

On the Relationship Between Differential Outcomes and Differential Sample Responding in Matching-to-Sample

Peter J. Urcuioli and Thomas DeMarse

Four experiments examined control over choice by differential sample responding in matching-to-sample with differential outcomes. In Experiment 1, pigeons initially learned to match with food versus no-food outcomes. Their performances later transferred to other samples to which responding versus not responding had been explicitly reinforced with a single outcome (food). In Experiment 2, pigeons initially learned to produce the comparisons by pecking one sample but not the other. Transfer was then observed to new samples associated with food versus no food (and thus often vs. seldomly pecked). Experiments 3 and 4 showed that transfer of matching required differential behavior to each sample set and did not depend on explicit conditioning of that behavior prior to acquisition. Together, these results show that differential sample behavior provides a redundant cue for choice in differential outcome matching-to-sample.

When different reinforcing outcomes are scheduled for correct choice in two-alternative matching-to-sample (MTS), acquisition is often faster and delay performances consistently better than when outcomes are the same on all trials (e.g., Alling, Nickel, & Poling, 1991; Brodigan & Peterson, 1976; Peterson, 1984; Santi & Roberts, 1985; Urcuioli, 1990). Matching choices in these types of tasks have been shown to be governed by a subject's "outcome expectancies." Operationally, what this means is that following acquisition, comparison choice continues to be highly accurate when novel stimuli paired with the same differential outcomes used in training replace the samples in MTS (Peterson, 1984; Urcuioli, 1990). Apparently, the ability to anticipate different outcomes early in a matching trial, and the redundant cue provided by those differential expectancies, underlie the facilitation of pigeons' MTS performances (Urcuioli, 1991).

Over the course of differential outcome training, pigeons often respond differentially to the sample stimuli (Alling et al., 1991; Brodigan & Peterson, 1976; DeLong & Wasserman, 1981; Santi & Roberts, 1985; Urcuioli, 1990). For example, Brodigan and Peterson (1976) observed different response topographies to samples associated with food and water reinforcers in MTS. Specifically, pigeons made sharp, open-beaked pecks to the food-associated sample versus slower, closed-beaked pecks to the water-associated sample (cf. Jenkins & Moore, 1973). Similarly,

Urcuioli (1990) found that with food and no-food outcomes, pigeons frequently pecked the food-associated sample stimulus but that they seldomly pecked the no-food-associated sample.

These latter observations are noteworthy because they potentially speak to one mechanism by which differential outcomes could influence matching performances: Through the differential sample responding they engender. Indeed, there are a number of parallels between the effects of differential sample responding (cf. Cohen, Looney, Brady, & Aucella, 1976) and those of differential outcomes that encourage such a view. For instance, pigeons acquire MTS more rapidly when comparison presentation is contingent on differential as opposed to nondifferential responding to the sample stimuli (Cohen et al., 1976; Urcuioli & Honig, 1980; Urcuioli, 1984). In addition, differential sample behaviors have been shown to control pigeons' matching choices in transfer-of-control tests analogous to those used to demonstrate the controlling properties of outcome expectancies (Cohen, Brady, & Lowry, 1981; Urcuioli & Honig, 1980; Urcuioli, 1984). Finally, differential sample behaviors, like differential outcome expectancies, enhance MTS performances by providing a redundant cue for choice (Urcuioli, 1985).

In view of these similarities, the issue addressed by our experiments was whether differential sample responding may provide a functional cue for choice in a differential outcome task. Although other researchers have observed differential sample responding in differential outcome MTS and have commented on its potential impact on matching performance, our research is the first, to our knowledge, to explicitly examine the role of such responding, if any, in the control over choice. If a controlling relationship is demonstrated, this would increase the plausibility of the argument that the enhancement of matching performance by differential outcomes may arise at least partly as a consequence of the pigeons' differential sample responding.

Peter J. Urcuioli and Thomas DeMarse, Department of Psychological Sciences, Purdue University.

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Correspondence concerning this article should be addressed to Peter J. Urcuioli, Department of Psychological Sciences, 1364 Psychology Building, Room 3180, West Lafayette, Indiana 47907-1364.

Experiment 1

In Experiment 1, we examined transfer of performance when samples associated with food versus no-food outcomes in MTS were replaced by other stimuli that generated differential responding similar to that observed to the samples but that were both associated with food. If such responding provides a source of conditional stimulus control during differential outcome training, then the substitution of novel stimuli for the training samples should produce transfer (cf. Urcuioli & Honig, 1980, Experiment 3). Conversely, if differential sample behaviors are merely a manifestation of pigeons' differential outcome expectancies but have no choice-controlling properties of their own, then no transfer would be expected.

Method

Subjects

Twelve White Carneaux retired breeder pigeons obtained from the Palmetto Pigeon Plant (Sumter, SC) served as subjects. All birds were housed individually in stainless steel, wire mesh cages in a colony room on a 14–10 light–dark cycle. They were always run during the light portion of this cycle. Grit and water were freely available in the home cages, but grain was generally provided only on the one day per week that they were not run. During the experiment, birds were maintained at approximately 80% of their free-feeding body weights by restricting feeding to the experimental sessions. All 12 birds had participated in a previous MTS study involving nondifferential outcomes. Most of the stimuli used as samples and comparisons in that previous study were not used here. Those that were appeared in the opposite "role" as samples or comparisons. Immediately prior to the start of the experiment, birds were randomly divided into two groups of 6.

Apparatus

Two BRS/LVE (Laurel, MD) three-key pigeon apparatuses (Model PIP-016 intelligence panels inside SEC-004 enclosures) were used for the experiment. The interior dimensions of each chamber, the size and spacing of the keys, the stimulus projectors, the location of the food hopper, and so forth, have been described in detail elsewhere (e.g., Urcuioli, 1990, 1991). The center-key stimuli used in this experiment were red, green, blue, and white homogeneous fields as samples, and a single white dot on a black background as a "trial-ready" stimulus (BRS/LVE Pattern Number 692). Side-key (comparison) stimuli were a white X and a white circular annulus on black backgrounds (BRS/LVE Pattern Number 696). All recording and controlling functions were done by an IBM-PCXT located in a room adjacent to the sound-isolated room that housed the experimental chambers.

Procedure

Preliminary keypeck training. Initially, pigeons were taught to peck the stimuli that would later appear as samples or comparisons in MTS. During the first two sessions of preliminary training, 3-s access to food was provided for single pecks to red and green on the center key. Center-key pecks to blue and white were then

reinforced during the next two sessions. During the final two preliminary training sessions, single pecks to red and green on the center key, and to the circular and X forms on the two side keys, were reinforced. All six sessions consisted of 60 trials divided equally among the stimuli that could appear in that session. Successive trials were separated by a 10-s intertrial interval (ITI), and the houselight remained on throughout the entire session.

Differential outcome pretraining. Once preliminary training had been completed, all birds received five 60-trial sessions of pretraining during which center-key presentations of red and green were followed by either food or the food-hopper light only ("no food"). Each pretraining trial began with presentation of the dot on the center key. A single peck to this trial-ready stimulus immediately turned it off and, 500 ms later, produced either red or green on the center key. Three seconds later, the red or green hue went off and either the food magazine was raised and the hopper light illuminated, or just the hopper light itself came on. For half of the birds, red was followed by food and green by no food; for the remaining birds, this relationship was reversed. Each session contained 30 presentations each of red and green in pseudorandom order. Successive trials were again separated by a 10-s ITI, the first 9 s of which were spent with the houselight off. The houselight then came on for the last 1 s of the ITI to signal the impending trial, and it remained on until the end of that trial.

MTS with differential outcomes. Next, all pigeons learned 0-delay MTS with red and green sample stimuli, circular and X forms as comparison stimuli, and food and no-food outcomes for correct choice. Each MTS trial began with presentation of the center-key dot. A single peck to the dot turned this stimulus off and, 500 ms later, produced a red or green sample stimulus on the same key. Three seconds after the sample was presented, it was automatically turned off and the two adjacent side keys were lit with the circular and X comparison alternatives. A single peck to either comparison turned both off and produced either food or no food if the choice was correct or turned the houselight off if the choice was incorrect.

