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CLASS-CONSISTENT DIFFERENTIAL REINFORCEMENT AND STIMULUS CLASS FORMATION IN PIGEONS

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Match-to-sample training clusters of A1 (sample): B1/B2 (comparisons), A2: B2/B1, B1: A1/A2, B2: A2/A1, B1: C1/C2, B2: C2/C1, C1: B1/B2, and C2: B2/B1 were presented to pigeons with class-consistent differential reinforcement using two dissimilar types of food reinforcers. Distinctive class-consistent response patterns occurred to the samples during the fixed-ratio 5 sample observing response requirement. Subsequent tests, modeled from the equivalence class paradigm demonstrated the emergence (80% class consistent) of the transitive-like A-C and C-A relations for 4 and 2 of 12 pigeons, respectively, and a strong trend (over 70%) for 7 and 6 others, respectively; the emergence of the reflexive-like identity relation when the nonidentical comparison was from the other class; and the disruption of the trained within-class relation with the addition of a reflexive comparison. After directional training of C1: D1/D2 and C2: D2/D1, tests indicated no emergence of the symmetric-like D-C relation or the composite D-B and D-A relations, but the B-D and A-D transitive-like relation occurred with some pigeons. Off-baseline training with class-consistent differential reinforcement contingent on responding to the D stimuli alone produced distinctive responding and, in turn, a trend to D-C symmetric-like control in 4 of 12 pigeons, as well as a shift toward class-consistent control on D-B and D-A test trials. Class-consistent differential reinforcement that produced distinctive sample behavior promoted stimulus control relations like those that circumscribe equivalence class formation. Respondent–operant interactions permit an analysis of the possible enrollment of stimulus values of distinctive responding to the discriminative stimuli forming the stimulus classes via processes corresponding to naming in humans.

Key words: equivalence class, functional class, stimulus–reinforcer relations, respondent–operant interactions, differential outcome, key peck, pigeons

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Research on stimulus equivalence class formation (Sidman, 1971; Sidman & Tailby, 1982) with nonhuman animals continues to focus on methodological features that occasion the stimulus control of behavior resembling the three requisite emergent stimulus relations of transitivity, reflexivity, and symmetry (Dube, McIlvane, Callahan, & Stoddard, 1993; Kuno, Kitadate, & Iwamoto, 1994; Tomonaga, 1993). Transitive relations require a three-member class and emerge after the training cluster (Fields & Verhave, 1987) that can be described by the rules "if A1 then select B1" and "if B1 then select C1," such that responding is emitted towards C1 following A1 (Stromer & Osborne, 1982). There is evidence of the emergence of transitive relations among discriminative stimuli in monkeys and chimpanzees (Boysen & Berntson, 1989; D'Amato, Salmon, Loukas, & Tomie, 1985; Premack, 1986) and the sea lion (Schusterman & Kastak, 1993). Kuno et al. (1994) recently reported some evidence of the emergence of transitive relations with pigeons, although other investigators have found none (D'Amato et al., 1985; Kendall, 1983; Lipkins, Kop, & Matthijs, 1988).

Unlike transitivity or symmetry, the reflexive relation depends on the formal perceptual characteristics of the discriminative stimuli (Hayes, 1989). Generally reflexivity coincides with behavior that can be described as based on a single rule specifying *sameness,* or generalized identity matching. Following training clusters with multiple sets of discriminative stimuli, subsequent tests with novel stimuli have demonstrated the emergence of identity matching with old- and new-world monkeys (D'Amato & Salmon, 1984), adult

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and infant chimpanzees (Nissen, Blum, & Blum, 1948; Oden, Thompson, & Premack, 1988), bottlenose dolphins (Herman & Gordon, 1974), and sea lions (Pack, Herman, & Roitblat, 1991). Early tests with pigeons typically failed to show generalized identity matching (e.g., Cumming, Berryman, & Cohen, 1965; Santi, 1982), although by utilizing massed multiple training clusters, Wright, Cook, Rivera, Sands, and Delius (1988) demonstrated behavior indicating the emergence of reflexive-like generalized identity match to sample with pigeons (see Dube, McIlvane, & Green, 1992).

Symmetric relations are the result of an emergent equality between two stimuli following directional training from which behavior is emitted that can be described as based on a single rule specifying *reversibility*. The results of tests of symmetric-like relations with primates have been equivocal or weak (D'Amato et al., 1985; Sidman et al., 1982; Tomonaga, Matsuzawa, Fujita, & Yamamoto, 1991), and very little evidence exists for the emergence of symmetric-like relations with pigeons (Gray, 1966; Hogan & Zentall, 1977; Kendall, 1983; Lipkins et al., 1988; Richards, 1988; Rodewald, 1974). Schusterman and Kastak (1993) were able to demonstrate the emergence of symmetric-like relations using multiple training clusters in a sea lion.

Class-Consistent Differential Reinforcement

Differential reinforcement under four-term contingency training clusters (Sidman, 1986) engenders relations between and among discriminative stimuli. Most often responding with such procedures is reinforced with a single hedonic outcome (O). A single class (i.e., correct responses) of various specific stimulus relations is strengthened; that is, responses that can be described by the rules "if A1 then select B1" and "if A2 then select B2" are reinforced with the O. As such, the possible influence of a *respondent–operant interaction* as a significant methodological feature on acquisition is negligible.

Discriminative stimuli that occur regularly with a given O may come to serve as conditioned stimuli (Hearst & Jenkins, 1974), thereby creating appended responses, which may enhance and expand the acquisition of stimulus control. The stimulus–reinforcer relation may produce effects that contribute to stimulus class formation (Catania, 1971; Lawrence, 1963; Ray & Sidman, 1970; Schoenfeld & Cumming, 1963; Sidman, 1986). Our understanding of stimulus class formation may benefit from a behavioral analysis of the effect of using a different O correlated with each class during training.

In the present study, bidirectional A-B and B-C relations were established with training clusters using class-consistent differential reinforcement with two different types of reinforcers. Tests were then conducted to investigate the possible emergent stimulus control relations delineating equivalence classes. The possible transitive-like A-C and C-A relations and the reflexive-like relations were first assessed. The symmetric-like D-C relation and composite (symmetric- and transitive-like) D-B and D-A relations were assessed twice, first after a unidirectional C-D training cluster and then after an off-baseline class-consistent differential-reinforcement procedure that produced sample-specific distinctive responding to the D stimuli.

METHOD

Subjects

Twelve White Carneau pigeons from the Palmetto Pigeon Plant and 4 loft-reared racing pigeons obtained from a local coop were individually housed under typical laboratory conditions, with water and grit always available. The pigeons were maintained at 80% of their ad libitum weights by limiting their access to food; they were maintained throughout the experiments on a 12:12 hr light/dark cycle.

Apparatus

Four typical operant chambers with BRS/LVE three-key intelligence panels (Model PIP-016) were controlled by a computer using CONMAN-E software (Lucas, 1992). Each panel contained a grain hopper opening, with hopper light, under the center key. Access to the mixed grain in the hopper, with the hopper light on for 3 s, was designated as Outcome 1 (O1).

A semicircular cup fabricated from sheet metal, approximately 4 cm high by 2.5 cm wide by 1.5 cm deep, was located 7 cm to the right of the hopper opening, into which Noyes 20-mg (C-1) pigeon pellets could be delivered from a Gerbrands G5120 dispenser located atop the chamber enclosure. A 28-V 0.1-A shielded white lightbulb was mounted 2.5 cm above the cup. Four dispenser operations, three to four pellets, and the dispenser cup light onset for 3 s were designated as O2. Outcomes, therefore differed in a number of ways, including type, amount, delivery, delay, and location.

Behind each response key was a 12-stimulus IEE in-line projector. A custom film was made which permitted projection of a white field and 11 color pictures of animals taken from *National Wildlife Magazine* onto each response key. Stimuli consisted of different animals, either singly or in groups (e.g., frog, parrot, fish, and leopard), and thereby varied across many dimensions such as color, shape, and brightness. Extraneous noise was masked by white noise at 60 dB presented through a speaker located behind the panel and by the chamber's exhaust fan. A 28-V 0.1-A shielded white bulb located 2.8 cm above the center key served as the houselight.

Procedure

Pretraining began with three sessions of approximately 25 presentations each of O1 and O2. The pellet cup was baited with pellets and grain on the first 2 days. More pellet presentations (O2) than hopper presentations (O1) were needed over the final 2 days to insure that pellets would be consumed. All pigeons reliably approached and consumed both O1 and O2 upon presentation by the end of the third session.

All pigeons came to reliably peck at white lit keys following three 48-trial sessions of an autoshaping procedure that used both O1 and O2. Next, five 33-trial exposure sessions were conducted during which one of the 11 picture stimuli was presented on one of the three keys. A fixed-ratio (FR) 1 schedule was in effect, and the probability of occurrence for O1 and O2 was .5 and was random with regard to both stimulus and key location. This training was done to insure that each pigeon would respond to all stimuli to be used in the study. Initial stimulus preferences were eliminated by the 5th day as indicated by equivalent response latencies to the various stimuli and locations. Finally, four sessions were conducted wherein a chain FR 5 to a white center key and then an FR 1 to a single white side key was established. As before, the probability of O1 and O2 was equal, and the occurrences were random.

