DIFFERENTIAL SAMPLE RESPONSE SCHEDULES IN THE ACQUISITION OF CONDITIONAL DISCRIMINATIONS BY PIGEONS[1]

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Pigeons were trained on four matching-to-sample tasks with various schedule requirements in effect on the sample key. Differential sample-schedule requirements (a differential-reinforcement-of-low-rates of 3 sec in the presence of one sample and a fixed-ratio 16 in the presence of the other) produced rapid rates of acquisition that did not differ across tasks. Nondifferential sample-schedule requirements (fixed-ratio 1, fixed-ratio 16 or a differential-reinforcement-of-low-rates of 3 sec in the presence of both samples) produced slower rates of acquisition, which depended on the difficulty of the discriminations between samples and between comparisons. Patterns of stimulus and position preferences were influenced both by the comparison stimuli in each task and by the sample-schedule requirements. Detailed analyses of acquisition revealed frequent instances of complete differential sample control of comparison responding at intermediate levels of overall "accuracy".

Key words: conditional discriminations, matching to sample, differential sample response, pigeons

SECTION I

Acquisition of Conditional Discriminations with and without Pretraining and Maintenance of Differential Sample Responding

In a conditional discrimination, the relationship between the discriminative stimuli and the reinforcement contingencies depends on the stimulus context in which they appear (Cumming and Berryman, 1965). The matching-to-sample procedure is a conditional discrimination procedure in which the subject is first presented with a sample stimulus, and then required to select the correct stimulus from a set (usually two) of comparisons. In identity matching, the correct choice is the comparison that is most like the sample. In nonidentity matching, the relation between

the sample and the correct comparison is arbitrary. (Ginsburg, 1957, referred to this as "amatching"; Cumming and Berryman, 1965, used the term "symbolic matching".) The terms "matching" and "matching to sample" in the present paper refer to the procedures described above and not to the subject's performance on those tasks.

Carter and Eckerman (1975) compared the acquisition of identity and nonidentity matching in pigeons. Using two stimulus dimensions, hues and lines, they examined acquisition of hue-hue and line-line identity tasks and hue-line and line-hue nonidentity tasks (where the first term designates the sample stimulus dimension and the second term the comparisons). They found that hue-hue matching was acquired most rapidly, and that line-line matching was the most difficult. Hue-line and line-hue matching were tasks of intermediate difficulty, increasing in that order. Carter and Eckerman (1975) also compared the performance of pigeons given matching training to that of subjects trained on simple successive and simultaneous discriminations with the same hues and lines used in the matching tasks. They concluded that the difference in rates of acquisition of the matching tasks was a function of the discriminability of one sample from another and not of a difference between identity and nonidentity maching *per se*.

In the present study, a direct test of their conclusion was made by pretraining pigeons on a successive discrimination task with the stimuli that were to be used as samples, maintaining differential sample responding during matching training, and then comparing the acquisition of the four tasks, two identity (hue-hue and line-line) and two nonidentity (hue-line and line-hue). The rates of acquisition of these four matching tasks should be similar if the differential sample performance is equated across tasks (by pretraining and maintaining a differential sample-schedule requirement) and discriminations between comparisons are equated (by comparing tasks with the same comparison stimuli).

EXPERIMENT I

Experiment I examined the effect of pretraining and maintenance of differential sample responses on the acquisition of identity and nonidentity tasks. A DRL (differential-reinforcement-of-low-rates-of-responding) schedule and an FR (fixed-ratio) schedule were chosen as favorable conditions for generating clearly different response patterns under the control of the sample stimuli (*cf.* Lydersen and Perkins, 1974). A DRL 3-sec and an FR 16 were chosen because pilot data indicated that these schedule requirements resulted in approximately equal sample durations. In addition, both schedules ensured a sample response at the onset of the comparison stimuli. This latter feature was included because Eckerman, Lanson, and Cumming (1968) showed that a DRO (differential-reinforcement-of-other-behavior) schedule on the sample retards acquisition.

METHOD

Subjects

Sixteen experimentally naive adult female White Carneaux pigeons obtained from Palmetto Pigeon Plant were maintained at 80% of their free-feeding weights throughout the experiment. They were housed in individual home cages with health grit and water continuously available under a 16-hr light/8-hr dark cycle.

Apparatus

The experimental chamber was a standard Lehigh Valley Electronics three-key pigeon chamber, Model #132-02, with the interior painted flat black. A minimum force of 0.25 N was required to operate each key. Three Grason-Stadler inline display projectors (pattern #E4580-153) transilluminated the response keys with vertical or horizontal lines (three white lines on a black background) or hues (nominally green and orange). A Spectra Brightness Spot Meter (Model #1505 UB) was used to calibrate the luminance of each of the four stimuli on each key. The luminance values were then equated for humans ($\pm$0.06 log unit) across the three keys by adding neutral density filters to four of the stimuli. A ventilation fan and white-noise generator provided masking noise.

Experimental contingencies were programmed automatically by solid-state modules and a paper-tape reader located in an adjacent room. Responses and interresponse times (IRTs) were recorded on counters and an Esterline-Angus event recorder.

Procedure

Four birds were assigned to each of four groups, which differed with respect to the stimuli used as the samples and comparisons during matching-to-sample training, as summarized in Table 1. Three birds from each group were pretrained with the differential sample response requirements, which were subsequently maintained during matching-to-sample training (differential condition). The remaining four birds, one from each group, were assigned to a condition (nondifferential, FR 1/FR 1) that omitted such differential pretraining and maintenance (*cf.* Carter and Eckerman, 1975).

Magazine training and shaping. All pigeons were first trained to eat from the hopper with

Table 1

Experimental conditions for the four matching-to-sample tasks.

Group	Sample Stimuli	Comparison Stimuli	
		"Correct"	"Incorrect"
1. Hue-hue (Identity)	orange green	orange green	green orange
2. Hue-line (Nonidentity)	orange green	vertical horizontal	horizontal vertical
3. Line-hue (Nonidentity)	vertical horizontal	orange green	green orange
4. Line-line (Identity)	vertical horizontal	vertical horizontal	horizontal vertical

all keys dark and the houselight on. During the next session, subjects were trained to peck the center key (illuminated with one of the appropriate samples for each bird) by the method of successive approximations. Following the initial peck on the center key, a discrete-trial procedure was arranged in which the response that met the schedule requirement (FR 2 for the differential birds in each group, FR 1 for the nondifferential bird in each group) turned off the stimulus and produced 3-sec access to grain. Each presentation of grain was followed by an intertrial interval (ITI) with the houselight on and all keys dark. Each of the two stimuli appropriate for a given bird (see Table 1) was presented 30 times in a Gellerman series, with the FR schedule in effect for both stimuli. The ITI was increased from 3 sec to 10 sec in 1-sec steps.