For half of the birds in each group (see below), choice of the circular form comparison after the red sample and choice of the X comparison after the green sample were correct. For the other half of the birds, these relationships were reversed. Additionally, for half of the birds in each group, correct choices on red-sample trials produced food, whereas correct choices on green-sample trials produced no food. These contingencies were reversed for the remaining birds. For all birds, the relationship between the hue samples and the two outcomes were the same as those established during the immediately preceding pretraining phase. The duration of food reinforcement (and of the equivalent no-food period) was adjusted daily for each bird in order to maintain its body weight as close to the 80% free-feeding weight as possible. Reinforcement durations ranged from 2 to 6 s across sessions.

Incorrect choices produced a time-out period (houselight off) of the same duration as the reinforcement period. In addition, following an incorrect choice, the trial was repeated until a correct choice was made. This correction procedure was in effect from the start of MTS training to avoid the possibility that birds would adopt position or stimulus preferences on trials scheduled to end in no food for correct choice. Only the first choice on each trial entered into the computation of matching accuracy, however.

Each 80-trial MTS session was divided equally among the four possible combinations of sample and comparison stimuli (2 samples \times 2 left–right comparison configurations). As before, successive trials were separated by a 10-s ITI with the first 9 s spent in darkness. The houselight came on for the last 1 s of the ITI and remained on until the end of the food/no-food cycle or until an

incorrect choice was made. Individual pigeons were trained on their respective tasks until they matched at 90% or better accuracy on five of six consecutive sessions.

Differential sample-response pretraining. On completion of MTS acquisition, each bird received five off-baseline, pretraining sessions during which pecking blue and white on the center key was reinforced on different reinforcement schedules. For half of the birds in each group, a modified fixed-interval (FI) 3-s schedule was in effect for blue and a differential-reinforcement-of-other-behavior (DRO) 3-s schedule was in effect for white. The remaining birds had the opposite assignments. For the FI schedule, the first peck to the stimulus initiated the 3-s interval, and the first peck after the interval expired produced food. For the DRO schedule, food was presented after 3 s without a peck to the center-key stimulus; each peck during the 3-s DRO interval simply reset the interval. These two reinforcement schedules were selected so that the pigeons' behavior in the presence of blue versus white would resemble their behavior to the red versus green samples in MTS (i.e., frequent pecking to one stimulus but infrequent or no pecking to the other). Each 60-trial pretraining session contained 30 presentations each of blue and white in pseudorandom order. As before, trials began with the center key lit by the dot as a ready stimulus and were separated from one another by a 10-s ITI.

MTS testing. After completion of differential sample-response pretraining, birds were tested on MTS with the blue and white samples substituted for the red and green samples used in acquisition. Each MTS test session was run in the manner described previously except for (a) the change in samples, (b) the implementation of the corresponding differential sample-response requirements (FI vs. DRO) for producing the circular and X form comparisons, (c) food reinforcement for every correct choice, and (d) the use of a noncorrection procedure. For the 6 birds assigned to Group Similar, the stimulus associated with the FI sample-response requirement replaced the food-associated sample in the original MTS task, and the stimulus associated with the DRO requirement replaced the no-food-associated sample. For the 6 birds assigned to Group Dissimilar, the substitution of blue and white for red and green reversed these relationships. These con-

tingencies, along with those in differential outcome training, are summarized in the top half of Table 1. The corresponding differential sample-response theoretics are shown in the bottom half of Table 1. All birds were tested for a minimum of 10 test sessions and until they once again achieved 90% or better accuracy on five of six consecutive sessions. Afterward, all birds received an additional five sessions of testing with mixed delays interspersed between sample offset and comparison onset. These delay tests were not germane to the issue addressed in this article, so we do not discuss them further.

Return to MTS with differential outcomes. After finishing testing, each bird was subsequently given differential outcome pretraining with red and green similar to that described previously for one or two sessions. It was then returned to its original MTS task for five sessions with the red and green samples and differential outcomes.

For all statistical analyses reported in this article, Type I error rate was .05 using the tabled *F* values reported by Rodger (1975).

Results

Original acquisition of MTS with differential outcomes, and performances at the end of this training, were comparable in the two groups. For example, the average number of training sessions to reach 90% or better accuracy was 5.3 in Group Similar versus 5.5 in Group Dissimilar, $F(1, 10) = 0.02$. Average accuracy on the last acquisition session for the two groups was 97.9% and 98.1% correct, respectively, $F(1, 10) = 0.05$. All birds also showed the differential patterns of sample responding that initially were conditioned during differential outcome pretraining: They pecked the food-associated sample but rarely pecked the no-food-associated sample. For example, the percentage of total sample responses to the food-associated sample on the last acquisition session was 94% in Group Similar (range = 84%–100%) and 96% in Group Dissimilar (range = 89%–99%).

Table 1
Matching-to-Sample (MTS) Training and Testing Conditions (Top) and Corresponding Theoretics (Bottom) for Groups Similar and Dissimilar in Experiment 1

Group	Differential outcome MTS training	MTS testing
Similar	R → C+ (food) G → X+ (no food)	B • FI 3 s → C+ (food) W • DRO 3 s → X+ (food)
Dissimilar	R → C+ (food) G → X+ (no food)	B • FI 3 s → X+ (food) W • DRO 3 s → C+ (food)
Similar	R • pecking → C+ G • no pecking → X+	B • pecking → C+ W • no pecking → X+
Dissimilar	R • pecking → C+ G • no pecking → X+	B • pecking → X+ W • no pecking → C+

Note. R = red; G = green; B = blue; W = white; C = white circular annulus; X = white X; FI = fixed-interval schedule; DRO = differential-reinforcement-of-other behavior schedule. Sample stimuli and sample-response schedules are shown to the left of the arrows, and correct comparisons (+) are shown to the right of the arrows. The outcome contingent on correct comparison choice is shown in parentheses. Incorrect comparisons, the sample-response interval during training, and various counterbalancing variables are omitted for clarity. Also omitted are the pretraining phases prior to training and testing.

Figure 1 shows each subject's performance on the first MTS test session in which blue and white replaced the red and green hues as samples. A substantial between-groups difference in matching accuracy is apparent. Group Similar was considerably more accurate in its matching choices than Group Dissimilar: 74.2% versus 51.2%, respectively, $F(1, 10) = 22.0$. Moreover, 5 of the 6 Group Similar birds matched at levels well above that expected on the basis of chance alone (50%). By contrast, most of the Group Dissimilar birds matched at levels close to chance, with 1 bird well below 50% accuracy. Not surprisingly, then, birds in the Group Similar achieved high levels of matching accuracy more quickly over successive test sessions than birds in Group Dissimilar. For example, Group Similar required significantly fewer test sessions (3.7) to reach 80% accuracy than did Group Dissimilar (5.5), $F(1, 10) = 6.80$.

The differences in responding to the blue and white samples produced by the FI versus DRO sample-response contingencies resembled those conditioned to the red and green samples by differential outcomes. For instance, on the first test session, the percentage of total responses occurring during the first 3 s of sample presentation to the sample associated with the FI response requirement was 90% in Group Similar (range = 82%–97%) and 84% in the Group Dissimilar (range = 74%–93%). In short, birds in both groups regularly pecked the sample associated with the FI schedule but seldom pecked the sample associated with the DRO schedule.

Figure 2 shows each group's performances on the five sessions of return to baseline (MTS with differential outcomes) that followed transfer testing. Recovery of original matching performances occurred more quickly during this final experimental phase in Group Similar than in Group Dissimilar. Indeed, on the first recovery session, average

accuracy in Group Similar was 89% compared with only 79% in Group Dissimilar. An analysis of variance (ANOVA) on the data from the five recovery sessions showed significant effects of group, $F(1, 10) = 5.94$, session, $F(4, 40) = 14.38$, and Group \times Session interaction, $F(4, 40) = 1.96$.