Training cluster sessions consisted of 96 trials of a two-comparison, 0-s delay, symbolic match-to-sample procedure. An FR 5 observing response requirement to the center-key sample was necessary to produce the two comparison side-key stimuli on each trial, to which a single response terminated the trial with an O or blackout. Responses to class-consistent comparisons (e.g., responding to B1 following Sample A1 or to B2 following A2) were followed by an O. All responses to class-inconsistent comparisons (e.g., responding to B1 following Sample A2 or to B2 following A1) produced a 60-s blackout; then the next trial occurred, or, when a correction procedure was used (see below), the trial was repeated. Further, a trial was terminated if no response was made within 60 s to either the sample or comparisons. Following either O or blackout, there was a 6-s intertrial interval of 3 s of darkness followed by 3 s of houselight onset before the next trial began. Sessions were terminated after 2 hr, if all 96 trials had not been completed by then.

Table 1 presents the trial types used during training with class-consistent differential reinforcement. Eight pigeons were given a sequence of A-B and B-A associative training until the criterion (i.e., two consecutive sessions at 90% correct) was met and the first 20 sessions of the A-B/B-A discrimination training cluster occurred without the correction procedure. The correction procedure repeated a trial until a correct response occurred. The other 8 pigeons were given a slightly different sequence in that the A-B and B-A associative training was limited to five sessions and the correction procedure was used throughout the A-B/B-A discrimination training cluster. The correction procedure was not used during the associative training clusters, which were designed to promote Type S (select) stimulus control (Carrigan & Sidman, 1992; Carter & Werner, 1978; Cumming & Berryman, 1965; Johnson & Sidman, 1993). Upon reaching criterion in the A-B/B-A training cluster, sessions either to criterion (Procedure 1) or five sessions (Procedure 2) of B-C and C-B associative training were presented, followed by the B-C/C-B discrimination training cluster until the same criterion

Table 1

Trial types in class-consistent training. The outcome type is shown in parentheses (O1 = grain; O2 = pellets).

Sample	Comparisons		Sample	Comparisons	
	Co+	Co−		Co+	Co−
Associative training A-B					
A1	B1 (O1)	E1	A2	B2 (O2)	E1
A1	B1 (O1)	E2	A2	B2 (O2)	E2
A1	B1 (O1)	E3	A2	B2 (O2)	E3
Associative training B-A					
B1	A1 (O1)	E1	B2	A2 (O2)	E1
B1	A1 (O1)	E2	B2	A2 (O2)	E2
B1	A1 (O1)	E3	B2	A2 (O2)	E3
Discrimination training A-B and B-A					
A1	B1 (O1)	B2	A2	B2 (O2)	B1
B1	A1 (O1)	A2	B2	A2 (O2)	A1
Associative training B-C					
B1	C1 (O1)	E1	B2	C2 (O2)	E1
B1	C1 (O1)	E2	B2	C2 (O2)	E2
B1	C1 (O1)	E3	B2	C2 (O2)	E3
Associative training C-B					
C1	B1 (O1)	E1	C2	B2 (O2)	E1
C1	B1 (O1)	E2	C2	B2 (O2)	E2
C1	B1 (O1)	E3	C2	B2 (O2)	E3
Discrimination training B-C and C-B					
B1	C1 (O1)	C2	B2	C2 (O2)	C1
C1	B1 (O1)	B2	C2	B2 (O2)	B1
Discrimination baseline trials					
A1	B1 (O1)	B2	A2	B2 (O2)	B1
B1	A1 (O1)	A2	B2	A2 (O2)	A1
B1	C1 (O1)	C2	B2	C2 (O2)	C1
C1	B1 (O1)	B2	C2	B2 (O2)	B1

was attained. If criterion during A-B/B-A discrimination training was not reached after 50 sessions (approximately 4,800 trials), the experiment was terminated for that pigeon.

For each of the two procedures, 4 pigeons were presented with class-consistent differential reinforcement with different Os, as shown in Table 1; the other pigeons were given the same training, with O1 and O2 occurring randomly following class-consistent responding. Each pigeon was assigned unique stimulus sets. Final results of the training clusters are given in the Appendix. The class-inconsistent differential reinforcement training failed to produce stimulus control consistent with the A-B/B-A relations and will not be discussed in this report. Four of the pigeons whose responding had not come under stimulus control with class-inconsistent training were retrained starting at exposure training with new stimuli and class-consistent differential reinforcement (see the Appendix). In total, 12 pigeons were presented with class-consistent differential reinforcement training clusters and were tested for the possible emergence of equivalence-class-like performances.

Distinctive responding to the sample was of special interest with this procedure. Pilot studies indicated that the pigeons developed distinctive response patterns to the stimuli correlated with each O. All samples required an identical observing response (FR 5 to the sample for presentation of the comparison stimuli); pigeons responded with shorter latencies and briefer interresponse times (IRT) to stimuli that were consistently correlated with O1 (grain) compared to O2 (the pellets). To gauge these differences, a simple ratio was calculated of the duration, in 0.1-s intervals, of the center key for Class 1 sample stimuli over duration of the center key for Class 2 sample stimuli. Equal latencies and IRTs to the samples of each class yielded values of 1.0; values below 1.0 indicated faster responding to the stimuli of Class 1.

Baseline. The 12 pigeons were exposed to an additional 12 96-trial baseline sessions before testing.

Testing transitive-like A-C C-A relations. This consisted of four consecutive sessions divided into an initial testing phase and the baseline training cluster. The test phase consisted of 24 trials presenting the novel A-C and C-A relations with an FR 5 center-key sample requirement and comparisons of the same letter designation (e.g., A1 and A2). Table 2 presents the trial configurations for this test. This phase was followed by a 96-trial baseline phase, shown in the bottom panel of Table 2. Each of the four possible trial types appeared six times during testing, and the position of comparisons and the sequence of samples were counterbalanced by random assignment of orders without replacement. Regardless of the comparison choice, all test trials had the same result: the intertrial interval followed by the next scheduled test trial.

Baseline. Next, the same 12 pigeons were given 12 96-trial baseline-only sessions. Percentage of class-consistent responding during baseline sessions remained high (97.6%; range, 93% to 100%) and continued at these

Table 2

Trial types in testing transitive- and reflexive-like relations. The outcome type is shown in parentheses (O1 = grain; O2 = pellets).

Sample	Comparisons		Sample	Comparisons	
	Co+	Co−		Co+	Co−
Test emergence of transitive-like relation A-C and C-A					
A1	C1	C2	A2	C2	C1
C1	A1	A2	C2	A2	A1
Between-class emergence test of reflexive-like (identity) relation					
A1	A1	A2	A2	A2	A1
B1	B1	B2	B2	B2	B1
C1	C1	C2	C2	C2	C1
Within-class emergence test of reflexive-like (identity) relation					
A1	A1	B1[a]	A2	A2	B2[a]
B1	B1	A1[a]	B2	B2	A2[a]
B1	B1	C1[a]	B2	B2	C2[a]
C1	C1	B1[a]	C2	C2	B2[a]
A1	A1	C1	A2	A2	C2
C1	C1	A1	C2	C2	A2
Baseline training trials					
A1	B1 (O1)	B2	A2	B2 (O2)	B1
B1	A1 (O1)	A2	B2	A2 (O2)	A1
B1	C1 (O1)	C2	B2	C2 (O2)	C1
C1	B1 (O1)	B2	C2	B2 (O2)	B1

[a] This Co− is the reinforced Co in training cluster trials.

levels throughout the remainder of the experiment.

Testing reflexive-like relations. This phase was based on the selection of a comparison that is identical to the sample. Two types of test trials were conducted: (a) the dissimilar comparison was from the other (*between*) class with the same letter designation (e.g., A1 is the sample and A1 and A2 are the comparisons); and (b) the reflexive comparison was pitted against stimuli from the same (*within*) class (i.e., a different letter designation). In the second case, the stimuli were either components of the training clusters (e.g., A1 was the sample and A1 and B1 were the comparisons) or transitive-like test stimuli (e.g., A1 was the sample and A1 and C1 were the comparisons).

Four consecutive between-class test sessions were conducted, structured as before with a test phase of 24 trials followed by the 96-trial baseline phase. Test trials were without scheduled consequences, and each of the six possible trial types occurred four times each session (see Table 2). Position of comparisons and sequence of samples were counterbalanced by random orders without replacement.

Baseline. Next, 12 96-trial baseline-only sessions were conducted, and class-consistent responding remained stable.

Four consecutive daily within-class test sessions were then conducted, during which each of the 12 possible trial types appeared twice. Table 2 shows the composition of the within-class trial types.

Baseline. Twelve 96-trial baseline-only sessions were conducted, and class-consistent responding remained stable.

Training the C-D relation. This was required, with single-direction class-consistent differential reinforcement (i.e., C1-D1 [O1] and C2-D2 [O2], but not D1-C1 or D2-C2 training) before testing symmetric-like relations could begin. Daily 96-trial sessions of a C1-D1 and C2-D2 training cluster were conducted until criterion was reached. Table 3 presents the two trial configurations used in training with the correction procedure (see the Appendix).

Testing symmetric-like D-C relations. This phase consisted of four consecutive sessions each with 24 test trials followed by the new 96-trial baseline training cluster. Table 3 presents the test-trial configurations. The composition of the baseline training cluster was altered from this point in the experiment on by adding C-D trials. The new baseline training trials were selected randomly without replacement such that no trial type could occur three times until all had occurred at least twice. The trial types were A-B, B-A, B-C, and C-B, as before, and C-D (see Table 3).

Baseline. Six 96-trial baseline-only sessions were conducted; percentage of class-consistent responding continued high and stable.