Following this shaping session, the four non-differential subjects went directly to matching-to-sample training as described below. The 12 differential birds were exposed to three sessions with a discrete-trial multiple schedule in effect on the center key.

Differential pretraining. Each session consisted of 60 trials, 30 with each stimulus presented in a Gellerman series. The ITI was 10 sec and the reinforcer was 3-sec access to grain. Only the center key was illuminated during trials, and pecks to any dark key had no scheduled consequence. A trial began with the onset of a stimulus on the center key, which remained on until the schedule requirement was met. For Groups 1 and 2, the stimuli were orange and green; for Groups 3 and 4 they were vertical and horizontal. On orange or vertical trials a DRL requirement, timed from the first response in the presence of the stimulus, was scheduled. The DRL value was 3 sec for all three pretraining sessions. On green or horizontal trials, an FR requirement was scheduled. The FR value was increased from FR 4 during the first half of the first pretraining session to FR 8 for the second half. The value was FR 8 for the first half of the second pretraining session and then was increased to FR 16 for the remaining one and one-half sessions of pretraining.

Matching-to-sample training. During matching training, a trial began with the onset of one of the two stimuli (samples) on the center key. For the three differential birds in each

group, a DRL 3-sec schedule was in effect in sample 1 and an FR 16 in sample 2, as in the last session of pretraining. For the four non-differential birds not exposed to differential pretraining, a single peck (FR 1) was required in the presence of either sample. When the schedule requirement was met on the center key, the comparison stimuli were presented on the side keys (see Table 1). When the side keys were illuminated (1) additional responses to the center key had no scheduled consequence; (2) a response to the incorrect comparison turned off the keys and the houselight, leaving the bird in a darkened cage for 3 sec; (3) a response to the correct comparison turned off the keys and produced 3-sec access to grain. At the end of either blackout or grain presentation, a 10-sec ITI ensued with all keys dark, all responses ineffective, and the houselight on. Each 80-trial session consisted of 20 random permutations of the four stimulus configurations; the correct comparison appeared equally often on each side key with each of the samples. Four different sequences of these permutations were rotated across sessions. Trials were arranged without respect to accuracy on the preceding trial (noncorrection).

During the first session of matching training a zero-delay procedure was used with all birds; the sample went off the center key as the comparisons came on the side keys. All subsequent sessions utilized a simultaneous matching-to-sample procedure in which the sample stayed on the center key until the bird pecked one of the comparisons. Daily experimental sessions were conducted whenever the birds were within 15 g of their 80% free-feeding weights, until an accuracy criterion of at least 96% correct for three consecutive sessions was met or for 100 sessions if the criterion was not met.

RESULTS

At the end of pretraining, all 12 differential subjects showed different IRT distributions in the presence of the two stimuli to be used as samples in the matching-to-sample task. With an FR 16 schedule in effect (in the presence of horizontal for half the birds and green for the remaining subjects), 95% to 100% of all IRTs were shorter than 1 sec. In contrast, only 24% to 58% of the IRTs were shorter than 1 sec when the DRL 3-sec schedule was in effect (in the presence of vertical or orange).

PANELS B-E:

DRL3/FRI6   ●—● FRI/FRI   ●--● FRI/FRI (CARTER & ECKERMAN, 1975)

A   MEAN DRL/FR
- HUE-HUE
- HUE-LINE
- LINE-HUE
- LINE-LINE

B   HUE-HUE
●-169
▲-9148
■-5540
●-98

C   HUE-LINE
■-9055
▲-4377
●-4612
●-1403

D   LINE-HUE
●-9902
▲-9735
■-5388
●-10287

E   LINE-LINE
●-1236
▲-5630
●-10966
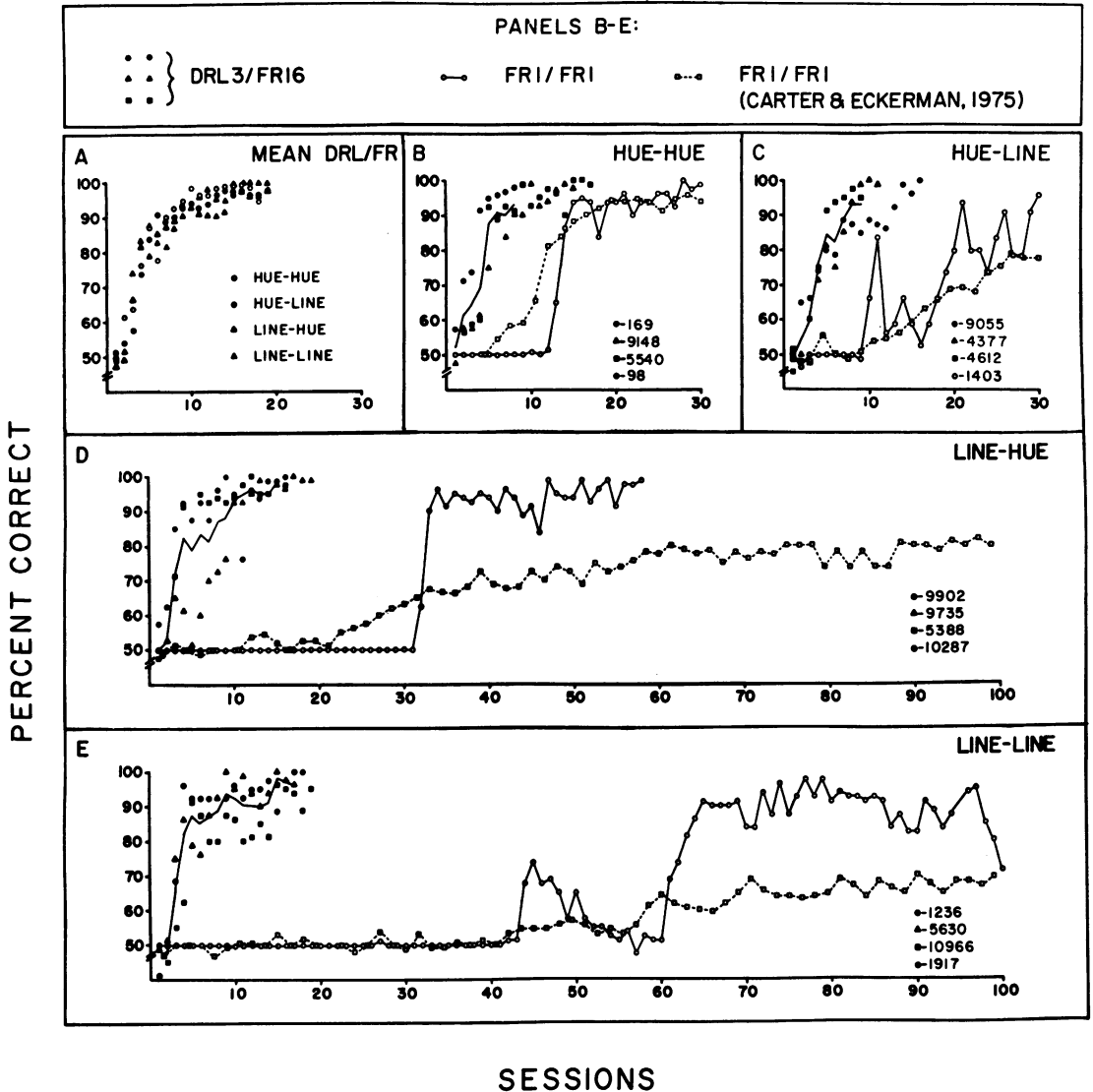●-1917