Discussion

If differential sample responding had controlled pigeons' choices during the differential outcome task, then those same response patterns, even though conditioned to other stimuli by contingent presentation of a *single* outcome (food), should nonetheless support transfer of matching when those stimuli replaced the original samples. In particular, positive transfer was predicted to occur when the sample that birds regularly pecked during training was replaced by another stimulus to which pecking had been explicitly reinforced, and when the sample that birds seldom pecked during training was replaced by another stimulus to which not pecking had been explicitly reinforced. Conversely, negative transfer was anticipated when the switch in stimuli reversed these relationships.

The results of Experiment 1 at least partially support these predictions. In particular, Group Similar showed a clear positive transfer effect on Day 1 testing. The corresponding negative transfer effect, however, did not materialize in Group Dissimilar: On the first test session, most birds in this latter group (with the notable exception of one) matched at accuracy levels close to chance. Nonetheless, the fact that the Group Dissimilar birds matched at significantly lower levels of accuracy than did the Group Similar birds indicates that the relationship between differential sample responding

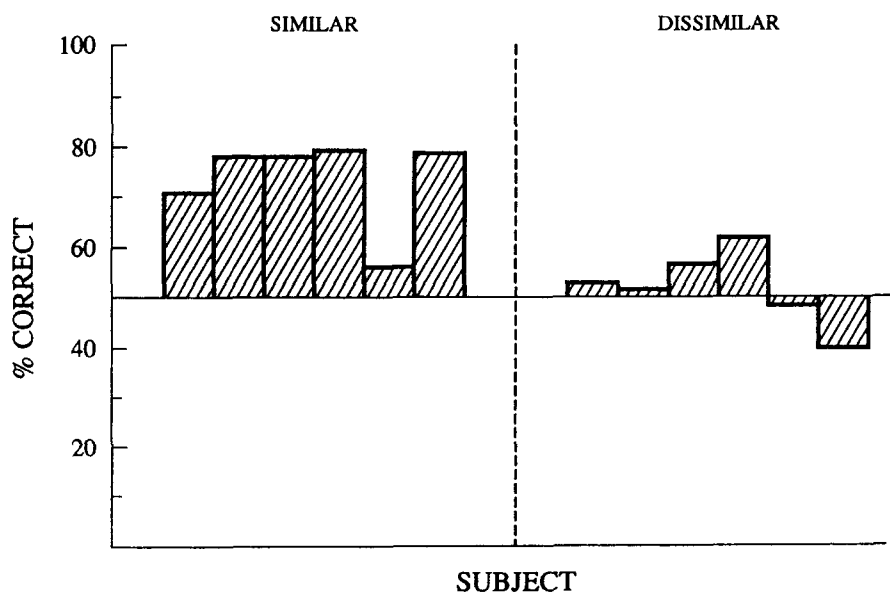


Figure 1. Percentage of correct matching choices for the individual subjects in each group on the first session of transfer testing in Experiment 1.

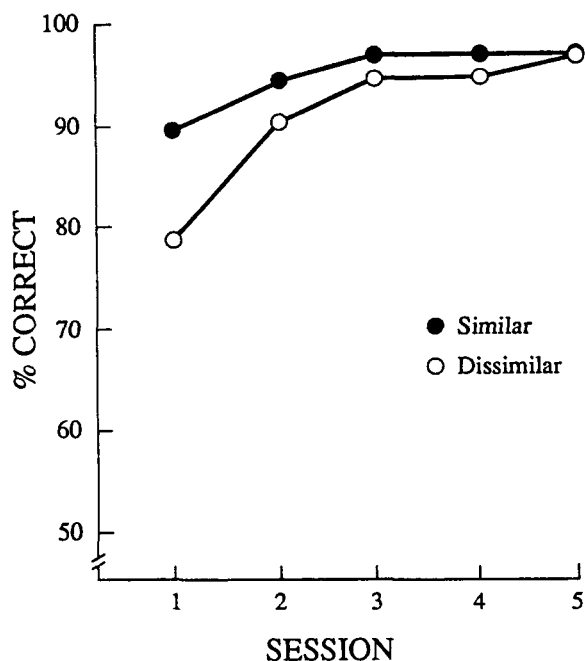


Figure 2. Average percentage of correct matching choices for each group in Experiment 1 on return to the baseline matching task following transfer testing.

and correct comparison choice was a major contributor to performance during differential outcome MTS. If there were no such contribution, then both groups should have matched at chance levels of accuracy at the outset of testing. The reason for this is that without any control by their differential sample behaviors, pigeons' choices between the comparisons in testing could be based only on the novel blue and white samples themselves, the common expectancy of food elicited by those samples, or by biases toward one particular comparison stimulus or position. Any one factor, or combination thereof, would produce only a 50% level of choice accuracy in initial testing.

Furthermore, in the absence of control by differential sample behaviors, there would be no reason to expect that the groups would differ on return to the well-learned differential outcome task after testing. Consequently, the finding that Group Similar matched more accurately than did Group Dissimilar on return to baseline provides additional support for a connection between differential sample behaviors and choice in differential outcome MTS. After all, for Group Similar, there continued to be a consistent relationship between pecking versus not pecking the samples and correct choice, whereas for Group Dissimilar, this relationship was again reversed in the shift from testing to the baseline recovery phase. The fact that the return-to-baseline performances were well above chance in both groups does not detract from the significance of these results. In other words, the relatively high absolute accuracy level in Group Dissimilar may simply reflect control over choice originally acquired by the red and green samples themselves.

Experiment 2

Experiment 2 provided another test of the notion that the differential sample responding engendered by food versus no-food outcomes in MTS enters into the control of choice. In this experiment, birds first learned an MTS task in which differential sample responding (pecking vs. no pecking) was required to produce the comparisons. Then, in an off-baseline phase, two new stimuli associated with food and no-food outcomes, respectively, were introduced and training continued until differential responding developed. Finally, in a test phase, these new stimuli (and their associated differential outcomes) replaced the samples in the MTS task.

Method

Subjects and Apparatus

Twelve experimentally naive White Carneaux retired breeders, obtained from the same source and housed in the same manner as the birds in Experiment 1, served as subjects in this experiment. Prior to the start of the experiment, they were randomly divided into two groups of 6. Two BRS/LVE pigeon chambers similar to those described in Experiment 1 were used for this study. These chambers were interfaced to a Zenith PC-AT microcomputer for process control.

Procedure

Preliminary training. Because the subjects for this experiment were experimentally naive, we first trained them to eat reliably out of a lit food hopper; they were then trained by the method of successive approximations to peck the center key whenever it was lit by the white dot. Further preliminary training beyond this, however, was identical to that described in Experiment 1.

Differential sample-response pretraining. All birds were then trained for five 60-trial sessions in which red and green center-key stimuli were associated with different reinforcement schedules. Half of all birds received food after completing a modified FI 3-s schedule in the presence of red and a DRO 3-s schedule in the presence of the green. The remaining birds were trained with the opposite contingencies. The details of these sessions and the counterbalancing of reinforcement schedules with the red and green hues were identical to those described for the corresponding phase in Experiment 1.

MTS with differential sample-response requirements. Following pretraining, all pigeons then learned to match red and green sample hues to circular and X comparison forms. To produce the comparison alternatives on each matching trial, however, birds had to complete either an FI 3-s or DRO 3-s sample-response requirement, the same requirements vis-à-vis red and green that had yielded food in the preceding pretraining phase. Once the comparisons were presented, a single peck to one alternative produced food on trials beginning with one sample, and a single peck to the other produced food on trials beginning with the other sample. As in Experiment 1, the sample-correct comparison relationships were counterbalanced across subjects. The procedural details of these matching sessions were identical to those described for MTS testing in Experiment 1 with the exception that (a) the samples were red and green hues and (b) a correction procedure was in effect for incorrect choices. (Although unnecessary, the correction

procedure was also used here in order to maintain procedural comparability with MTS acquisition in Experiment 1.) All birds were trained on their respective tasks until they matched correctly on 90% or more of all matching trials for five of six consecutive sessions. Accuracy was computed on the basis of the bird's first choice on each trial; performance on correction trials was excluded from the calculation.