Retesting A-C transitive- and reflexive-like relations. Retests were conducted by presenting two sessions of A-C and C-A tests and then two sessions of between-class reflexive-like tests to determine if these emergent relations remained intact (see Table 3). As before, each daily test phase was followed by the 96-trial baseline phase.

Baseline. Next, six 96-trial baseline-only sessions were conducted.

Testing composite D-B and transitive-like B-D relations. These tests were conducted by pre-

Table 3

Trial types in testing symmetric-like relations. The outcome type is shown in parentheses (O1 = grain; O2 = pellets).

Sample	Comparisons Co+	Co−	Sample	Comparisons Co+	Co−
Train C-D					
C1	D1 (O1)	D2	C2	D2 (O2)	D1
Test emergence of symmetric-like relation D-C					
D1	C1	C2	D2	D2	C1
Retest of transitive- and between-class reflexive-like relations					
Transitive-like relation A-C and C-A					
A1	C1	C2	A2	C2	C1
C1	A1	A2	C2	A2	A1
Between-class reflexive-like (identity) relation					
A1	A1	A2	A2	A2	A1
B1	B1	B2	B2	B2	B1
C1	C1	C2	C2	C2	C1
Test emergence of relations between D and Class Members A and B					
Transitive-like relation B-D					
B1	D1	D2	B2	D2	D1
Composite symmetric- and transitive-like relation D-B					
D1	B1	B2	D2	B2	B1
Transitive-like relation A-D					
A1	D1	D2	A2	D2	D1
Composite symmetric- and transitive-like relation D-A					
D1	A1	A2	D2	A2	A1
Baseline trials					
A1	B1 (O1)	B2	A2	B2 (O2)	B1
B1	A1 (O1)	A2	B2	A2 (O2)	A1
B1	C1 (O1)	C2	B2	C2 (O2)	C1
C1	B1 (O1)	B2	C2	B2 (O2)	B1
C1	D1 (O1)	D2	C2	D2 (O2)	D1
Off-baseline training					
D1	White (O1)	none	D2	White (O2)	none

senting four consecutive sessions of 24 test trials consisting of 12 trials each of B-D and D-B, which were followed by the 96-trial baseline phase (see Table 3).

Baseline. Next, six 96-trial baseline-only sessions were conducted.

Testing composite D-A and transitive-like A-D relations. These tests were conducted by presenting four consecutive sessions of 24 test trials consisting of 12 trials of each of A-D and D-A, which were followed by the 96-trial baseline phase (see Table 3).

Baseline. Next, 12 96-trial baseline-only sessions were conducted; class-consistent responding remained stable.

Off-baseline training the D-O relation. This phase was conducted to establish distinctive sample responding to D stimuli by presenting 20 consecutive 96-trial sessions of class-consistent differential reinforcement of a chain FR 5 to D1 or D2 on the center key and FR 1 to a white lit side key. The bottom line of Table 3 presents the two trial configurations used in training. Sample class-consistent reinforcement followed side-key responding on all trials of the 20 sessions. Side-key position was counterbalanced. Sample duration ratios from the last session are shown in the Appendix. All subjects demonstrated distinctive sample responding that corresponded to the class-consistent differential-reinforcement contingency. Following this off-baseline training, the pigeons were tested again as after D-C training in the same sequence as before: testing symmetric-like D-C relations; baseline; retesting A-C transitive-like and reflexive-like relations; baseline; testing composite D-B and transitive-like B-D relations; baseline; and testing composite D-A and transitive-like A-D relations.

RESULTS

Figure 1 presents the results of testing transitive-like A-C C-A relations. On the A-C trials, 4 of the 12 pigeons selected the class-consistent comparison on over 80% of the trials for both classes, and 7 more were above 70% class-consistent responding for both classes. On the C-A trials, 2 of the 12 demonstrated class-consistent performance above 80%, and 6 others were above 70% class-consistent responding for both classes. The sample duration ratios during the test trials indicated the sample-distinctive responding produced by class-consistent differential reinforcement. There was clear evidence of the emergence of a transitive-like relation for pigeons with the use of class-consistent differential reinforcement during training clusters.

The results of testing between-class reflexive-like relations are presented in Figure 2. On trials when A was the sample, the performance of 7 of the 12 pigeons was above 80% class consistent for both classes, and all but five of the values were above 70%. On trials when B and C were the samples, the perfor-

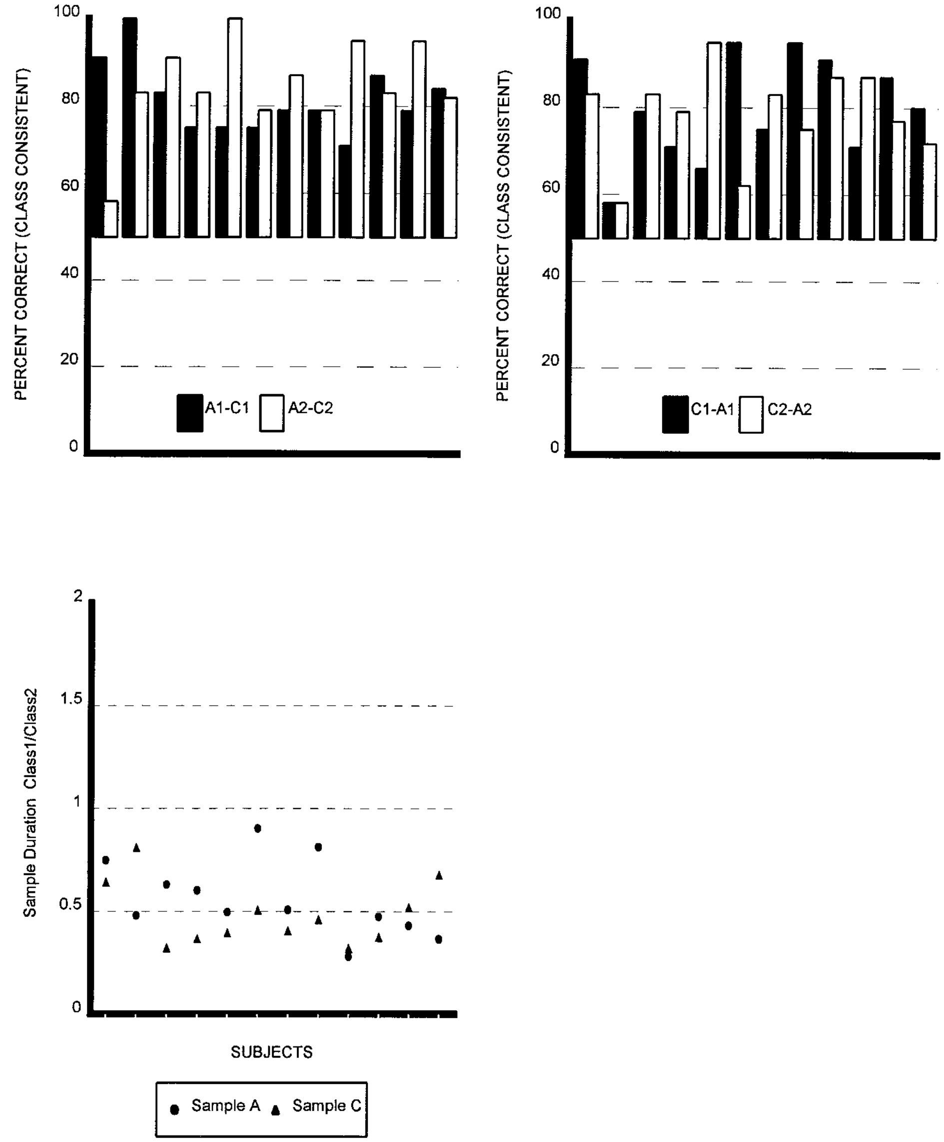

Fig. 1. Results of testing transitive-like relations. The top left panel presents the percentage of trials with class-consistent A-C responses for each class for each pigeon. The top right panel presents the results for the C-A test trials, and the bottom panel presents the sample duration ratio for the A and C samples during testing.

mance of 9 of the 12 pigeons was above 80% class consistent for both classes, and all but 2 of the test performances (when C was the sample) were above 70% class consistent. When the sample and one comparison were identical (i.e., the other comparison had a different number designation), pigeons selected the comparison from the same class as the sample, displaying emergent reflexive-like relations.