PERCENT CORRECT

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Fig. 1. Acquisition functions for all subjects in Experiment I. Panel A shows group means for DRL 3-sec/FR 16 subjects on all four conditional discrimination tasks. In Panels B through E, filled points represent individual data for each of the DRL 3-sec/FR 16 subjects. The solid lines passing through these points are the group mean functions for each task, plotted until the session on which the first bird in a group met the criterion. Data for the one FR 1/FR 1 subject on each task are represented by open circles and solid connecting lines. Carter and Eckerman's (1975) data (open squares connected by broken lines) are mean functions for five birds. Since sessions in Carter and Eckerman's study were 120 trials rather than 80 trials in length, the squares are spaced along the abscissa so that equal distances represent equal numbers of trials, rather than equal numbers of sessions.

The course of acquisition of the conditional discrimination as indicated by overall accuracy, is shown in Figure 1 for all pigeons. In Panel A, the mean percentage of correct responses for the three differential birds on each of the four tasks is shown as a function of sessions. The rates of acquisition were similar for all tasks, whether identity or nonidentity. Accuracy was consistently above "chance" (50%) for all birds by the third session and reached levels of 80% or better by the ninth session, with complete overlap of these indices across groups.

Panels B through E compare acquisition of

each of the conditional discriminations with and without the pretraining and maintenance of differential sample responding. All pigeons with pretraining and maintenance of DRL 3-sec/FR 16 sample-schedule requirements (filled points) showed facilitated acquisition compared to their FR 1/FR 1 counterparts with no pretraining (open circles and squares).

The procedure used with the FR 1/FR 1 subjects in the present study was identical to that used by Carter and Eckerman (1975), except that there were 80 trials per session rather than 120, and a 10-sec ITI rather than 25 sec. Relative acquisition rates for the FR 1/FR 1 birds were consistent with those reported by Carter and Eckerman: the hue-hue conditional discrimination (Panel B) was acquired first (P#98 took 13 sessions to reach 80% correct and not drop back below that accuracy level). The line-line conditional discrimination (Panel E) was acquired last (P#1917 took 62 sessions to reach the same criterion). The two nonidentity conditional discriminations were of intermediate difficulty, with hue-line (Panel C) acquired more quickly (P#1403 took 19 sessions to reach 80%) than line-hue (Panel D, P#10287 took 32 sessions to reach that criterion). All the rates of acquisition for the four tasks were similar when birds were pretrained and maintained on DRL 3-sec/FR 16 sample-schedule requirements and all these tasks were acquired more rapidly than was the "easiest" task (hue-hue) when such pretraining and maintenance were not involved.

DISCUSSION

The data from the FR 1/FR 1 subjects in the present study replicate the ordering of difficulty of the four conditional discriminations reported by Carter and Eckerman (1975): hue-hue, hue-line, line-hue, and line-line (from least to most difficult). The DRL 3-sec/FR 16 sample-schedule requirements, however, facilitated acquisition on all tasks relative to the "easiest" (hue-hue) task with an FR 1/FR 1 requirement. In addition, pretraining and maintenance of differential sample responding produced similar rates of acquisition for all four tasks. These data are consistent with Carter and Eckerman's (1975) suggestion that rates of acquisition of matching-to-sample tasks by pigeons can be accounted for by the discriminability between sample stimuli and be-

tween comparison stimuli. There is no evidence in the present data for a distinction between identity and nonidentity tasks for the pigeon. This is true even though on the nonidentity tasks the birds were exposed to novel stimuli as comparisons during matching-to-sample training; on the identity task this was not the case, at least with respect to those same stimuli on the center key. For example, both hue-line and hue-hue subjects learned to discriminate between orange and green on the center key during pretraining. During matching-to-sample training the hue-line task required the additional discrimination between vertical and horizontal as comparison stimuli, whereas the hue-hue task required that orange and green be discriminated on the side keys *as well as* on the center key.

The rate of acquisition of the conditional discriminations was more rapid with the DRL 3-sec/FR 16 sample-schedule requirements than that reported previously for other kinds of differential sample requirements. For example, Eckerman (1970) examined the acquisition of a hue-line matching-to-sample task in pigeons as a function of the distance between the required sample responses on a wide key. He demonstrated that the final accuracy level, as well as the rate of acquisition, was directly related to the amount of separation. Most final accuracy levels were low, however (ranging from 42% for 0 mm separation to 91% for 152 mm separation), in comparison with the subjects in the present study and those in the Carter and Eckerman (1975) study with no differential sample requirement on a hue-line matching task. Eckerman (1970) suggested that two apparatus characteristics may have accounted for this lower accuracy: the wide sample display area (25 cm) or the low position of the comparison keys (16 cm from the floor as compared with the more standard 20 to 25 cm).

