7	0/7	0/7	—	—	—	—	—	—	—	—
GL5	—	—	—	—	0/24	2/24	0/24	0/24	—	—	—	—
GL6	0/24	0/24	0/24	0/24	—	—	—	—	—	—	—	—
GL7	—	—	—	—	10/112	2/112	1/112	0/112	10/112	0/112	0/112	1/112
GL8	0/24	1/24	1/24	0/24	—	—	—	—	—	—	—	—
GL9	—	—	—	—	0/112	1/112	0/112	0/112	8/112	2/112	0/112	2/112

Table 6

Number of errors in each symmetry trial type (of 24 trials) and in each transitivity trial type (of eight trials) for the first session of the symmetry and transitivity tests.

Subjects	Symmetry trial types						
	B1A1 _L	B1A1 _R	B2A2 _L	B2A2 _R	A1 _L B1	A1 _R B1	A2 _L B2
GL1	21	4	22	11	—	—	—
GL2	(2/20)	(12/19)	(19/19)	(1/20)	—	—	—
GL3	15	11	12	3	—	—	—
GL4	(4/6)	(2/7)	(7/7)	(0/7)	—	—	—
GL5	—	—	—	—	4	15	17
GL6	15	0	24	11	—	—	—
GL7	—	—	—	—	12	19	11
GL8	18	2	22	13	—	—	—
GL9	—	—	—	—	10	14	17

	Transitivity trial types						
	A1 _L C1 _L	A1 _L C1 _R	A1 _R C1 _L	A1 _R C1 _R	A2 _L C2 _L	A2 _L C2 _R	A2 _R C2 _L
GL1	2	0	1	1	8	5	8
GL3	4	0	0	3	8	7	7
GL7	3	0	2	0	8	6	8
GL9	1	0	0	0	8	8	8

were orange during the training, illumination of the B keys might have been a contextual stimulus for selecting the right or the left key conditionally upon the green or the red sample. In Kendall's study, the mediating stimuli were also unlit during testing. However, the presence of the feeding aperture in the panel with the mediating keys may have been significant in his finding that some of his subjects did show mediating behavior or made some orienting movements toward these keys.

Reflecting on the failure to demonstrate a true matching-to-sample performance in rhesus monkeys and baboons, Sidman and his colleagues (1982) argued that "incorrect specification by the experimenter of the controlling stimuli in the conditional discriminations may be the most fundamental factor underlying the absence of symmetry" (p. 43). The controlling stimuli as specified by the experimenter need not correspond with the stimuli actually controlling the behavior of the animal (Sidman, 1978). Iversen and his colleagues (1986) have demonstrated that the spatial location of the samples and comparisons can be an additional defining aspect of the effective stimuli, so that failure to demonstrate equivalence with the common matching-to-sample procedure may not be conclusive regarding sample-comparison interchangeability. In the present experi-

ment, key location also exerted some control over the pigeons' behavior, as shown by the type of errors made on baseline trials during testing. The number of errors on particular conditional discriminations was correlated with the left and right presentation of the sample and comparison stimuli. It should be noted that in the present experiment, the location of the keys as a controlling aspect of the stimuli does not, in itself, prevent the formation of symmetrical and transitive relations, because these stimuli were always presented on the same location, independently of their function as sample or comparison. However, equivalence relations can fail to emerge because a stimulus presented separately as a sample can be a different stimulus when presented as a comparison in combination with another comparison even though its spatial location remains the same. In addition, in the present experiment, in which the A, B, and C stimuli were presented respectively on Walls A, B, and C, the pigeons had to follow a particular path depending on the specific conditional relation. For example, in the A1B1 training, when the red sample was presented left, the distance from A1 to B1 was much longer than when the red sample was presented right. The various paths the pigeon has to follow in the different conditional relations can, together with

Table 6 (Continued)

Symmetry trial types								
A2 _R B2	C1 _L B1	C1 _R B1	C2 _L B2	C2 _R B2	B1C1 _L	B1C1 _R	B2C2 _L	B2C2 _R
—	23	22	5	1	—	—	—	—
—	—	—	—	—	—	—	—	—
—	10	19	6	5	—	—	—	—
—	—	—	—	—	—	—	—	—
21	—	—	—	—	4	15	17	21
—	—	—	—	—	—	—	—	—
13	—	—	—	—	7	10	15	10
—	—	—	—	—	—	—	—	—
18	—	—	—	—	8	13	15	11

Transitivity trial types								
A2 _R C2 _R	C1 _L A1 _L	C1 _L A1 _R	C1 _R A1 _L	C1 _R A1 _R	C2 _L A2 _L	C2 _L A2 _R	C2 _R A2 _L	C2 _R A2 _R
6	8	0	6	0	8	1	8	3
7	8	0	8	0	8	0	8	0
7	8	8	8	8	1	0	1	0
8	8	8	6	7	0	1	1	1

the specific sample stimulus, exert control over its choices.