The results of testing within-class reflexive-like relations are presented in Figure 3. When A was the sample, 5 of the 12 pigeons selected the baseline trained comparison (e.g., A1-B1) on over 80% of the trials for both classes, as indicated by values less then 20% of the identity relation. One pigeon was above 70% for both classes. When B was the sample, none of the 12 pigeons selected the baseline trained comparison (A or C) on over

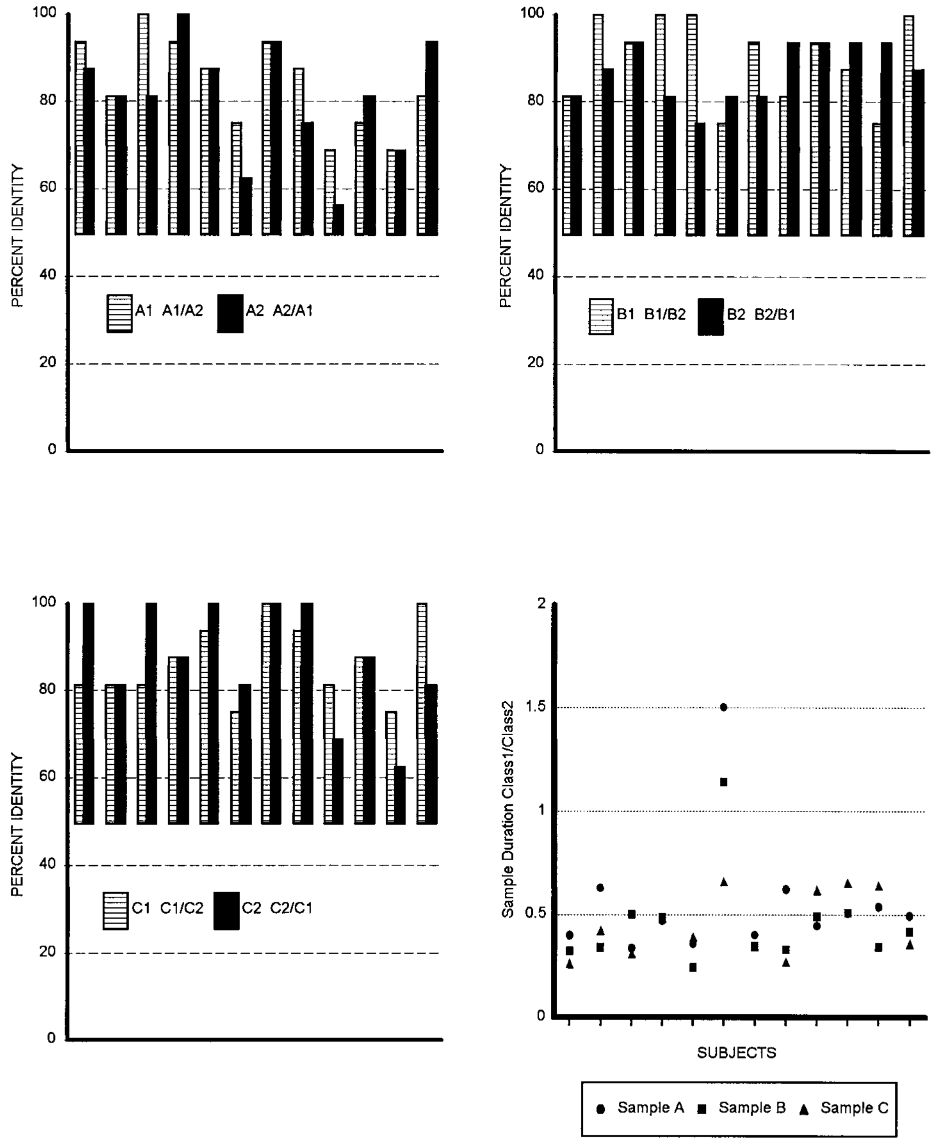

Fig. 2. Results of testing between-class reflexive-like relations. The percentage of class-consistent (identity) trials is indicated for each sample designation for each pigeon. The top left, top right, and bottom left panels present the results when A, B, and C were the samples, respectively. The bottom right panel presents the sample-duration ratio for samples during testing.

80% of the trials for both classes, although 2 pigeons were at or above 70% on the B-C relation only. When C was the sample, 3 of the 12 pigeons selected the baseline trained comparison (e.g., C1-B1) on over 80% (i.e., less than 20% identity matching) of the trials for both classes, and 2 others selected the baseline trained comparison above 70%. When the A-C relation was assessed, 1 of the 12 pigeons selected the transitive-like C comparison on over 80% of the trials for both classes, and none selected the transitive-like A comparison above 80%, although 1 was above 70% of the trials for both classes.

Pigeons did not respond systematically to the previously trained comparison when the other comparison was identical to the sample (i.e., the stimulus control baseline was dis-

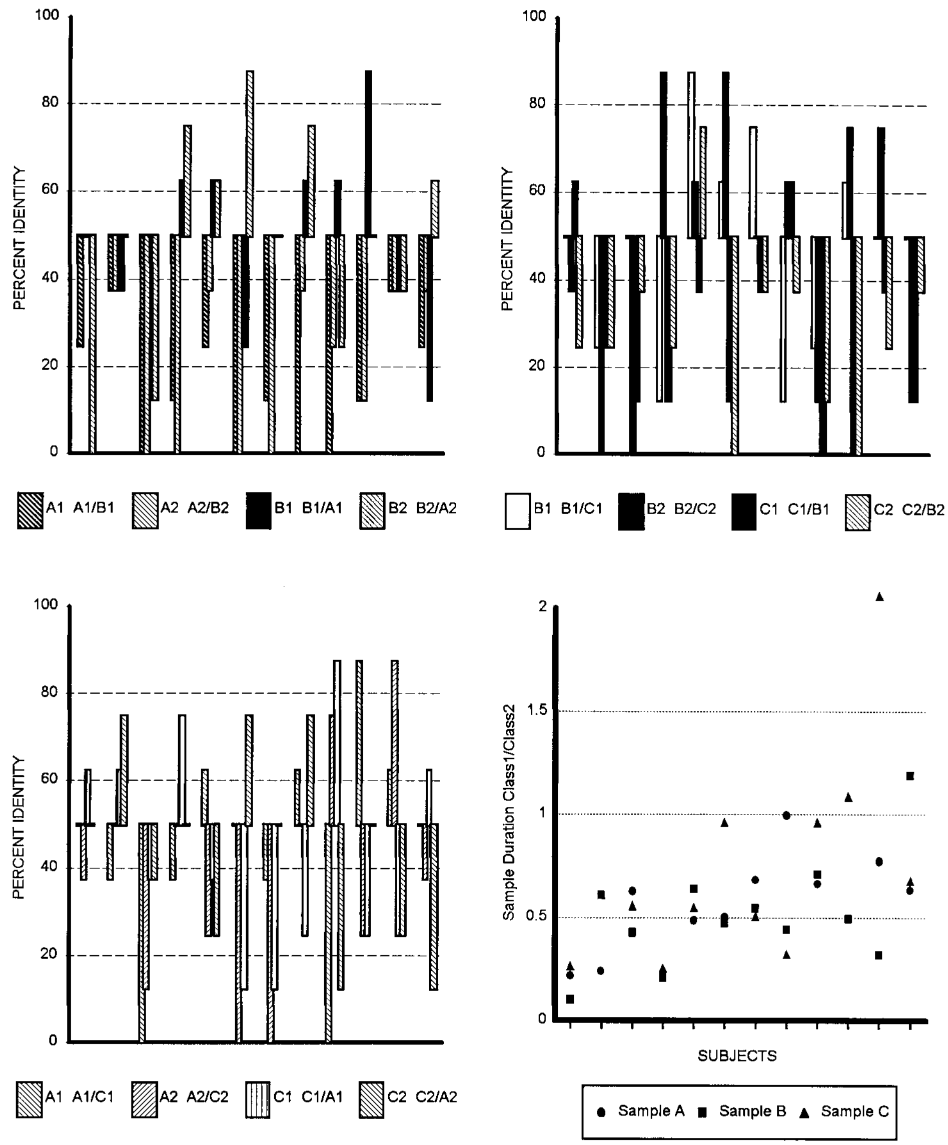

Fig. 3. Results of testing within-class reflexive-like relations. The top left, top right, and bottom left panels present the results when the A-B, B-C, and A-C relations, respectively, were pitted against the reflexive-like relation for each pigeon for each class. The bottom right panel presents the sample-duration ratio for samples during testing.

rupted). For each of the trained relations, each pigeon had responded and its responding had been reinforced over 1,000 times during training and baseline sessions. The overall pattern of responding indicated somewhat less stimulus control by the training clusters on trials with B as the sample compared to those with either A or C as the sample. The present study cannot account for this effect, but the B stimulus, like a nodal value, served as both sample and comparison with two other classes, whereas the A and C stimuli each occurred with only the B stimuli. Further experimental analysis of each stimulus control relation in terms of the combined control to select (Type S) the "correct" comparison and reject (Type R) the other comparison is suggested by these data.

The results of testing the symmetric-like, composite (symmetric- and transitive-like), and transitive-like relations with the D stimulus following C-D training are presented in Figure 4. There was no evidence of the emergence of the symmetric-like relation, and sample-duration ratios during test trials indicated that there was no distinctive sample response pattern when D stimuli were samples. There was no indication of the emergence of the composite D-B or D-A relations. In the tests for the transitive-like B-D and A-D relation (see middle row of Figure 4), 6 and 3 of the 12 pigeons, respectively, were near or above 80% in class-consistent responding for both classes, and the overall pattern of responding indicated class-consistent responding.

Upon retesting, the transitive-like A-C relation and between-class identity-like relation began to degrade. Overall percentage of class-consistent responding was down to 81.08%, 80.92%, and 85.5% for the 12 pigeons for the A-C transitive-like, the C-A transitive-like, and the between-class reflexive-like relations, respectively.

The results of the second testing of the symmetric-like, composite (symmetric- and transitive-like), and transitive-like relations with the D stimulus following off-baseline training are presented in Figure 5. There was the suggestion of an emergent symmetric-like relation; 4 of 12 pigeons demonstrated a tendency (above 70% for both classes) for class-consistent responding. There was emergence of the composite symmetric- and transitive-like D-B and D-A relations in 1 of the pigeons, and 3 others approached (70%) class-consistent performances on the D-B relation. The transitive-like B-D and A-D relations continued to occur for 2 and 5 of the 12 pigeons, respectively. Comparison of Figures 4 and 5 indicates the effects of the off-baseline training. The off-baseline training provided two components, the presentation of D stimuli in the role of samples, in a different (i.e., center key) location (Iversen, Sidman, & Carrigan, 1986) and the stimulus-consistent differential reinforcement.