Lydersen and Perkins (1974) used two fixed-ratio (FR 8 and FR 16) requirements as the differential sample schedules for pigeons on a zero-delay, hue-hue matching-to-sample task. Although these subjects as a group showed higher levels of accuracy than control subjects, only one of the three with the differential sample-schedule requirements rose above 50% accuracy before Session 32 (each session consisting of 72 trials). This rate of acquisition was quite slow compared to that obtained by

Cumming, Berryman, and Cohen (1965) with a similar zero-delay hue-hue matching-to-sample task and the traditional FR 1 requirement. Whether the slower acquisition in the Lydersen and Perkins (1974) study was a result of the differential FR requirements or some other procedural difference (*e.g.*, ITI value, length of access to grain, length of blackout) is unclear. Two FR requirements may have been a good choice for examining the effect of "response produced stimuli" on performance on a matching task, in that such requirements have been shown to serve well as discriminative stimuli in simple discrimination situations (Hobson, 1975; Pliskoff and Goldiamond, 1966; Rilling, 1967, 1968; Rilling and McDiarmid, 1965). Such schedule requirements need not have facilitated discriminative control by the sample hues, however, since the pigeons could simply have continued pecking on the sample key until the comparison stimuli came on. In the present study, it was clear that after three sessions of pretraining, the sample hues and lines were controlling differential patterns of sample responding for all birds with the DRL 3-sec/FR 16 requirements. These subjects had only to learn to respond differentially to the comparisons in order to acquire the correct performance. The rapid acquisition of accurate performance in the present experiment was probably due to the presence of differential sample responding at the start of matching-to-sample training. However, since the sample durations were also considerably longer for the DRL 3-sec/FR 16 condition compared with the FR 1/FR 1 condition, the facilitation could be attributed to sample duration *per se*. Experiment II explored this possibility.

EXPERIMENT II

Using a zero-delay matching-to-sample procedure with pigeons, several investigators have demonstrated that accuracy levels increased as a function of sample duration (Maki and Leuin, 1972; Maki and Leith, 1973; Roberts and Grant, 1974). Roberts (1972) and Sacks, Kamil, and Mack (1972) showed that accuracy of delayed matching to sample in pigeons was facilitated by increasing a nondifferential FR requirement in the presence of the samples, and thereby also increasing the sample durations.

In Experiment I, the DRL 3-sec/FR 16 subjects differed from the FR 1/FR 1 subjects with respect to sample duration as well as the differential sample-schedule requirement. The facilitation observed in Experiment I could therefore be attributed to an increase in sample duration alone. To assess the effect of increased sample duration, and to equate for exposure to the samples during the pretraining sessions, Experiment II examined the course of acquisition of the hue-line conditional discrimination under two additional nondifferential sample-schedule requirements: DRL 3-sec/DRL 3-sec and FR 16/FR 16. This also tested the possibility that the facilitation observed in Experiment I was somehow due to one of the schedules *per se*.

METHOD

Subjects

Four experimentally naive adult female White Carneaux pigeons obtained from Palmetto Pigeon Plant and maintained under the same living conditions as in Experiment I were used in Experiment II.

Apparatus

The apparatus was the same as that used in Experiment I.

Procedure

Magazine training and shaping. All four birds were first trained to eat from the hopper with all keys dark and the houselight on. During the next session, the subjects were trained by successive approximations to peck the center key illuminated with either orange or green. Following the initial peck on the center key, an FR 2 was in effect such that the second key peck turned off the stimulus and produced 3-sec access to grain. Each presentation of grain was followed by an ITI that increased from 3 sec to 10 sec in 1-sec steps. Each of the two hues was presented 30 times in a Gellerman series.

Nondifferential pretraining. The four birds were then exposed to three pretraining sessions. Each session consisted of 60 trials, 30 with each hue, presented on the center key in a Gellerman series. The ITI was 10 sec, and the reinforcer was 3-sec access to grain. Only the center key was illuminated during trials, and pecks to any dark key had no scheduled consequence. A trial began with the onset of a

stimulus, which remained on until the schedule requirement was met. For two birds (P#5597 and P#501), the schedule was a DRL 3-sec (timed from the first response) in the presence of both orange and green for all three pretraining sessions. For the remaining two birds (P#4987 and P#5249), an FR schedule was in effect in the presence of both hues. The FR value was increased from FR 4 to FR 16 in the same sequence that was used in Experiment I.

Matching-to-sample training. After pretraining, the birds were exposed to one session of zero-delay matching to sample followed by additional sessions of simultaneous matching to sample as described for Experiment I. For all birds, the schedules in the presence of the samples were the same as those used during the last session of pretraining. The comparisons were horizontal and vertical lines, with responses to vertical reinforced when the sample was orange and responses to horizontal rein-

forced when the sample was green (hue-line conditional discrimination). Daily experimental sessions were conducted whenever the birds were within 15 g of their 80% weights, until the accuracy criterion of at least 96% correct for three consecutive sessions was met, or for 100 sessions if the criterion was not met.

RESULTS

At the end of pretraining, only one of the four birds (P#5597) showed different IRT distributions in the presence of the two hues. Although the schedule requirement was DRL 3-sec in the presence of both hues, this subject showed many more IRTs shorter than 1 sec (50% as compared with 15% of all IRTs) in the presence of green than in the presence of orange. Informal observations indicated that the response topography was also quite different in the presence of the two samples.

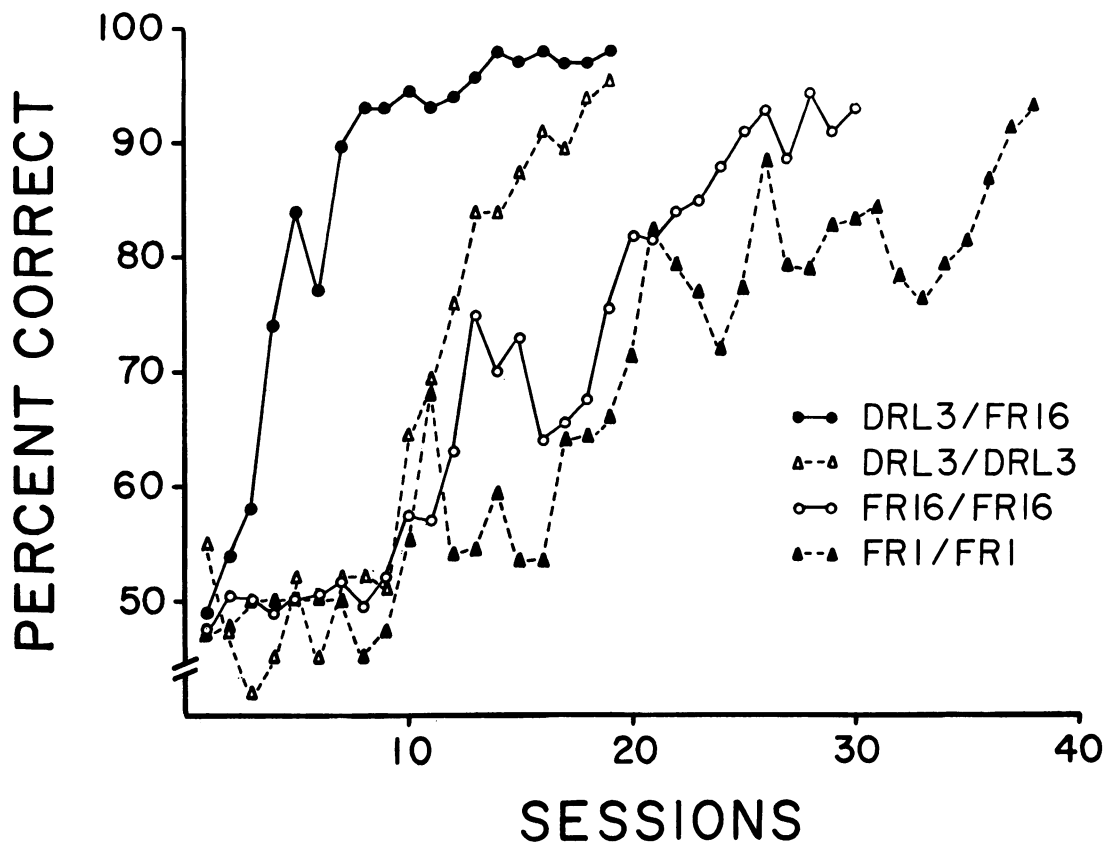Figure 2 plots the mean acquisition functions for all groups exposed to the hue-line