Differential outcome pretraining. After completing training on MTS, all birds received five 60-trial pretraining sessions in which blue and white center-key stimuli were followed by differential (food vs. no-food) outcomes. With the exception of blue and white as stimuli, these sessions were identical in all respects to the differential outcome pretraining sessions in Experiment 1.

MTS testing. After differential outcome pretraining, pigeons received one to three refresher sessions on their training task (MTS with differential sample-response requirements). They were then tested for 10 sessions on MTS with the circular and X form comparisons, but with blue and white (replacing red and green) as samples and with differential outcomes in effect for correct comparison choice. For birds in Group Similar, the center-key hue associated with food in the immediately preceding pretraining phase replaced the training sample to which birds pecked in order to produce the comparisons, and the center-key hue associated with no food in differential outcome pretraining replaced the training sample associated with the DRO (no-pecking) requirement. For birds in the Group Dissimilar, these substitutions were reversed. For both groups, correct comparison choice produced food on trials beginning with one sample and no food on trials beginning with the other. All remaining procedural details were identical to those for MTS with differential sample-response requirements. It is important to note that for both groups, the relationship between the blue and white samples and the outcomes following correct choice was identical to that scheduled in differential outcome pretraining. The groups differed only in the relationship between their sample behavior and correct comparison choice: That relationship was maintained from

training to testing in Group Similar but was reversed in Group Dissimilar.

Return to MTS with differential sample-response requirements. Following the last test session, all birds were returned to their baseline MTS task for five sessions.

Results

Acquisition of MTS with differential sample-response requirements was comparable in the two groups. The average number of training sessions to reach the 90% criterion was 6.5 in Group Similar and 7.3 in Group Dissimilar, $F(1, 10) = 0.51$. Matching accuracy at the end of training, and on the final refresher session preceding testing, was also comparable: 94.8% and 94.6%, respectively, in Group Similar and Group Dissimilar on the last training session and 92.9% and 93.8%, respectively, on the final refresher session preceding testing. Neither of these differences were significant, $F_s(1, 10) = 0.02$ and 0.32 , respectively. Finally, the FI and DRO sample-response requirements had the desired effect of producing differential sample responding. For example, on the last training session, the proportion of all sample keypecks occurring to the sample associated with the FI requirement was .92 in Group Similar (range = .86–1.0) and .94 in Group Dissimilar (range = .88–.99).

Figure 3 shows performance by individual subjects on the first MTS test session in which the blue and white stimuli (and their associated differential outcome contingencies) were substituted for the red and green training samples. As in Experiment 1, there was a substantial between-groups difference in matching accuracy on the initial test session. Specifically, birds in Group Similar chose the correct comparison on the average of 68.8% of all matching trials

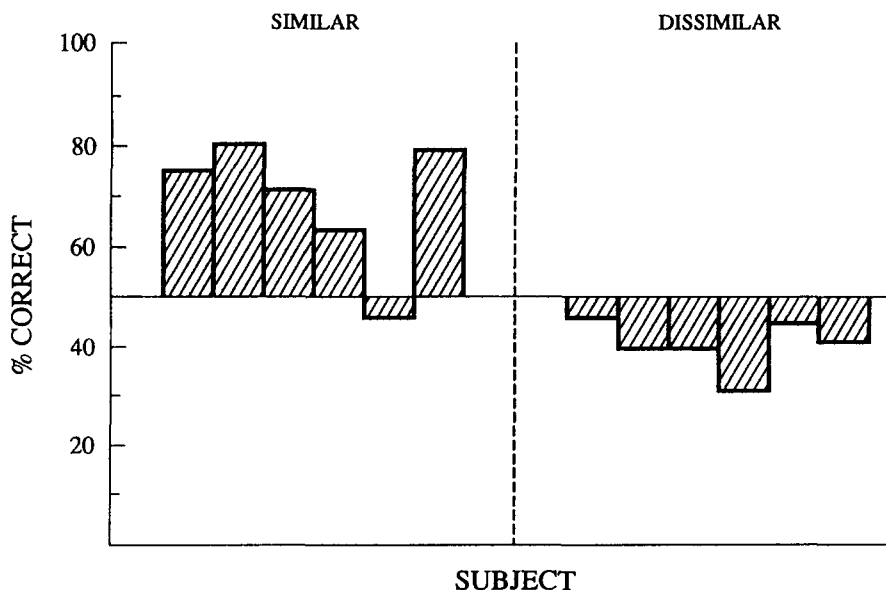


Figure 3. Percentage of correct matching choices for the individual subjects in each group on the first session of transfer testing in Experiment 2.

compared with only 39.4% by Group Dissimilar, $F(1, 10) = 25.51$. In addition, 5 of the 6 Group Similar birds showed positive transfer from training, matching well above the level expected on the basis of chance alone. By contrast, most Group Dissimilar birds showed a sizable negative transfer effect, matching on fewer than 50% of all matching trials.

As with the red and green samples used in training, birds responded differentially to the substituted blue and white samples, frequently pecking the sample associated with food and seldom pecking the sample associated with no food. On the first test session, the percentage of sample pecks occurring to the food-associated sample was 88% in Group Similar (range = 59%–95%) and 83% in Group Dissimilar (range = 64%–94%). Interestingly, the Group Similar bird showing the poorest sample discrimination was also the one bird in that group not showing positive transfer.

Figure 4 shows the average performance of each group on return to MTS with differential sample-response requirements. The return to baseline following testing was clearly less disruptive in Group Similar than in Group Dissimilar. An ANOVA on these data showed that over the five sessions, Group Similar was more accurate in their matching choices than Group Dissimilar, $F(1, 10) = 6.94$. An ANOVA also revealed a significant effect of session, $F(4, 40) = 27.34$, and a significant Group \times Session interaction, $F(4, 40) = 8.77$.

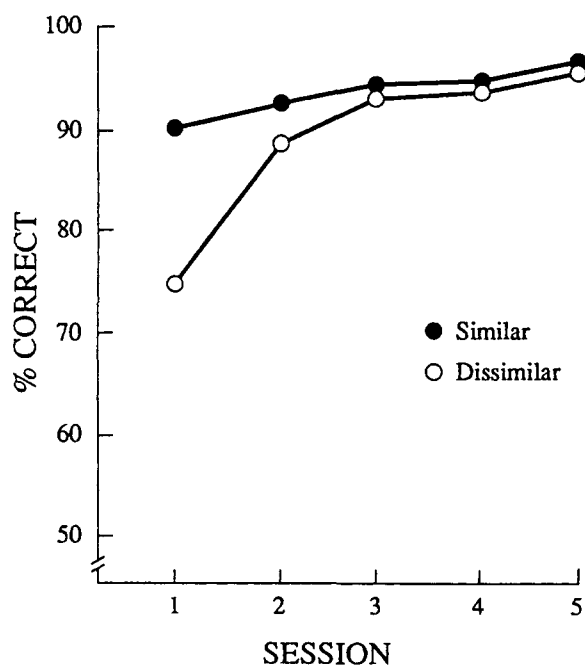


Figure 4. Average percentage of correct matching choices for each group in Experiment 2 on return to the baseline matching task following transfer testing.

Discussion

The results of this experiment nicely complement those of Experiment 1. In Experiment 2, birds that had been trained on an MTS task already known to produce conditional stimulus control by differential sample behavior (Urcuioli & Honig, 1980, Experiment 3) transferred their performances to new samples that occasioned similar differential responding via their association with food and no-food outcomes. Furthermore, the direction of transfer (positive or negative) was a function of whether the relationship between differential sample responding and correct comparison choice in training was maintained or reversed during testing. These results, then, are one more (albeit indirect) indication that the differential responding observed to stimuli associated with differential outcomes can and does enter into the discriminative control of subsequent behavior.