The second retesting of the transitive-like A-C and between-class reflexive-like relations indicated further weakening. Overall percentage of class-consistent responding was down to 72.11%, 74.11%, and 78.31 for the 12 pigeons for the A-C transitive-like, the C-A transitive-like, and the between-class reflexive-like relations, respectively.

DISCUSSION

Training clusters that arranged class-consistent differential reinforcement with different outcomes resulted in distinctive sample responding. Subsequent tests for emergence demonstrated transitive-like, reflexive-like, and symmetric-like relations. The respondent–operant interaction apparently augmented emergent relations and encouraged a nonhuman model of stimulus class formation that is distinct from classes established by stimulus generalization and from functional classes. It is possible that stimulus generalization could explain various stimulus control relations, although the systematic nature of the results among individuals and the fact that each pigeon had a unique set of stimuli prohibit a simple stimulus-generalization account.

Not all pigeons responded under stimulus-class-like control on each test. Nevertheless, the basic intention of the study was accomplished; to enhance the emergence of stimulus–stimulus relations through class-consistent differential reinforcement. The stimulus classes formed were not simply functional classes (Goldiamond, 1966), such as those established by Vaughan (1988, 1989) wherein stimuli were equivalent in behavioral function or substitutable (Galloway & Petre, 1968; Sidman, Wynne, Maguire, & Barnes, 1989) for one another in terms of a reinforcement contingency (also see Nakagawa, 1986, 1992). Equivalence-like classes were produced, wherein untaught stimulus–stimulus relations emerged from training clusters that set the occasion for reinforcement in a four-term contingency (Sidman, 1986). The class members were substitutable in the match-to-sample procedure, based on conditional discriminations, and the stimulus control relations resembled those that define equivalence classes.

To best understand how this procedure might enhance equivalence-class-like formation, consideration must be made within the four-term contingency of (a) the sample followed by (b) the comparison controlling (c) a terminal response that (d) produces reinforcement (Sidman, 1986). Does the re-

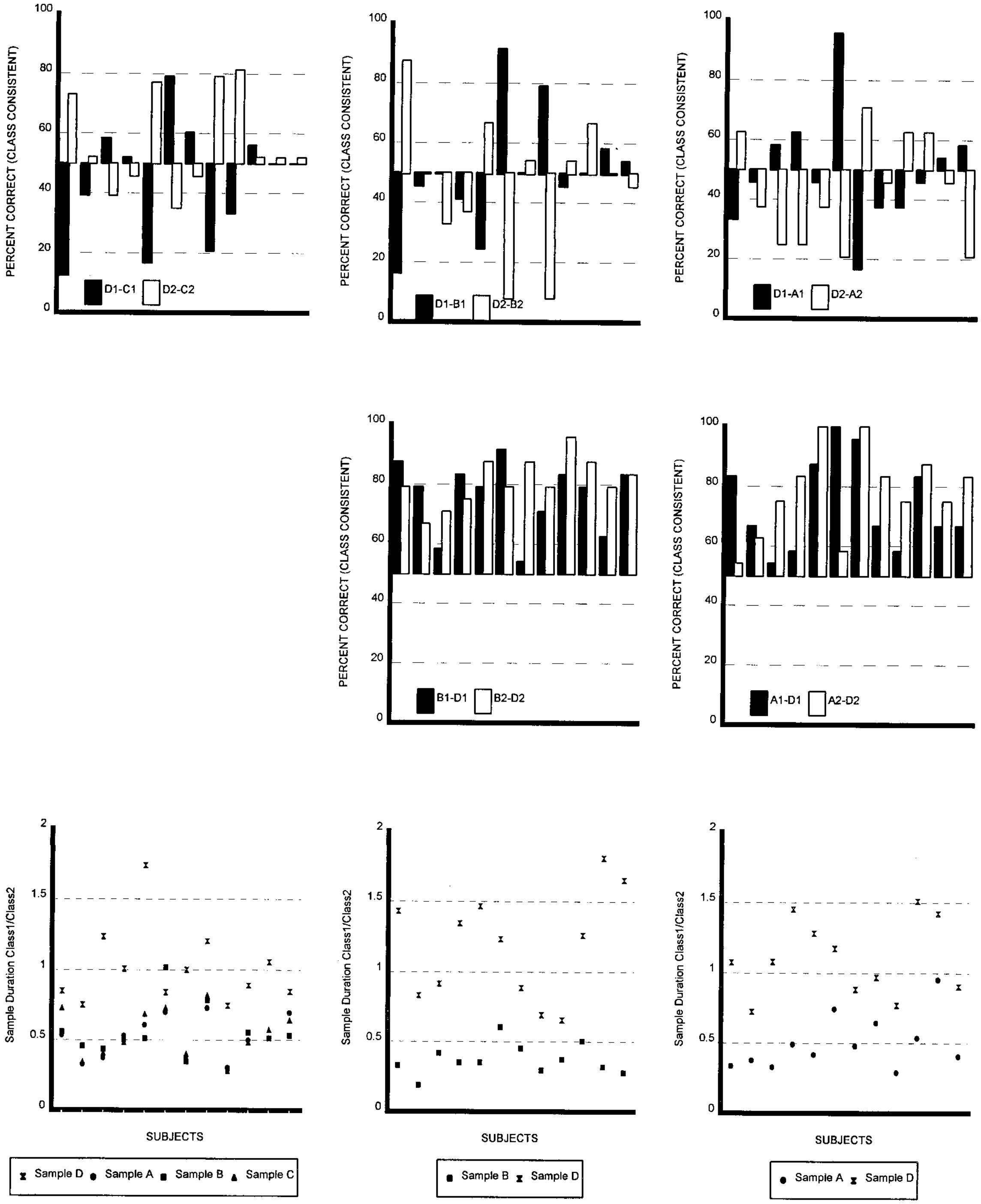

Fig. 4. Results of testing the symmetric-like, composite (symmetric- and transitive-like), and transitive-like relations following C-D training. The top left, center, and right panels present the percentage of trials with class-consistent responses for the D-C symmetric-like, the D-B composite, and the D-A composite relations, respectively, for each pigeon for each class. The middle row presents the results of the B-D and A-D transitive-like tests, and the bottom row presents the sample-duration ratios during testing.

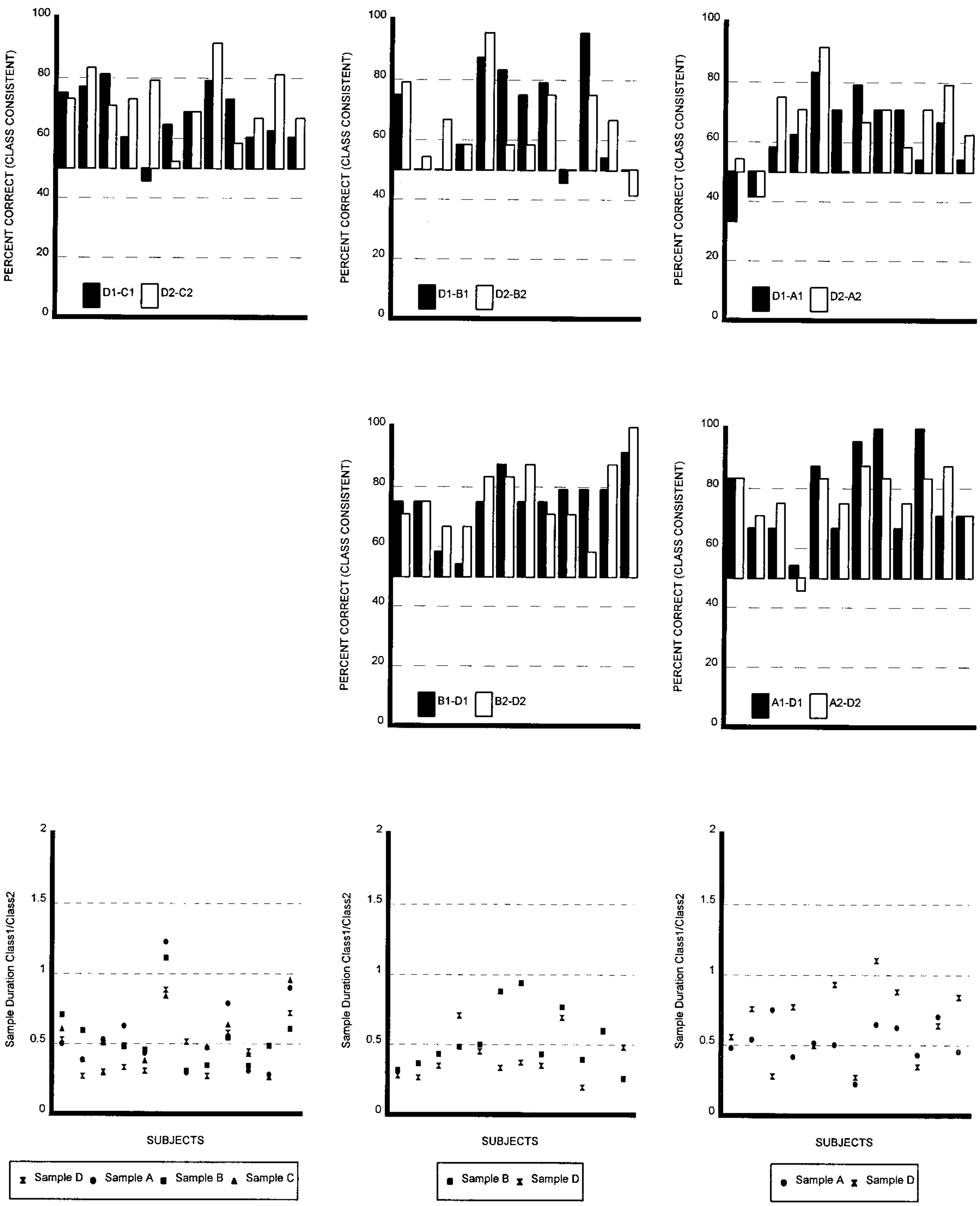

Fig. 5. Results of testing the symmetric-like, composite (symmetric- and transitive-like), and transitive-like relations following off-baseline training of the D-O relation. See Figure 4 for details.

quired observing response to the sample create an additional intermediate term? Perhaps we should posit a response to any stimulus that enters into a stimulus control relation whether the response is required by contingency, elicited by sign tracking, or is procedurally unobservable (see the ''coding response'' of Lawrence, 1963, and the ''perceptual response'' of Schoenfeld & Cumming, 1963). Nevertheless, in the current procedure a response was required to the sample to produce the comparisons. Conceivably, class-consistent differential reinforcement with different outcomes sequentially augments the relations between the terminal response and the outcome, the comparison and terminal response, the observing response and comparison, and the sample and observing response, all of which consequently may contribute to the emergent stimulus–stimulus relations between sample and comparison on transitive-like, reflexive-like, and symmetric-like test trials.