Fig. 2. Group mean acquisition functions for differential birds from Experiment I (hue-line task) and non-differential birds from Experiment II (DRL 3-sec/DRL 3-sec and FR 16/FR 16). Data are also plotted for two FR 1/FR 1 birds.

task in Experiments I and II. The mean function for the FR 1/FR 1 condition includes data from P#1403 (Experiment I) and from a second bird, P#3995, exposed to identical training conditions. All three birds with the differential sample-schedule requirements (DRL 3-sec/FR 16) showed the earliest deviation from "chance" performance (by the fourth session) and the earliest acquisition of 80% or above levels of accuracy (by the seventh session). In addition, all three birds met the accuracy criterion before any bird with non-differential sample-schedule requirements (P#4612 by the ninth, P#4377 by the eleventh, and P#9055 by the sixteenth session).

P#5597, the DRL 3-sec/DRL 3-sec subject that showed different IRT distributions in the presence of the two samples, acquired the accurate conditional discrimination performance more rapidly than any other subject with nondifferential schedule requirements. Even this subject, however, did not show accuracy levels consistently above 80% until Session 10, four sessions later than the two slower DRL 3-sec/ FR 16 birds (P#4377 and P#9055). Although all the "nondifferential" subjects reached accuracy levels above 50% between the eighth and eleventh sessions, the two DRL 3-sec/DRL 3-sec subjects rose to accuracy levels consistently above 80% sooner (P#5597 by Session 9 and P#501 by Session 12) than the FR 16/FR 16 and the FR 1/FR 1 subjects. The DRL 3-sec/DRL 3-sec subjects also met the accuracy criterion in fewer sessions (23 for P#501 and 33 for P#5597) than any of the FR/FR birds. One of the FR 16/FR 16 subjects (P#4987) went for 100 sessions without ever meeting criterion. This subject, however, did meet the accuracy criterion in Session 116 after a DRL 3-sec schedule was substituted for one of the FR 16 schedules in Session 101.

Although the DRL 3-sec and FR 16 schedule values had been chosen on the basis of pilot data that indicated that these values would result in nearly equal sample durations, this was not the case for any of the differential birds. In addition, the sample durations overlapped across the DRL 3-sec/FR 16 group and both the DRL 3-sec/DRL 3-sec and FR 16/FR 16 groups. The rates of acquisition were not directly related to these durations. For example, P#5249 (FR 16/FR 16) had sample durations averaging 11 sec that were longer than P#4612's (DRL 3-sec/FR 16) averaging 8 sec,

but acquired accurate performance more slowly.

DISCUSSION

The results for Experiment II indicate that the facilitation observed in Experiment I cannot be attributed to increased exposure to the samples during pretraining, to increased sample duration during matching-to-sample training, or to the schedules *per se*. Acquisition of conditional discrimination in subjects with DRL 3-sec/FR 16 sample-schedule requirements was facilitated relative to subjects with DRL 3-sec/DRL 3-sec and FR 16/FR 16 requirements. The subject (P#5597) that acquired accurate hue-line performance most rapidly with nondifferential sample-schedule requirements was the one bird that showed differential control by the samples at the end of nondifferential pretraining. This is further evidence that the facilitation observed in subjects with a differential sample-response requirement is due to the presence of differential sample responding at the start of matching-to-sample training.

Earlier studies that had examined the effect of increased sample duration (Roberts and Grant, 1974) or increased FR requirement in the presence of both samples (Roberts, 1972; Sacks *et al.*, 1972) on delayed matching tasks also afforded the pigeons a greater opportunity to respond differentially in the presence of the samples. The facilitation in rate of acquisition and final accuracy level observed may have been due, as it is in the present study with a simultaneous matching-to-sample task, to the effects of such differential responding.

SECTION II

Stimulus and Position Preferences in the Presence of Each Sample During Acquisition of Conditional Discriminations

Pretraining and maintenance of differential sample responding produced similar rates of acquisition for all four tasks, two identity and two nonidentity, as indicated by overall accuracy. Since overall accuracy is a gross measure of performance, it might obscure differences in stimulus control during acquisition.