One feature of the test results from this experiment that differed from those of Experiment 1, however, was the negative transfer observed in Group Dissimilar. In Experiment 1, the corresponding group was mostly at chance levels of accuracy on the first test session (i.e., negative transfer was not generally apparent). The reason for the difference in results across experiments is not completely clear. One possibility is that the training task used in Experiment 2 more clearly established control by differential sample behaviors. As a consequence, the two new stimuli to which differential responding was later conditioned might have then become more "substitutable" for the samples used in original training.

Another possibility is that the bias to peck one particular comparison stimulus as opposed to the other was weaker in this experiment than in Experiment 1. After all, the MTS training task in this experiment was one in which correct choices to *both* comparisons were reinforced by food. By contrast, only one choice alternative in Experiment 1 was associated with food. This difference is potentially important because any comparison-stimulus bias (e.g., primarily pecking the comparison yielding food when correct) would tend to push accuracy toward 50%, lessening the chance of observing negative transfer. In fact, the percentage of choices made by the Group Dissimilar birds of Experiment 1 to the comparison that had been uniquely associated with the food outcome during differential outcomes training was 86.25%. By contrast, the percentage of choices made by the corresponding birds in this experiment to the comparison that became uniquely associated with food during testing was only 57.3% on Day 1 transfer. The latter figure, unlike the former, indicates a weak bias, one more conducive to detecting transfer.

Experiment 3

This experiment was designed to assess whether samples associated with different outcomes in one MTS task would be interchangeable with samples from another task involving the same outcome on all trials but differential sample-response requirements. The results of the first two experi-

ments suggest that transfer of control in both directions (i.e., from one task to the other) ought to be observed when the cue governing comparison choice is identical (or at least highly similar) in the two tasks. Experiment 3 also included a control group that received MTS training with *nondifferential* outcomes. This group was predicted to show little if any transfer because nondifferential outcomes typically do not produce differential responding to the samples.

Another purpose of Experiment 3 was to test an alternative interpretation (E. Wasserman, personal communication, November 15, 1992) of the results of Experiments 1 and 2. In those experiments, the delay to reinforcement on the DRO schedule during differential sample-response training was undoubtedly longer on average than on the FI schedule because any DRO response reset the interval. This difference could potentially provide a basis of transfer if, for instance, the anticipation of delayed reward is similar to the anticipation of no food in the differential outcome procedure. To evaluate this hypothesis, we scheduled longer reinforcement delays on the FI than on the DRO in one of the transfer conditions of this experiment. This manipulation should preclude transfer of performance if the anticipation of different delays to reinforcement mediated the earlier effects.

Method

Subjects and Apparatus

Twelve White Carneaux retired breeders served in the experiment. All 12 subjects were experienced in MTS, but none had previously received differential outcome or differential sample-response training. Prior to the start of this experiment, they were divided into two groups of 6 (see below), with previous stimulus and training experiences balanced across groups. The apparatuses were identical to those used in Experiment 2 except that the photographic films in the projectors behind each key were changed in order to present different sets of sample and comparison stimuli. The center-key (sample) stimuli in this experiment were red and green hues and white "plus" and white square forms on black backgrounds (BRS/LVE Pattern Number 696). In addition, a solid white homogeneous field served as a trial-ready stimulus. The two side-key projectors were equipped to project blue and yellow hues, a white inverted triangle on a black background, and a solid white dot on a black background (BRS/LVE Pattern Number 692).

Procedure

Because all birds had participated in other experiments, we did not require any magazine or preliminary keypeck training.

Differential versus nondifferential outcome pretraining. During the first three sessions of this experiment, all pigeons received 30 presentations each of the plus and square forms on the center response key followed by either differential or nondifferential outcomes. Trials began with the white trial-ready stimulus that, when pecked, was immediately turned off and followed 500 ms later by the plus or the square form. The trial stimulus was then turned off automatically 3 s later and followed by food or no food. For birds in Group Nondiff, the outcome following stimulus offset was randomly determined: Each outcome occurred about equally often following both the plus and the square. For birds in Group

Diff, food was always presented after one form and no food was always presented after the other, with the form–outcome relationship counterbalanced across birds. All other details of pretraining were identical to those described in the preceding experiments.

MTS acquisition with differential versus nondifferential outcomes. Next, all birds were trained on MTS with plus and square sample forms and blue and yellow comparison hues. For Group Nondiff, correct choices following each sample produced food and no food on an equiprobable basis. For Group Diff, all correct choices following one sample yielded food, whereas those following the remaining sample always produced no food. The sample–outcome relationship for each subject in this group was the same as it was during the immediately preceding pretraining phase. In both groups, the comparison hue designated as the correct choice for each sample was balanced across subjects.

Trial scheduling was identical to that described for differential outcome MTS training in Experiment 1 but with white as the trial-ready stimulus. Also, as in Experiment 1, incorrect choices for both groups resulted in repetition of the trial following the contingent time-out and subsequent ITI (i.e., a correction procedure was used). Each bird was trained on its respective MTS task until it reached a performance criterion of 90% or better accuracy for five of six consecutive sessions.

Differential sample-response pretraining. After reaching criterion in MTS, birds in both groups were given five 60-trial sessions during which differential responding to red and green center-key hues was reinforced. On trials with one hue, food was contingent on the first peck after a 3-s interval initiated by a peck (the modified FI 3-s schedule); on trials with the other hue, food was presented after 3 s without a response (a DRO 3-s schedule). These schedules were counterbalanced with respect to hue within each group. All other procedural details were identical to those described for the corresponding pretraining sessions in Experiment 1.

MTS with differential sample-response requirements. Next, birds in both groups were trained to criterion on a second MTS task with red and green sample hues, triangle and dot comparison forms, and FI versus DRO sample-response requirements. Other than the change in stimuli, these sessions were identical to those described for the corresponding sessions in Experiment 2.

MTS Test 1. The first transfer test involved replacement of the red and green hue samples in the second MTS training task with the plus and square form samples from the first task. For Group Diff, the form sample that was frequently pecked in differential outcome MTS (because it had been associated with food) was substituted for the hue to which pecking was explicitly reinforced in the differential sample-response task. Similarly, the form sample that was seldom pecked in differential outcome MTS (because of its prior association with no food) replaced the hue to which not pecking had been explicitly reinforced. For Group Nondiff, substitution on the basis of similar patterns of differential sample responding was not possible because these birds frequently pecked both the plus and square samples. Consequently, for them, the substitution was done such that the various sample-correct comparison contingencies in Group Diff were equally represented in Group Nondiff.

During the test, incorrect choices did not cause the trial to be repeated (i.e., the correction procedure was discontinued). Also, food was presented after every correct choice (i.e., the "no-food" outcome was discontinued). Prior to testing, each bird received as many refresher sessions as necessary on its initial (differential or nondifferential outcome) MTS task until it matched correctly on 90% or more trials for a single session. This ensured that the plus and square samples still exerted accurate control over matching before testing began. If more than three refresher sessions were

required to recover 90% performance, birds were returned to MTS with differential sample-response requirements for one or two sessions to ensure that those performances were intact. After that, additional refresher training on the differential or nondifferential outcome task was given until 90% or better accuracy was reached.