First, the terminal response–outcome relation generates, perhaps through a Pavlovian process, remarkably sensitive and consistent variation in behavior on the basis of the qualities and quantities of hedonic stimuli (Allan & Zeigler, 1994). If the present procedure had required an FR 5 comparison requirement, perhaps this distinctiveness would have been illustrated in the terminal response. From this respondent–operant view, the comparison now, in part, serves as a conditioned stimulus (CS) and, in turn, the sample acquires CS properties, illustrated in the present study by the development of distinctive class-consistent sample duration ratios. From outcome to terminal response, by means of a Pavlovian process, the comparison and the sample, perhaps by means of higher order conditioning for the sample, manifest an appended association that is correlated with the operant discriminative contingencies. There is known to be an enhancement of stimulus control when operant contingencies require distinctive responding to specific discriminative stimuli, especially samples in the match-to-sample procedure (Cohen, Brady, & Lowry, 1981; Cohen, Looney, Brady, & Aucella, 1976; McIntire, Cleary, & Thompson, 1987; Paul, 1983; Sacks, Kamil, & Mack, 1972). A more detailed analysis of the procedure is required to assess whether the nature of this advantage is based on an augmented composite stimulus control relation through the addition of respondent discriminative control, or if the conditioned responses, both to sample and comparison, provide additional stimulus elements which, in turn, expand the contingent stimulus control relation.

Distinctive responding to stimulus class members, whether elicited via stimulus–reinforcer contiguity, occasioned by way of contingency, or both (Urcuioli & DeMarse, 1994), is significant because it summons many traditional accounts of emergence based on response mediation (e.g., Jenkins, 1963; Miller & Dollard, 1941; Osgood, 1953), is identified with recent deliberation regarding naming and emergence (see Horne & Lowe, 1996; Lowe & Horne, 1996), and corresponds with contentions that a linguistic repertoire is required for equivalence class formation and, conversely, that verbalization may be the product of equivalence class formation (R. R. Saunders & Green, 1992; Sidman, 1990). A claim of equivalence class formation with nonhuman animals by McIntire et al. (1987) was criticized (Hayes, 1989; K. J. Saunders, 1989) on the basis that if the training clusters required distinctive responses to the discriminative stimuli, response mediation precluded the demonstration of emergent stimulus–stimulus relations (Sidman & Tailby, 1982). Such an analysis of these procedures suggests that the performances indicating emergence in the novel arrangements of test trials are not, in fact, untrained. Procedures that result in distinctive responding, however, should not be precluded from an analysis of stimulus class formation (Bentall, Dickins, & Fox, 1993; Dickins, Bentall, & Smith, 1993; Manabe, Kawashima, & Staddon, 1995) because distinctive responding to different discriminative stimuli, as a paradigm, may be pivotal for understanding equivalence class formation in humans. The difficulty ahead lies in establishing a vocabulary that can narrate a dynamic process wherein responses, or perhaps the stimulus properties they engender, enter into the stimulus control relations that influence emergence.

Finally, emergent relations may not meet the formal requirements of equivalence class formation if O1 and O2 enter into stimulus control relations due to their stimulus properties. Reinforcers become members of the equivalence classes and can be used to expand class membership with humans (Dube, McIlvane, MacKay, & Stoddard, 1987; Dube, McIlvane, Maguire, Mackay, & Stoddard, 1989; Shenck, 1994). In the present study, by training A1-B1-O1 and B1-C1-O1, the A-C relation may not entail a transitive relation with the B stimulus as the node, but may reflect stimulus relations between each Class 1 discriminative stimulus and O1, such that A1-O1 and C1-O1 account for the control by C1 following A1. When hedonic stimuli have been utilized as discriminative stimuli (Hall, Ray, & Bonardi, 1993; Holland, 1981; Holland & Forbes, 1982; Steirn, Jackson-Smith, & Zentall, 1991; Zentall, Sherburne, & Steirn, 1992), emergent-like relations occur, although as above, these may not meet the formal requirements for the definition of equivalence class formation. Outcomes as class members, however, might help to explain the emergence of the transitive-like B-D and A-D relations following the C-D training cluster. Further investigation into the enrollment of the stimulus properties of the reinforcing event as a class member will be required to address this issue.

Behavior demonstrating emergent-like relations described by a rule such as "if the sample is of Class 1, then select a Class 1 comparison" was observed, and when a reflexive comparison was presented with a same-class member, the addition of the second within-class alternative disrupted stimulus control. Of further interest, in the within-class reflexive-like tests, was the apparent difference between the B stimuli, which had served as both sample and comparison with two other class members, and the A and C stimuli, which each occurred only with the B stimuli. Specifically, the baseline stimulus control relations were disrupted more by the addition of a reflexive comparison when B stimuli were samples than when either A or C stimuli served as samples. This result suggests that various relations within the class may vary in strength based on training procedure and encourages additional study of the matter.

The present procedure permits the observation of distinctive responding to discriminative stimuli which appears to covary with the emergence of stimulus control. Procedures that generate distinctive responding to discriminative stimuli need not be linked to attempts to postulate central explanatory mechanisms of behavioral control (Dickinson, 1980; Hull, 1931, 1939; Rescorla & Solomon, 1967). The three-term operant contingency (Skinner, 1935) places the reinforcer such that no additional characterization of Pavlovian conditioning is required. Class-consistent differential reinforcement with different outcomes requires appending the role of response–reinforcer and stimulus–reinforcer relations in creating and shaping new stimulus control relations and new responses during acquisition that may enter into the initial-training reinforcement contingency (Balsam, 1988).

REFERENCES

Allan, R. W., & Zeigler, H. P. (1994). Autoshaping the pigeon's gape response: Acquisition and topography as a function of reinforcer type and magnitude. *Journal of the Experimental Analysis of Behavior, 62,* 201–223.

Balsam, P. D. (1988). Selection, representation, and equivalence of controlling stimuli. In R. C. Atkinson, R. J. Herrnstein, G. Lindzey, & R. D. Luce (Eds.), *Stevens' handbook of experimental psychology* (2nd ed., pp. 111–166). New York: Wiley.

Bentall, R. P., Dickins, D. W., & Fox, S. R. A. (1993). Naming and equivalence: Response latencies for emergent relations. *Quarterly Journal of Experimental Psychology: Comparative and Physiological Psychology, 46B,* 187–214.

Boysen, S. T., & Berntson, G. G. (1989). Numerical competence in a chimpanzee (*Pan troglodytes*). *Journal of Comparative Psychology, 103,* 23–31.

Carrigan, P. F., & Sidman, M. (1992). Conditional discrimination and equivalence relations: A theoretical analysis of control by negative stimuli. *Journal of the Experimental Analysis of Behavior, 58,* 183–204.

Carter, D. E., & Werner, T. J. (1978). Complex learning and information processing by pigeons: A critical analysis. *Journal of the Experimental Analysis of Behavior, 29,* 565–601.

Catania, A. C. (1971). Elicitation, reinforcement, and stimulus control. In R. Glasser (Ed.), *The nature of reinforcement* (pp. 196–220). New York: Academic Press.

Cohen, L. R., Brady, J., & Lowry, M. (1981). The role of differential responding in matching-to-sample and delayed matching performance. In M. L. Commons & J. A. Nevin (Eds.), *Quantitative analyses of behavior: Vol. 1. Discriminative properties of reinforcement schedules* (pp. 345–363). Cambridge, MA: Ballinger.

Cohen, L. R., Looney, T. A., Brady, J. H., & Aucella, A. F. (1976). Differential sample response schedules in the acquisition of conditional discriminations by pigeons. *Journal of the Experimental Analysis of Behavior, 26,* 301–314.

Cumming, W. W., & Berryman, R. (1965). The complex discriminated operant: Studies of matching-to-sample and related problems. In D. I. Mostofsky (Ed.), *Stim-*

ulus generalization (pp. 284–330). Stanford, CA: Stanford University Press.

Cumming, W. W., Berryman, R., & Cohen, L. R. (1965). Acquisition and transfer of zero delay matching. *Psychological Reports, 17,* 435–445.

D'Amato, M. R., & Salmon, D. P. (1984). Cognitive processes in cebus monkeys. In H. L. Roitblat, T. G. Bever, & H. S. Terrace (Eds.), *Animal cognition* (pp. 149–168). Hillsdale, NJ: Erlbaum.