To examine more closely the course of acquisition of these conditional discriminations, Figures 3 through 6 show the percentage of "correct" comparison responses and the per-
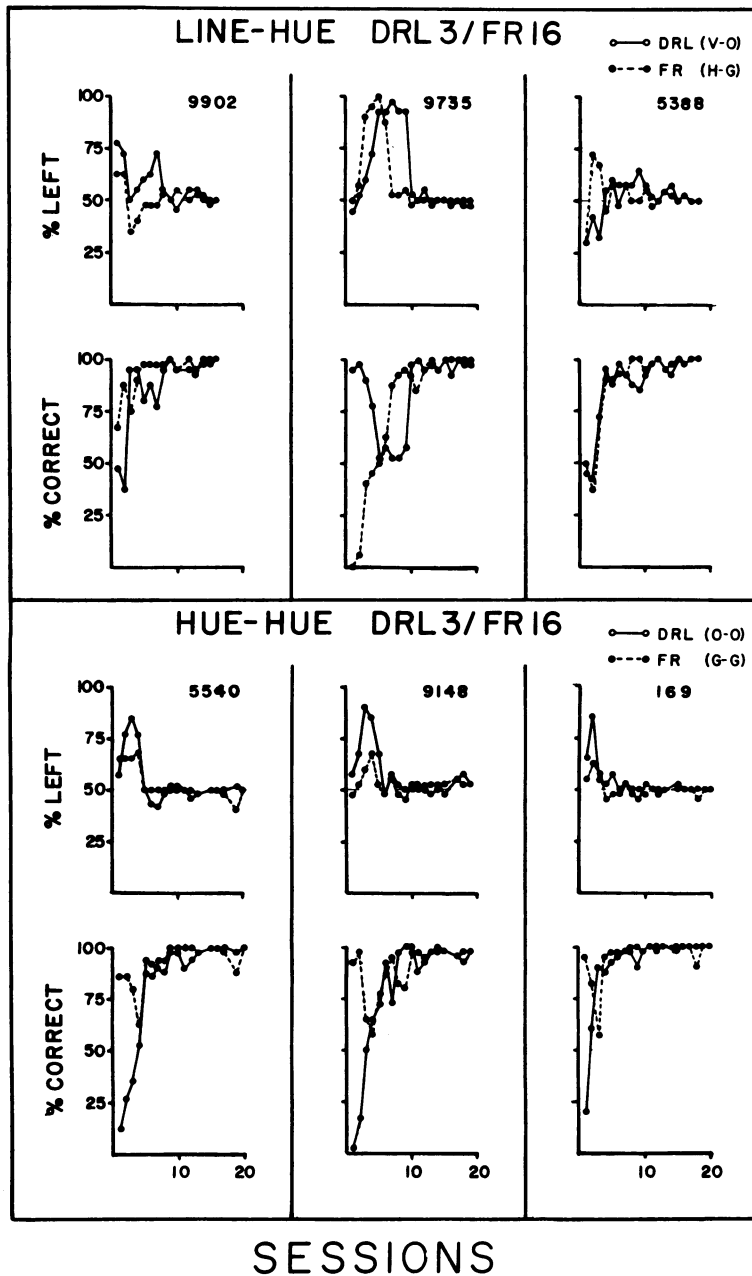
Fig. 3. Individual accuracy and position preference functions for each of the DRL 3-sec/FR 16 subjects with hues as comparisons. Data are plotted separately for trials on which the sample was correlated with a DRL requirement (open circles connected by solid lines) and those on which the FR requirement was in effect (filled circles connected by broken lines).

centage of left-key responses in the presence of each sample as a function of sessions for each of 20 subjects in Experiments I and II. Figure 3 shows the position preference and accuracy functions in the presence of each sample for the two groups of DRL 3-sec/FR 16 subjects