MTS Test 2. In the second transfer test, all birds were required to match red and green samples, to which differential responding had been explicitly conditioned, to the blue and yellow comparisons used during initial MTS training. As before, the sample substitution in Group Diff involved stimuli that occasioned similar differential response patterns: The hue to which pecking had been reinforced replaced the form that birds frequently pecked because of its prior association with food, and the hue to which not pecking had been reinforced replaced the form that birds rarely pecked because of its prior association with no food. For Group Nondiff, the sample substitution simply ensured that the various sample-comparison contingencies experienced by the Group Diff birds in testing were equally represented in this control group. For this test (as for Test 1), every correct comparison choice produced food, and incorrect choices did not result in trial repetition. Additionally, for each bird, the FI value for the hue sample associated with that contingency was increased from 3 s (the training value) to a value approximately 2 s longer than the sample duration estimated for DRO trials. The estimate was based on the average DRO sample duration during three refresher sessions on MTS with differential sample-response requirements that immediately preceded this test. Thus, during Test 2, the scheduled time to reinforcement from sample onset was longer on trials involving the FI sample-response requirement than on trials involving the DRO requirement.

Results

Acquisition of MTS with differential versus nondifferential outcomes was more rapid in Group Diff than in Group Nondiff, reproducing the well-established differential outcome effect (e.g., Peterson, 1984). The average number of sessions to reach the first session of each bird's criterion "run" (i.e., 90% accuracy for five of six consecutive sessions) was 4.0 in Group Diff versus 21.0 in Group Nondiff, $F(1, 10) = 8.32$. Also, performance over the last five sessions was slightly but significantly more accurate in Group Diff (96.2%) than in Group Nondiff (93.9%), $F(1, 10) = 5.08$.

In contrast to these differences, the rate of acquisition of the second training task, MTS with differential sample-response requirements, was comparable in the two groups, as was accuracy of performance at the end of training. For example, the average number of sessions to 90% accuracy for the two groups was 11.2 and 8.5, respectively, $F(1, 10) = 0.34$. Matching accuracy over the last five sessions was 95.3% and 96.4%, respectively, $F(1, 10) = 0.79$.

Differential sample responding, the presumed basis for any subsequent transfer of matching, was observed in both groups during the second training task. On the last acquisition session, for example, the average proportion of all sample pecks to the hue associated with the FI sample-response contingency was .90 in each group (ranges = .75–.97 in Group Diff and .84–.98 in Group Nondiff). By contrast, the groups differed substantially in the pattern of sample responding during the initial MTS task. On the last acquisition session of differential versus nondifferential outcome MTS, the average proportion of all sample pecks

occurring to the form associated with food in Group Diff was .96 (range = .86–1.00). By contrast, the average proportion of all pecks by Group Nondiff to the plus sample (which, like the square sample, was associated with both food and no food) was .50 (range = .34–.71).

The top panel of Figure 5 shows the individual performances on the first transfer test. Four of the 6 Group Diff birds showed positive transfer of performance when the plus and square samples from the differential outcome task were substituted for red and green as samples in the differential sample-response task. By contrast, all 6 Group Nondiff birds matched at approximately chance levels of accuracy when the comparable substitution was made. The average level of performance on this test, 68.4% in Group Diff versus 48.4% in Group Nondiff, was significantly different, $F(1, 10) = 11.50$.

During the first test, the Group Diff birds continued to respond differentially to the plus and square samples despite the fact that all correct choices now produced food. The average number of pecks to the form sample that had been previously associated with food during differential outcome training was .93 (range = .82–.93). Interestingly, the Group Diff bird showing the lowest sample-discrimination ratio in testing was one of the 2 birds that transferred poorly, if at all. The other bird showed a large decrease in pecks to the previously food-associated sample during testing. Indeed, by the end of the test session, this latter bird rarely pecked either sample. It also showed a strong bias to choose the comparison that had been correct on no-food-sample trials in differential outcome training (i.e., that had previously been correct on trials in which little if any sample pecking occurred).

The bottom panel of Figure 5 shows the results from the second MTS test. Again, a substantial between-groups difference is apparent. Virtually every Group Diff bird showed positive transfer of performance when they were required match the blue and yellow comparisons from the initial MTS task to the red and green samples, whereas only 1 of the 6 birds in Group Nondiff matched at levels substantially above chance. The average level of performance on the second test was 75.2% for Group Diff and 50.9% for Group Nondiff, $F(1, 10) = 17.9$. Furthermore, the consistent pattern of positive transfer in Group Diff occurred despite the fact that, on average, the length of time to complete the FI sample-response requirement was longer than that to complete the DRO requirement (6.2 s vs 3.8 s).

Responding to red and green samples in the second test continued to show the differential pattern conditioned in training. For Group Diff, the proportion of all sample pecks occurring to the sample associated with the FI contingency was .94 (range = .86–.97); for Group Nondiff, the average proportion was .91 (range = .86–.97).

Discussion

This experiment replicated the transfer observed in the Group Similar conditions of the preceding two experiments and also showed that such transfer depends on conditioning of differential responding to both sets of samples involved

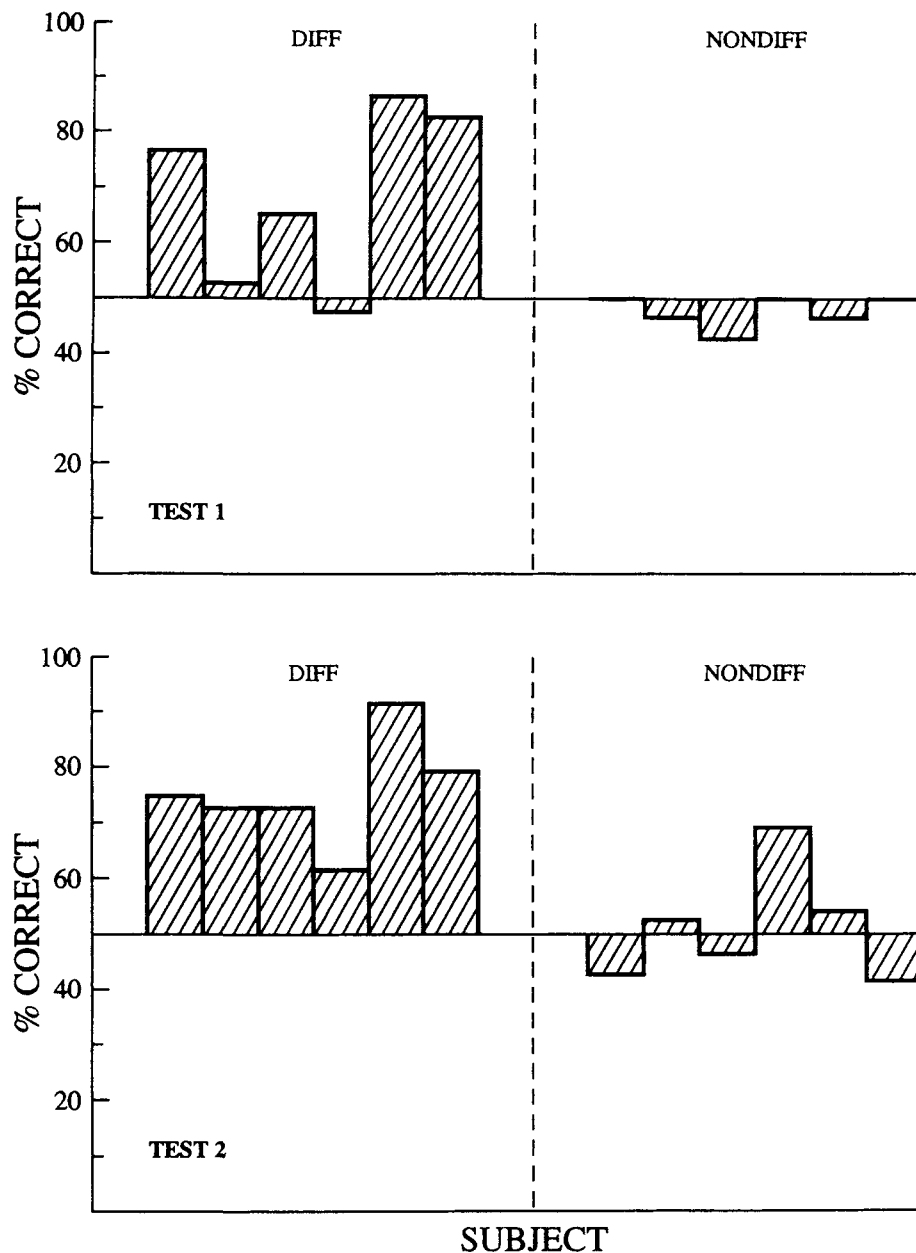


Figure 5. Average percentage of correct matching choices for individual subjects in each group on the first and second transfer tests (top and bottom panels, respectively) in Experiment 3. DIFF = differential group; NONDIFF = nondifferential group.

in the substitution test. When one set produced the same pattern of responding to both samples (e.g., pecking), as in Group Nondiff, transfer of performance was essentially nonexistent. Furthermore, the results from that group's second test show that differential sample responding to just one set of samples is not sufficient to produce transfer. Accurate matching performances in testing occurred only when the substituted samples replaced others that also occasioned a similar pattern of pecking versus not pecking.