D'Amato, M. R., Salmon, D. P., Loukas, E., & Tomie, A. (1985). Symmetry and transitivity of conditional relations in monkeys (*Cebus apella*) and pigeons (*Columba livia*). *Journal of the Experimental Analysis of Behavior, 44,* 35–47.

Dickins, D. W., Bentall, R. P., & Smith, A. B. (1993). The role of individual stimulus names in the emergence of equivalence relations: The effects of paired-associates training between names. *The Psychological Record, 43,* 713–724.

Dickinson, A. (1980). *Contemporary animal learning theory.* Cambridge, England: Cambridge University Press.

Dube, W. V., McIlvane, W. J., Callahan, T. D., & Stoddard, L. T. (1993). The search for stimulus equivalence in nonverbal organisms. *The Psychological Record, 43,* 761–778.

Dube, W. V., McIlvane, W., & Green, G. (1992). An analysis of generalized match-to-sample test procedures. *The Psychological Record, 42,* 17–28.

Dube, W. V., McIlvane, W. J., Mackay, H. A., & Stoddard, L. T. (1987). Stimulus class membership established via stimulus-reinforcer relations. *Journal of the Experimental Analysis of Behavior, 47,* 159–175.

Dube, W. V., McIlvane, W. J., Maguire, R. W., Mackay, H. A., & Stoddard, L. T. (1989). Stimulus class formation and stimulus-reinforcer relations. *Journal of the Experimental Analysis of Behavior, 51,* 65–76.

Fields, L., & Verhave, T. (1987). The structure of equivalence classes. *Journal of the Experimental Analysis of Behavior, 48,* 317–332.

Galloway, C., & Petre, R. D. (1968). An analysis of the functional equivalence of stimulus class members. *Journal of Experimental Child Psychology, 6,* 384–390.

Goldiamond, I. (1966). Perception, language, and conceptualization rules. In B. Kleinmuntz (Ed.), *Problem solving* (pp. 183–224). New York: Basic Books.

Gray, L. (1966). Backward association in pigeons. *Psychonomic Science, 4,* 333–334.

Hall, G., Ray, E., & Bonardi, C. (1993). Acquired equivalence between cues trained with a common antecedent. *Journal of Experimental Psychology: Animal Behavior Processes, 19,* 391–399.

Hayes, S. C. (1989). Nonhumans have not yet shown stimulus equivalence. *Journal of the Experimental Analysis of Behavior, 51,* 385–392.

Hearst, E., & Jenkins, H. M. (1974). Sign-tracking: The stimulus-reinforcer relation and directed action. *Monograph of the Psychonomic Society.*

Herman, L. M., & Gordon, J. A. (1974). Auditory delayed matching in the bottlenosed dolphin. *Journal of the Experimental Analysis of Behavior, 21,* 19–26.

Hogan, D. E., & Zentall, T. R. (1977). Backward associations in the pigeon. *American Journal of Psychology, 90,* 3–15.

Holland, P. C. (1981). Acquisition of representation-mediated conditioned food aversions. *Learning and Motivation, 12,* 1–18.

Holland, P. C., & Forbes, D. T. (1982). Control of conditional discrimination performance by CS-evoked event representations. *Animal Learning & Behavior, 10,* 249–256.

Horne, P. J., & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior, 65,* 185–242.

Hull, C. L. (1931). Goal attraction and directing ideas conceived as habit phenomena. *Psychological Review, 38,* 487–506.

Hull, C. L. (1939). The problem of stimulus equivalence in behavior theory. *Psychological Review, 46,* 9–30.

Iversen, I. H., Sidman, M., & Carrigan, P. (1986). Stimulus definition in conditional discriminations. *Journal of the Experimental Analysis of Behavior, 45,* 297–304.

Jenkins, J. J. (1963). Mediated associations: Paradigms and situations. In C. N. Cofer & B. S. Musgrave (Eds.), *Verbal behavior and learning: Problems and processes* (pp. 210–245). New York: McGraw-Hill.

Johnson, C., & Sidman, M. (1993). Conditional discrimination and equivalence relations: Control by negative stimuli. *Journal of the Experimental Analysis of Behavior, 59,* 333–347.

Kendall, S. B. (1983). Tests for mediated transfer in pigeons. *The Psychological Record, 33,* 245–256.

Kuno, H., Kitadate, T., & Iwamoto, T. (1994). Formation of transitivity in conditional matching to sample by pigeons. *Journal of the Experimental Analysis of Behavior, 62,* 399–408.

Lawrence, D. H. (1963). The nature of a stimulus: Some relationships between learning and perception. In S. Koch (Ed.), *Psychology: a study of science* (Vol. 5, pp. 179–212). New York: McGraw-Hill.

Lipkens, R., Kop, P. F. M., & Matthijs, W. (1988). A test of symmetry and transitivity in the conditional discrimination performances of pigeons. *Journal of the Experimental Analysis of Behavior, 49,* 395–409.

Lowe, C. F., & Horne, P. J. (1996). Reflections on naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior, 65,* 315–340.

Lucas, G. (1992). *CONMAN-E.* Bloomington, IN: Spyder Systems.

Manabe, K., Kawashima, T., & Staddon, J. E. R. (1995). Differential vocalization in budgerigars: Towards an experimental analysis of naming. *Journal of the Experimental Analysis of Behavior, 63,* 111–126.

McIntire, K. D., Cleary, J., & Thompson, T. (1987). Conditional relations by monkeys: Reflexivity, symmetry, and transitivity. *Journal of the Experimental Analysis of Behavior, 47,* 279–285.

Miller, N. E., & Dollard, J. (1941). *Social learning and imitation.* New Haven, CT: Yale University Press.

Nakagawa, E. (1986). Overtraining, extinction and shift learning in a concurrent discrimination in rats. *The Quarterly Journal of Experimental Psychology, 38B,* 313–326.

Nakagawa, E. (1992). Effects of overtraining on reversal learning by rats in concurrent and single discriminations. *The Quarterly Journal of Experimental Psychology, 44B,* 37–56.

Nissen, H. W., Blum, J. S., & Blum, R. A. (1948). Analysis of matching behavior in chimpanzee. *Journal of Comparative and Physiological Psychology, 41,* 62–74.

Oden, D. L., Thompson, R. K. R., & Premack, D. (1988). Spontaneous transfer of matching by infant chimpanzees (*Pan troglodytes*). *Journal of Experimental Psychology: Animal Behavior Processes, 14,* 140–145.

Osgood, C. E. (1953). *Method and theory in experimental psychology.* New York: Oxford University Press.

Pack, A. A., Herman, L. M., & Roitblat, H. L. (1991). Generalization of visual matching and delayed matching by a California sea lion (*Zalophus californianus*). *Animal Learning & Behavior, 19,* 37–48.

Paul, C. (1983). Sample-specific ratio effects in matching to sample. *Journal of the Experimental Analysis of Behavior, 39,* 77–85.

Premack, D. (1986). *Gavagai! or the future history of the animal language controversy.* Cambridge, MA: MIT Press.

Ray, B. A., &, Sidman, M. (1970). Reinforcement schedules and stimulus control. In W. N. Schoenfeld (Ed.), *The theory of reinforcement schedules* (pp. 187–214). New York: Appleton-Century-Crofts.

Rescorla, R. A., & Solomon, R. L. (1967). Two-process learning theory: Relationships between Pavlovian conditioning and instrumental learning. *Psychological Review, 74,* 151–182.

Richards, R. W. (1988). The question of bidirectional associations in pigeons' learning of conditional discrimination tasks. *Bulletin of the Psychonomic Society, 26,* 577–579.

Rodewald, H. K. (1974). Symbolic matching-to-sample by pigeons. *The Psychological Record, 34,* 987–990.

Sacks, R. A., Kamil, A. C., & Mack, R. (1972). The effects of fixed-ratio sample requirements on matching to sample in the pigeon. *Psychonomic Science, 26,* 291–293.

Santi, A. (1982). Hue matching and hue oddity in pigeons: Is explicit training not to peck incorrect hue combinations a sufficient condition for transfer? *The Psychological Record, 32,* 61–73.

Saunders, K. J. (1989). Naming in conditional discrimination and stimulus equivalence. *Journal of the Experimental Analysis of Behavior, 51,* 379–384.

Saunders, R. R., & Green, G. (1992). The nonequivalence of behavioral and mathematical equivalence. *Journal of the Experimental Analysis of Behavior, 57,* 227–241.

Schoenfeld, W. N., & Cumming, W. W. (1963). Behavior and perception. In S. Koch (Ed.), *Psychology: A study of science* (Vol. 5, pp. 213–252). New York: McGraw-Hill.

Schusterman, R. J., & Kastak, D. (1993). A California sea lion (*Zalophus californianus*) is capable of forming equivalence relations. *The Psychological Record, 43,* 823–839.

Shenck, J. J. (1994). Emergent relations of equivalence generated by outcome-specific consequences in conditional discrimination. *The Psychological Record, 44,* 537–558.

Sidman, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research, 14,* 5–13.

Sidman, M. (1986). Functional analysis of emergent verbal classes. In T. Thompson & M. D. Zeiler (Eds.), *Analysis and integration of behavioral units* (pp. 213–245). Hillsdale, NJ: Erlbaum.

Sidman, M. (1990). Equivalence relations: Where do they come from? In D. E. Blackman & H. Lejeune (Eds.), *Behaviour analysis in theory and practice: Contributions and controversies* (pp. 93–114). Hillsdale, NJ: Erlbaum.