with hues as comparisons. Figure 4 shows these data for the two differential groups with lines as comparisons. Figures 5 and 6 show data for the nondifferential birds from Experiments I and II respectively. For each bird, the two upper functions indicate the course of position
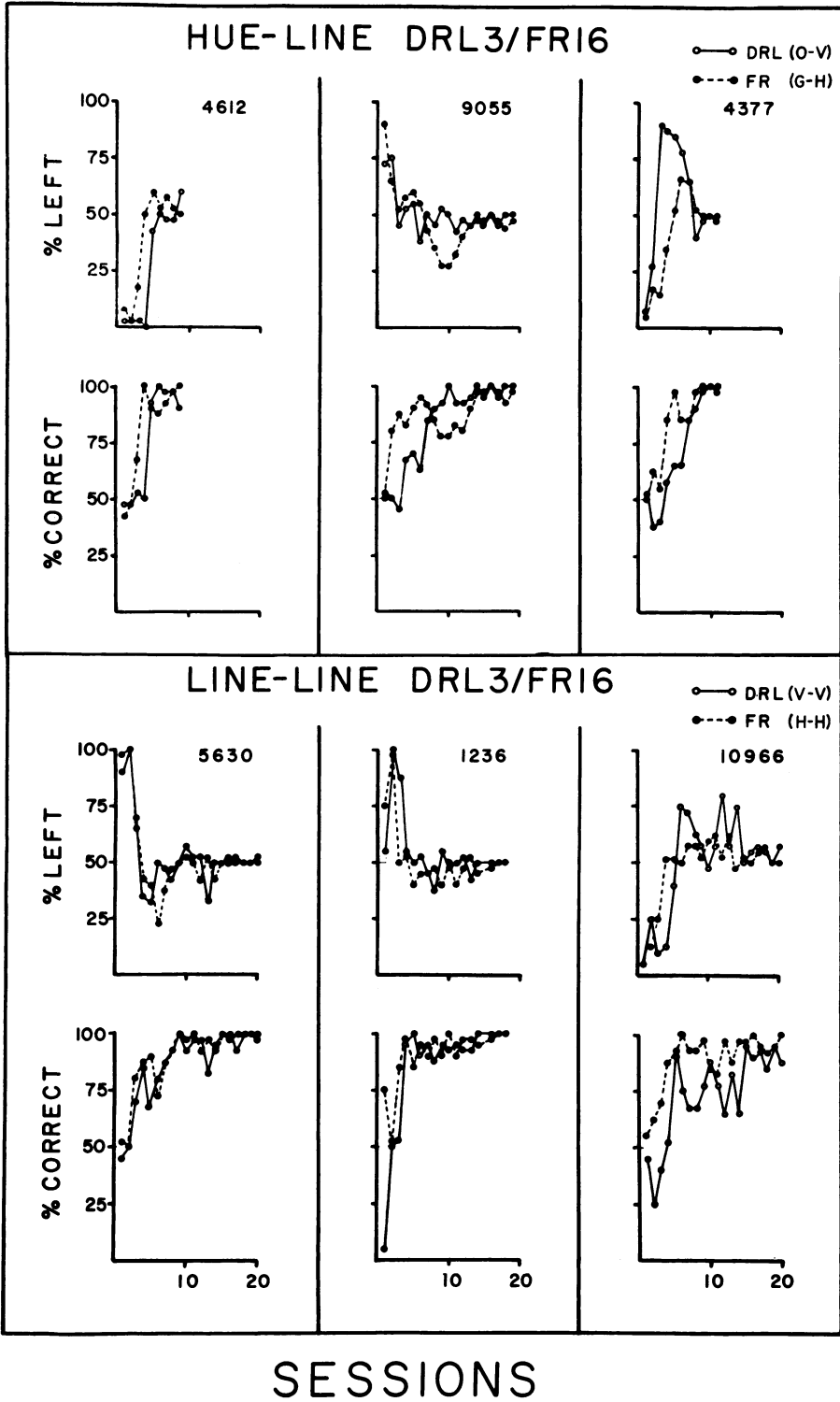
Fig. 4. Individual accuracy and position preference functions for each of the DRL 3-sec/FR 16 birds with lines as comparisons. Data are plotted separately according to the schedule requirement on the sample key as in Figure 3.
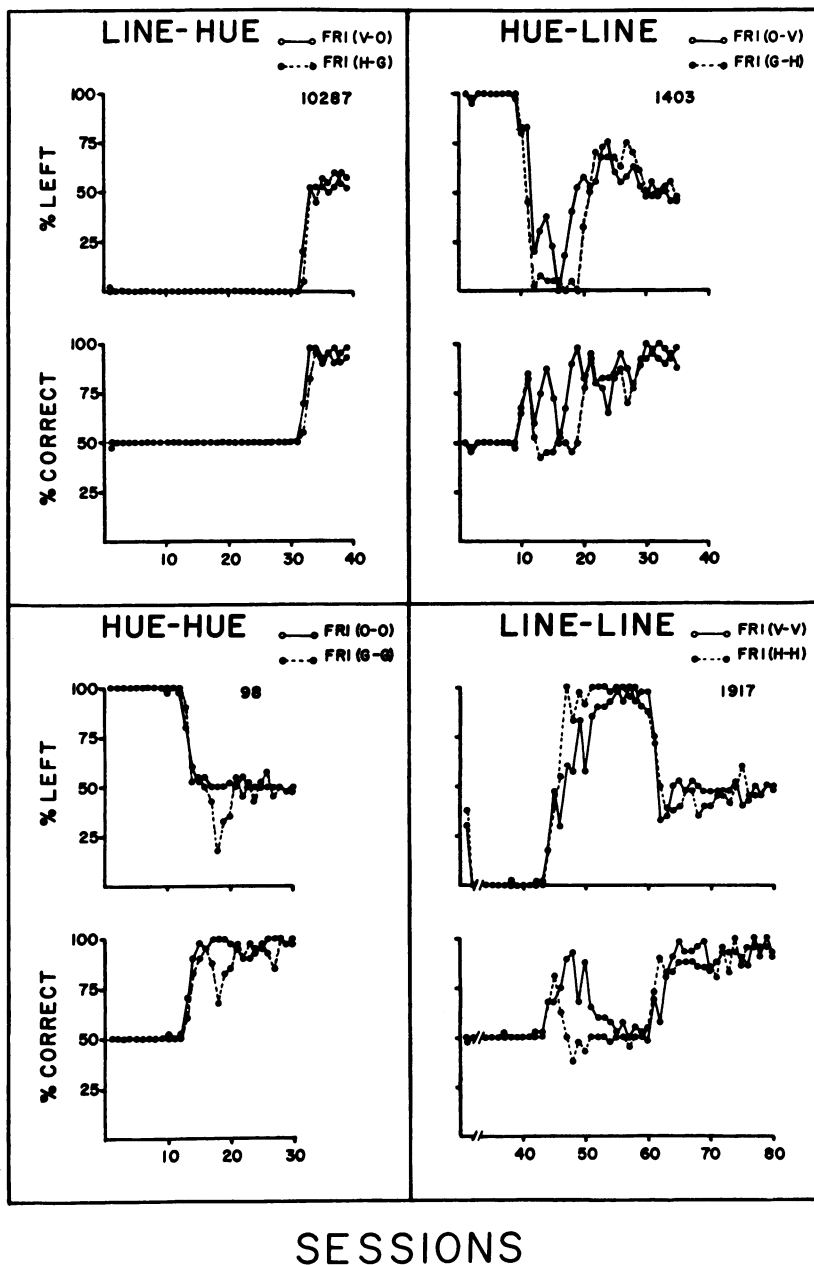
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Fig. 5. Individual accuracy and position preference functions for all birds with a nondifferential FR 1 requirement on the sample key. Data are plotted separately for the two samples in effect for each subject (open circles connected by solid lines: orange or vertical sample; filled circles connected by broken lines: green or horizontal sample). Note that Sessions 3 through 33 have been deleted for P#1917. This subject showed 0% left responses and 50% correct responses for both samples on all of these sessions.

preference in the presence of each sample, points above and below the 50% level indicating a left- and right-key preference respectively. The two lower functions, for each bird, indi-

cate "accuracy" in the presence of each sample. A stimulus preference is represented when "accuracy" is simultaneously close to 100% in the presence of one sample and close to 0% in the
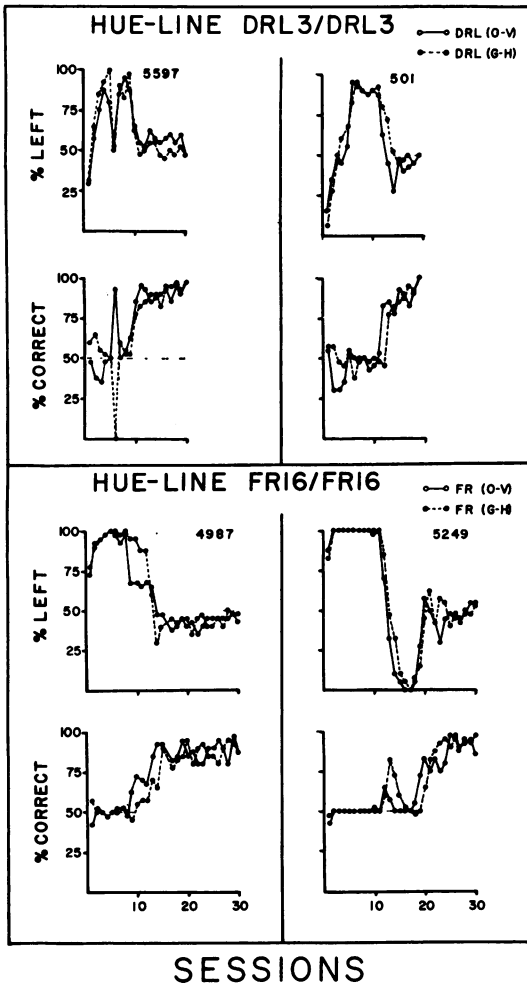
Fig. 6. Individual accuracy and position preference functions for birds with DRL 3-sec/DRL 3-sec or FR 16/FR 16 sample-schedule requirements. Data are plotted separately for the two samples (open circles connected by solid lines for orange; filled circles connected by broken lines for green).

presence of the other; that is, the bird is responding to one comparison stimulus regardless of sample.