Finally, although it is possible that the transfer observed in the first two experiments might have been mediated in

part by the anticipation of different delays to reinforcement, the results of this experiment clearly show that such anticipation is not necessary to produce the effect. If it were, Group Diff should have shown poor transfer on its second test. To the contrary, their transfer performances were highly accurate. Furthermore, matching accuracy in this group tended to get better, not worse, across trials within that session. This additional point is important because a differential delay-to-reinforcement account would predict that as the session progressed, birds would (if anything) show a drop in performance attributable to their increasing

exposure to the scheduled reversal in delay to reinforcement associated with the two samples.

Experiment 4

In the differential groups of each of the preceding experiments, initial MTS acquisition was preceded by a phase during which differential responding was established by either Pavlovian or operant conditioning to stimuli that later served as the samples for MTS. For example, in Experiment 1, pecking versus not pecking red and green samples were conditioned for five sessions prior to acquisition by presenting food versus no food response independently following these center-key stimuli. In most differential outcome studies, however, no such pretraining precedes MTS acquisition, so the development of any differential sample responding occurs within the context of acquisition itself. This raises the issue, then, of whether differential sample responding would also mediate differential outcome performances when the potential cue provided by such responding is not immediately available when acquisition begins. In other words, would the same transfer effects described previously occur if differential sample responding were acquired concurrently with matching performances? It is conceivable that they would not, especially if accurate matching developed as quickly, or more quickly than, a consistent pattern of differential sample behavior. To investigate this possibility, in Experiment 4 we examined transfer of matching on the basis of such behavior when MTS acquisition was conducted without a prior pretraining phase.

Method

Subjects and Apparatus

Twelve experimentally naive White Carneaux pigeons (retired breeders) obtained from the Palmetto Pigeon Plant (Sumter, SC) served as subjects. They were housed and maintained in the same fashion as that described previously. Prior to the start of the experiment, they were randomly divided into three groups of 4.

The two experimental chambers were the same as those used before, but with the center-key stimulus projector equipped to project red, green, blue, and solid white samples and a white dot on a black background as a trial-ready stimulus (BRS/LVE Pattern Number 692). The two side-key projectors could project three white vertical and horizontal lines on a black background (BRS/LVE Pattern Number 692).

Procedure

Preliminary training. Preliminary training to get all of the experimentally naive birds to eat out of a lit food hopper and to peck the center- and side-key stimuli that would later serve as samples and comparisons, respectively, was conducted in the same fashion as in Experiment 2.

MTS acquisition with differential versus nondifferential outcomes. As soon as preliminary training was completed, all birds began MTS acquisition with red and green sample hues, vertical and horizontal comparison lines, and food and no-food outcomes that were either differential (Groups Diff-P and Diff-N)

or nondifferential (Group Nondiff) with respect to the samples. The sample-correct comparison contingencies were counterbalanced across the 4 birds in each group. Additionally, the relationship between the samples and the two outcomes was counterbalanced across the 4 birds in the two differential groups. All other details of this acquisition phase, including the performance criterion, were identical to those described for the corresponding phase in Experiment 3.

Differential sample-response pretraining. Next, birds in all three groups learned to respond differentially to two new center-key stimuli (blue and white hues) off the MTS baseline. For half of the birds in each group, pecking the blue hue was reinforced with food on the modified FI 3-s schedule described previously; not pecking the white hue for 3 s was likewise reinforced with food (i.e., on a DRO 3-s schedule). For the remaining birds in each group, these contingencies were reversed. All other details for this pretraining phase were identical to those described for the corresponding phases in the preceding experiments.

MTS testing. After finishing differential sample-response pretraining and receiving a refresher session on their MTS acquisition task, all birds were then tested for a minimum of 10 sessions (and until the 90% performance criterion was reached) on MTS with blue and white substituted for the original red and green samples. For Group Diff-P, this substitution maintained the relationship between sample responding and correct choice that had developed during acquisition, whereas for Group Diff-N, the sample substitution reversed that relationship. Thus, positive (P) and negative (N) transfer, respectively, were predicted for these two differential groups. For Group Nondiff, blue and white were substituted for red and green in such a manner that the relationship between the new samples and correct choice, and between the differential responding conditioned during the immediately preceding phase and correct choice, were counterbalanced across subjects. During testing of all three groups, all correct choices produced food reinforcement (i.e., the no-food outcome did not occur on any trial).

Return to baseline. The final phase of this experiment involved five sessions of retraining on each bird's original MTS acquisition task.

Results and Discussion

The typical differential outcome effect was evident during initial MTS acquisition: Criterion levels of accuracy were achieved more rapidly in the two differential groups than in the nondifferential group. For example, the average number of sessions needed to reach 90% or better accuracy was only 7.25 and 4.5 for Groups Diff-P and Diff-N, respectively, versus 22.5 for Group Nondiff. Post hoc contrasts (Rodger, 1975) across these means showed that the two differential groups did not differ from one another, $F(2, 9) = 0.21$ but that they learned in significantly fewer sessions than did Group Nondiff, $F(2, 9) = 10.08$.

Figure 6 shows the percentages of correct choice responses (filled symbols) and the development of differential responding to the two sample stimuli (open symbols) over the first eight acquisition sessions in the two differential groups. Differential responding was indexed by sample discrimination ratios that were computed by dividing the total number of responses to the sample on food-reinforced trials by the total number of responses to both samples. Because the alternative sample was associated with no food, responses to this stimulus should extinguish over sessions,

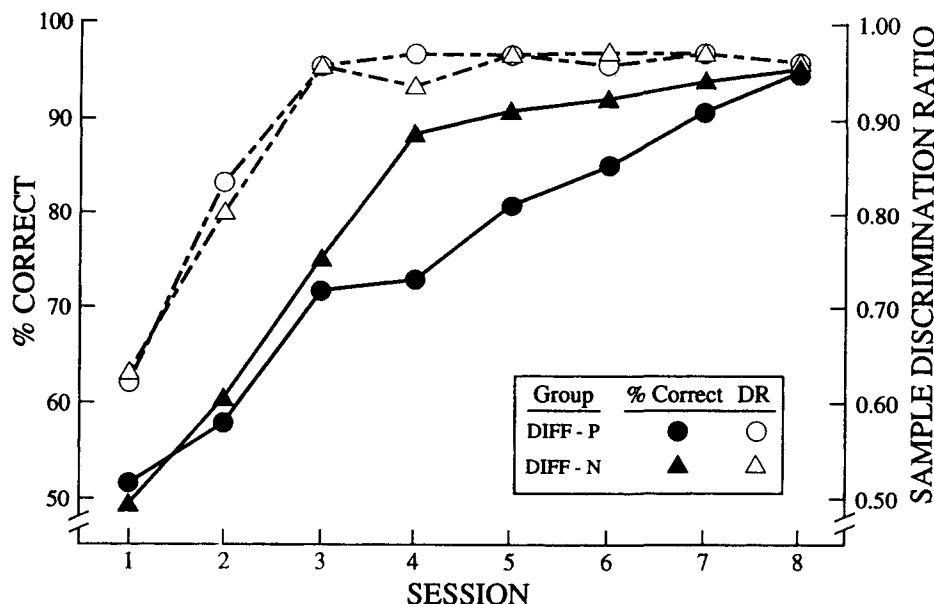


Figure 6. Average percentage of correct matching choices and the average proportion of all responses to the sample associated with the food outcome (sample discrimination ratio [DR]) for the two differential outcome groups during matching acquisition in Experiment 4. DIFF-P = differential-positive group; DIFF-N = differential-negative group.

yielding a discrimination ratio approaching 1.0. This is precisely what was observed. More important, perhaps, was the finding that in both Groups Diff-P (circles) and Diff-N (triangles), the sample discrimination developed more quickly than matching accuracy. On each bird's final training session, these ratios equaled .96 in Group Diff (range = .92–1.00) and .95 in Group Diff-N (range = .93–.99). By comparison, the corresponding ratio in Group Nondiff averaged .46 (range = .32–.70).