From the foregoing considerations, it is possible that in the present experiment the pigeon responded to stimuli other than those that controlled our behavior as experimenters. Our definition of the controlling stimuli simply consisted of hues, the left and right position of the B keys, and the presence or absence of lines. For us these stimuli maintained their identity when they were presented on different keys (for the hues and the lines) and in different trials. When a physically identical stimulus is not identified by the subject as the same stimulus each time it is presented, this stimulus is not reflexive. This absence of reflexivity precludes the development of symmetrical and transitive control.

Future research must concentrate on achieving congruence between the experimenter specification of the controlling stimuli and the actual controlling stimuli. To avoid the spatial location of the individual sample and comparison stimuli becoming a controlling aspect of these stimuli, Sidman and his colleagues (1982) suggested a training procedure in which the samples and comparisons are presented on any key instead of the common matching-to-sample technique with the sample stimuli always presented on the center key and the compar-

isons always presented on the other peripheral keys. However, we suggest that even with this procedure, the conditional discrimination can still be based on specific trial configuration learning. Therefore, it might be better to use a matching-to-sample procedure with one single key, on which the sample is presented first and thereafter the correct or the incorrect comparison is presented. With such a procedure it may be easier to ensure that the stimuli maintain their functional identity. In addition, the contingencies require the subject to learn not only the positive relation between the sample and the correct comparison (if A1, then peck B1), but also the negative relation between the sample and the incorrect comparison (if A1, then do not peck B2). Perhaps the explicit establishment of a negative controlling relation between the sample and the negative comparison facilitates the development of stimulus equivalence. With a common experimental arrangement in which two comparisons are presented simultaneously, there remains the possibility that the subject's selection of the correct comparison is based on the exclusion of the incorrect one (Sidman, 1987). Because exclusion and equivalence are incompatible, Sidman argues that it is best to use at least three comparison stimuli to foster selection by choice. A single-key procedure, however, pre-

vents the subject from learning the conditional discrimination by exclusion based on simultaneous comparison. Another advantage of the one-key procedure appears in the method to test for the existence of stimulus classes. With the commonly used matching-to-sample technique a perfect score on the symmetry test is not a necessary indication of the functional interchangeability of the sample and its corresponding comparison stimulus. Such a score may also result from the subject having learned to respond to the sample and the correct comparison as a stimulus compound (Hayes, personal communication, 1986). This compound may continue to control the subject's behavior when, during the symmetry test, its elements are still present, differing only from the previous training phase with respect to their position (Stromer & Osborne, 1982). A correct performance on the standard transitivity test also has to be interpreted cautiously. The choice of the correct comparison may, for example, be determined by the simultaneous presence of the incorrect comparison. Therefore, a perfect score on the commonly used transitivity test may be deceptive and may even lead to incorrect conclusions, because it suggests the existence of equivalence relations. In research with schizophrenic patients, we found that such a performance was the result of the subject considering the sample and the incorrect comparison as belonging to different classes instead of considering the sample and the correct comparison as members of the same class.

In conclusion, in the present experiment no evidence was found for the formation of equivalence classes in pigeons. This is in agreement with other studies that used nonhuman animals as subjects. Pigeons with previous experience with arbitrary stimulus relations may develop equivalence relationships, but current procedures for training and testing are inadequate to establish and to assess such relations. A training procedure that succeeds in establishing a congruence between the experimenter's and the subject's definition of the controlling stimulus properties, as well as a valid test, is necessary to give a more definite answer to the question whether the difficulties of nonhuman animals to form equivalence classes reflect a true phylogenetic-based difference from humans or whether these difficulties can be overcome by changing our own behavior as experimenters.

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