The initial preferences exhibited by birds in the present study support a suggestion (Carter, 1971) that subjects on a matching-to-sample task with two samples should be equally likely to exhibit a stimulus as a position preference during initial sessions. Carter pointed out that traditionally, pigeons showed an initial position preference on a simultaneous matching-to-sample task with three hues as samples (Cumming and Berryman, 1961, 1965; see also Farthing and Opuda, 1974). In

that case, a preference for the right or left key would result in 50% of the trials terminating with a reinforcer, while a preference for one hue would result in less reinforcement. On a matching-to-sample task with only two samples, either a complete position preference or a complete stimulus preference would result in the same number of reinforcers (50% of the trials). Data from the subjects with the DRL 3-sec/FR 16 sample requirements do show both types of initial preferences. Five of the six birds with hues as comparisons (Figure 3) showed initial stimulus preferences, and all six birds with lines as comparisons (Figure 4) showed initial position preferences. Although the reinforcement contingencies are equally favorable to both preferences, the stimuli used as comparisons also affect which preference will occur. The fact that all birds with the non-differential sample requirements showed initial position preferences regardless of comparison stimuli (Figures 5 and 6) is further evidence that these subjects were not under differential control by these stimuli during early matching-to-sample sessions. In addition, the finding that the birds in Experiment II showed the same acquisition patterns as the FR 1/FR 1 subjects of Experiment I indicates that increased exposure to the samples during pretraining and increased sample durations during matching-to-sample training were not the critical aspects of the DRL 3-sec/FR 16 training with respect to its effects on performance.

A detailed analysis of position and stimulus preferences in the presence of each sample (Figures 3 through 6) provides a more complete picture of acquisition than either overall accuracy or overall measures of position preference and stimulus preference (*cf.* Cumming and Berryman, 1961). Examples of complete differential sample control of comparison responding at intermediate levels of overall accuracy were found in subjects with both differential and nondifferential sample-schedule requirements. The common case of a complete position preference in the presence of one sample, and a complete stimulus preference (for the "correct" comparison) in the presence of the other sample, results in an overall accuracy of 75%, an overall position preference of 75% (or 25%) and an overall stimulus preference of 75% (or 25%). All three indices fail to reflect the fact that control by the samples of comparison responding is complete

in such a case. Cumming and Berryman in a later paper (1965, pp. 323-326) describe a very similar example of complete control by the samples at an accuracy level of 74% by a pigeon on a form matching-to-sample task.

In the present study, in all cases of this type of complete, albeit not "correct", control by the samples for the DRL 3-sec/FR 16 birds, the position preference occurred in the presence of the sample correlated with the DRL 3-sec requirement (orange or vertical) while the stimulus preference came under the control of the sample correlated with the FR 16 requirement (green or horizontal). That this was not a function of the particular stimuli involved is demonstrated by data from the nondifferential subjects. Four of these birds showed stimulus preferences in the presence of orange or vertical samples, accompanied by position preferences in the presence of green or horizontal samples. It appears then that the consistent finding of position preference under the control of the "DRL" sample and stimulus preference under the control of the "FR" sample is somehow related to the schedule requirements themselves. It is not clear what aspect of the schedule requirements might be responsible for this effect.

SECTION III

General Discussion

The results of Experiment I demonstrated that the rates and patterns of acquisition of both identity and nonidentity tasks were the same for pigeons on a matching-to-sample procedure with two samples and a differential sample-response requirement. These data support Carter and Eckerman's (1975) suggestion that for both identity and nonidentity, the rates of acquisition can be accounted for by the discriminability between sample stimuli and between comparison stimuli.

The combined results of Experiments I and II indicated that differential patterns of responding in the presence of the samples facilitated acquisition of all four matching-to-sample tasks. Whether or not this facilitation came about because subjects began matching training when they were already differentially responding to the samples and needed only to learn the appropriate comparison discrimination in the presence of each sample is open to further investigation. Pigeons have, for exam-

ple, learned spatial discriminations that were conditional on two FR requirements (Pliskoff and Goldiamond, 1966; Rilling and Mc-Diarmid, 1965). In these experiments, pigeons reported which of two FRs had just been completed on the center key by pecking either a right- or left-side key. Lydersen and Perkins (1974) extended that finding to a nonspatial matching-to-sample task in which one group of pigeons reported which of two FRs had just been completed on the white center key by pecking either a red or green comparison regardless of spatial location. Another group in that same study showed facilitated rates of acquisition and higher final accuracy levels when two hues were combined with the two FR requirements as samples. Perhaps the facilitation observed in the present study was due to the greater effectiveness of a compound sample, consisting of both a visual stimulus and a specific pattern of responding, as compared with a visual stimulus alone.

It was suggested above that improvement on delayed matching-to-sample tasks observed with increased sample durations and increased FR requirements (Roberts and Grant, 1974; Sacks *et al.*, 1972) may be due to differential sample responding. Blough's (1959) report that pigeons performed with higher accuracy on a delayed matching task when sample-specific delay behaviors occurred, than when differential delay behaviors were not observed, provides further support for this possibility. A more direct test would be to examine performance on a delayed matching-to-sample task with the DRL 3-sec/FR 16 sample schedule requirements employed in the present study.

Whether or not *both* the pretraining and maintenance of differential sample responding are necessary for the facilitation observed in the present study is also open to question. Perhaps it is only critical that the subjects begin matching-to-sample training already differentially responding to the samples. This could be determined by giving pretraining with the differential schedule requirements and then matching-to-sample training with an FR 1/FR 1 requirement. Conversely, it is possible that pretraining is not necessary at all, and acquisition of matching-to-sample tasks with differential sample-schedule requirements would be equally rapid without pretraining.

The detailed analysis of acquisition in terms of position and stimulus preferences in the

presence of each sample reveals the stereotyped performances described in earlier studies of performance on matching-to-sample tasks in pigeons (*e.g.*, Cumming and Berryman, 1961, 1965; Cumming *et al.*, 1965; Eckerman, 1970; Lydersen and Perkins, 1974). In addition, an interesting example of complete, albeit not "correct", control by the samples of comparison responding (in which one sample controls a position preference while the other sample controls a stimulus preference) occurred for several subjects. It is unclear exactly which variables control these patterns, and how they interact with the differential sample-response requirements, although the present results do point up the importance of both the reinforcement contingencies and the particular stimuli used as comparisons.

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