Sidman, M., Rauzin, R., Lazar, R., Cunningham, S., Tailby, W., & Carrigan, P. (1982). A search for symmetry in the conditional discriminations of rhesus monkeys, baboons, and children. *Journal of the Experimental Analysis of Behavior, 37,* 23–44.

Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching-to-sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior, 37,* 5–22.

Sidman, M., Wynne, C. K., Maguire, R. W., & Barnes, T. (1989). Functional classes and equivalence relations. *Journal of the Experimental Analysis of Behavior, 52,* 261–274.

Skinner, B. F. (1935). The generic nature of the concepts of stimulus and response. *Journal of General Psychology, 12,* 40–65.

Steirn, J. N., Jackson-Smith, P., & Zentall, T. R. (1991). Mediational use of internal representations of food and no-food events by pigeons. *Learning and Motivation, 22,* 353–365.

Stromer, R., & Osborne, J. G. (1982). Control of adolescents' arbitrary matching-to-sample by positive and negative stimulus relations. *Journal of the Experimental Analysis of Behavior, 37,* 329–348.

Tomonaga, M. (1993). Tests for control by exclusion and negative stimulus relations of arbitrary matching to sample in a "symmetry-emergent" chimpanzee. *Journal of the Experimental Analysis of Behavior, 59,* 215–229.

Tomonaga, M., Matsuzawa, T., Fujita, K., & Yamamoto, J. (1991). Emergence of symmetry in a visual conditional discrimination by chimpanzees (*Pan troglodytes*). *Psychological Reports, 68,* 51–60.

Urcuioli, P. J., & DeMarse, T. (1994). On the relationship between differential outcomes and differential sample responding in matching-to-sample. *Journal of Experimental Psychology: Animal Behavior Processes, 20,* 249–263.

Vaughan, W. (1988). Formation of equivalence sets in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes, 14,* 36–42.

Vaughan, W. (1989). Reply to Hayes. *Journal of the Experimental Analysis of Behavior, 51,* 397.

Wright, A. A., Cook, R. G., Rivera, J. J., Sands, S. F., & Delius, J. D. (1988). Concept learning by pigeons: Matching-to-sample with trial-unique video picture stimuli. *Animal Learning & Behavior, 16,* 436–444.

Zentall, T. R., Sherburne, L. M., & Steirn, J. N. (1992). Development of excitatory backward associations during the establishment of forward associations in a delayed conditional discrimination by pigeons. *Animal Learning & Behavior, 20,* 199–206.

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APPENDIX

A summary of the training clusters presents the total number of sessions and, for the last session of each cluster, the percentage of class-consistent responses, the sample duration ratio (duration of Class 1 samples over duration of Class 2 samples), the percentage of responses to Class 1 comparisons, and the percentage of responses to the left comparison.

		Last session					Last session			
Pigeon	Sessions	% class consis-tent	Sample duration ratio	% Class 1	% left	Sessions	% class consis-tent	Sample duration ratio	% Class 1	% left
Procedure 1 (A-B and B-A criterion; first 20 sessions of A-B/B-A without correction)										
Class-inconsistent differential reinforcement										
		A-B associative training					B-A associative training			
10	10	98	0.85	51	50	11	95	0.96	52	51
16	5	95	0.76	50	48	4	95	1.17	51	47
20	9	97	1.29	51	50	2	90	0.82	48	49
21	4	98	0.93	52	49	3	99	1.00	47	50
Class-consistent differential reinforcement										
		A-B associative training					B-A associative training			
11	10	92	0.63	51	48	3	92	0.80	50	49
13	9	97	0.39	51	50	4	97	0.52	47	48
15	13	90	0.49	52	49	5	92	0.62	50	51
18	6	95	0.60	47	50	5	93	0.52	49	52
Procedure 2 (five sessions each of A-B and B-A; all A-B/B-A with correction)										
Class-inconsistent differential reinforcement										
		A-B associative training					B-A associative training			
09	5	58	1.12	60	43	5	94	0.96	49	48
19	5	88	0.89	44	46	5	92	1.08	46	46
53	5	66	1.30	47	51	5	98	0.93	50	50
54	5	88	0.96	51	42	5	88	0.87	58	54
Class-consistent differential reinforcement										
		A-B associative training					B-A associative training			
01	5	77	0.75	52	51	5	96	0.53	51	47
17	5	72	0.61	61	54	5	99	0.77	49	50
51	5	75	0.87	56	33	5	80	0.29	54	45
52	5	69	0.54	69	71	5	97	0.65	52	53
Procedure 2 (five sessions each of A-B and B-A; all A-B/B-A with correction) retrained, including all pretraining phases										
Class-consistent differential reinforcement										
		A-B associative training					B-A associative training			
19	5	58	0.78	79	47	5	94	0.64	55	48
20	5	68	0.81	77	51	5	89	0.41	50	49
21	5	79	0.73	62	52	5	82	0.81	66	60
54	5	68	0.65	79	41	5	93	0.59	48	49
Procedure 1 (A-B and B-A criterion; first 20 sessions of A-B/B-A without correction)										
Class-inconsistent differential reinforcement										
		A-B/B-A discrimination training without correction procedure					A-B/B-A discrimination training with correction procedure			
10	20	51	0.99	51	10	50[a]	56	1.01	46	41
16	20	56	0.95	48	81	50[a]	83	1.03	48	47
20	20	60	1.03	40	23	34[b]	90	1.30	50	49
21	20	71	1.11	48	43	50[a]	83	1.00	54	46
Class-consistent differential reinforcement										
		A-B/B-A discrimination training without correction procedure					A-B/B-A discrimination training with correction procedure			
11	20	70	0.39	74	58	11	92	0.30	52	51
13	20	63	3.18	88	50	34	95	0.55	51	48
15	20	83	2.27	67	42	27	97	0.39	51	50
18	20	82	0.82	65	54	9	92	0.74	52	48

APPENDIX

(*Continued*)

		Last session					Last session			
Pigeon	Sessions	% class consis-tent	Sample duration ratio	% Class 1	% left	Sessions	% class consis-tent	Sample duration ratio	% Class 1	% left
Procedure 2 (five sessions each of A-B and B-A; all A-B/B-A with correction)										
Class-inconsistent differential reinforcement										
						A-B/B-A discrimination training with correction procedure				
09						50[a]	69	1.00	50	34
19						50[a]	77	1.15	48	50
53						50[a]	70	0.98	52	44
54						50[a]	69	1.02	50	63
Class-consistent differential reinforcement										
						A-B/B-A discrimination training with correction procedure				
01						14	91	0.79	50	51
17						13	95	0.43	50	47
51						7	94	0.26	47	50
52						5	94	0.32	49	51
Retrained, including pretraining phases										
Class-consistent differential reinforcement										
		A-B/B-A discrimination training								
19						11	94	0.35	47	49
20						8	96	0.73	49	50
21						4	90	0.78	46	51
54						9	96	0.55	51	50
Class-consistent differential reinforcement										
		B-C associative training					C-B associative training			
11	11	95	0.53	48	49	2	96	0.63	50	51
13	8	96	0.87	51	49	4	97	0.55	50	51
15	13	92	0.28	50	47	8	92	0.72	52	51
18	3	94	0.66	49	53	2	95	0.85	51	53
01	5	97	0.51	52	47	5	95	0.74	47	50
17	5	96	0.78	50	51	5	100	0.58	51	51
51	5	95	0.65	47	49	5	90	0.62	48	49
52	5	89	0.75	48	49	5	100	0.71	50	50
19	5	96	0.74	51	49	5	96	0.61	51	48
20	5	94	0.48	48	50	5	97	0.60	50	50
21	5	93	0.37	48	51	5	95	0.72	49	52
54	5	96	0.84	49	50	5	92	0.46	51	52
Class-consistent differential reinforcement										
		B-C/C-B discrimination training with correction procedure								
11	8	91	0.81	51	47					
13	4	97	0.40	51	51					
15	8	92	0.66	49	50					
18	6	100	0.77	48	50					
01	3	92	0.59	52	52					
17	3	99	0.71	49	51					
51	4	92	0.43	51	52					
52	5	95	0.35	50	51					
19	3	91	0.37	51	51					
20	3	95	0.94	50	49					
21	5	95	0.42	50	50					
54	4	92	0.52	53	51					

APPENDIX

(*Continued*)

		Last session					Last session			
Pigeon	Sessions	% class consis-tent	Sample duration ratio	% Class 1	% left	Sessions	% class consis-tent	Sample duration ratio	% Class 1	% left
Class-consistent differential reinforcement										
		C-D discrimination training with correction procedure				Off discrimination training baseline				
11	29	96	0.75	52	51	20	100	0.52	[c]	[d]
13	10	93	0.41	50	49	20	100	0.27		
15	19	92	0.39	49	50	20	100	0.35		
18	11	95	0.49	50	49	20	100	0.31		
01	5	99	0.61	50	52	20	100	0.25		
17	4	94	0.75	49	48	20	100	0.81		
51	8	97	0.45	49	51	20	100	0.51		
52	10	91	0.80	52	50	20	100	0.48		
19	5	95	0.32	50	50	20	100	0.62		
20	6	90	0.50	48	51	20	100	0.54		
21	4	92	0.54	53	51	20	100	0.46		
54	5	94	0.60	49	52	20	100	0.73		

[a] Indicates that the procedure was terminated without reaching the criterion.
[b] This pigeon was not continued to B-C training cluster.
[c,d] Not reported because there was no comparison choice.