During subsequent pretraining in which reinforcement was contingent on responding versus not responding to two new stimuli (blue and white), birds in all three groups developed clear differential responding to those stimuli. For example, on the last pretraining session, the percentage of responses occurring to the hue to which birds had to respond in order to obtain food was 93%, 92%, and 90% in Groups Diff-P, Diff-N, and Nondiff, respectively. The groups did not differ from one another on this measure, $F(2, 9) = 0.36$.

Figure 7 shows individual performances on the first transfer session in which blue and white were substituted for red and green as samples for MTS. Just as in the previous experiments, pigeons for which pecking versus not pecking were associated with the same correct choices as in acquisition (Group Diff-P) were considerably more accurate in their test performances than pigeons for which the sample response–correct comparison relationship was reversed (Group Diff-N). Indeed, all Group Diff-P birds matched well above the level expected by chance alone on the first test session, and all Group Diff-N birds matched below chance. The average matching accuracies in these two groups—74.7% versus 42.5%, respectively—were significantly different, $F(2, 9) = 5.30$. These results, then, show

that the development of different sample-response patterns within the context of MTS acquisition with differential outcomes is sufficient to obtain transfer effects similar to those observed in the preceding experiments.

First-session test performances in the nondifferential control group were highly variable: One bird matched at high levels of accuracy, another well below 50% accuracy, and the remaining two near chance. The average first-session performance in this group (59.7%) was higher than in Group Diff-N but lower than in Group Diff-P, falling almost exactly at the midpoint vis-à-vis the differential groups, $F(2, 9) = 0.01$. The strong transfer effects observed in 2 of the nondifferential subjects was unexpected, however. One possible explanation is generalization between the training and test samples. Specifically, if birds coded the blue test sample as if it were the green training sample and the white test sample as if it were red (cf. Wright & Cumming, 1971), then performances like these would be anticipated. In fact, given the correct choices for the test samples vis-à-vis the training samples, generalization of this type would predict that at least initially, above-chance accuracy should be observed for 2 nondifferential birds and below-chance accuracy for the other 2. In fact, that prediction was nicely confirmed when accuracies were computed over just the first 20 test trials: the two “positive” nondifferential birds matched at 80% and 65% and the two “negative” nondifferential birds both matched at 30%.

It is important to realize, however, that although similar across-sample generalization could have also occurred in Groups Diff-P and Diff-N, the uniformity of results in those groups indicate that any such generalization was overridden by differential sample responses. Moreover, the impact of

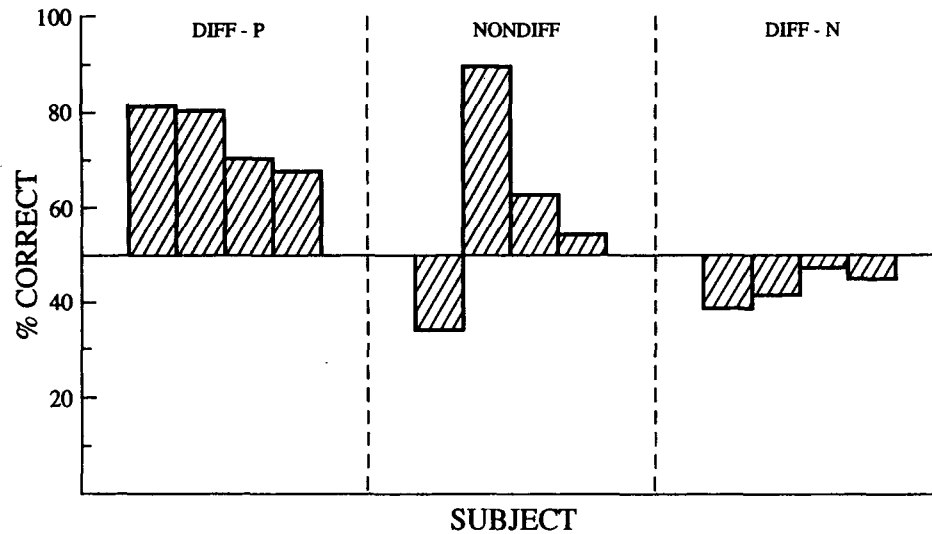


Figure 7. Percentage of correct matching choices for the individual subjects in each group on the first session of transfer testing in Experiment 4. DIFF-P = differential-positive group; NONDIFF = nondifferential group; DIFF-N = differential-negative group.

their differential sample responding was apparent immediately: Over the first 20 test trials, matching accuracy in Group Diff-P was 67.5% correct compared with 27.5% correct in Group Diff-N.

Finally, the return-to-baseline results obtained following the completion of testing closely resembled those obtained in Experiments 1 and 2 (cf. Figures 2 and 4). For example, on the first session of reexposure to their differential outcome MTS task, the Group Diff-P birds were considerably more accurate in their matching choices than the Group Diff-N birds: 91.2% versus 60.6%, $F(2, 9) = 6.34$. In Group Nondiff, the average matching accuracy on return to their nondifferential outcome task (80.3%) was at a level intermediate between the performance levels of the two differential groups, $F(2, 9) = 0.17$. Once again, this pattern of results is consistent with the notion that in Groups Diff-P and Diff-N, differential sample responding that originally developed during MTS acquisition had entered into the control over choice.

General Discussion

The issue addressed by these experiments was whether differential sample responding in MTS with differential outcomes would provide a cue for comparison choice. The answer is clearly yes. All four experiments showed that samples to which birds responded differentially because they were associated with different outcomes were, to some degree, interchangeable with other stimuli that occasioned similar differential responding because they were associated with different food reinforcement schedules.

Admittedly, the transfer produced by such an exchange was neither perfect nor as strong as that observed in other differential sample-response or differential outcome studies (e.g., Urcuioli, 1990, Experiment 3b; Urcuioli & Honig,

1980, Experiment 3). However, there was no a priori reason to expect especially strong transfer given that there was no guarantee that differential responding to the stimuli involved in the exchanges would be identical. After all, one pattern of pecking versus not pecking was generated by a Pavlovian procedure of presenting food only on trials beginning with one stimulus and no food only on trials beginning with the other, whereas the other differential pattern was generated by the operant contingencies of making food, or the comparison stimuli, contingent on pecking or not pecking. Transfer on the basis of these response patterns should be limited by the similarity of their individual components (e.g., how similar not pecking a stimulus signaling no food is to not pecking a stimulus in order to produce food). The working assumption behind our studies was simply that stimuli producing similar response patterns should produce some degree of transfer if those patterns truly controlled pigeons' matching choices. That prediction is clearly supported by the data.

A larger issue is whether differential outcome effects in MTS can generally be interpreted as reflecting the influence of differential sample responding. In other words, is the often-observed facilitation in acquisition (Edwards, Jagielo, Zentall, & Hogan, 1982; Peterson, 1984; Santi & Roberts, 1985; Urcuioli, 1990; Williams, Butler, & Overmier, 1990) and the enhancement of memory performance (Brodigan & Peterson, 1976; Urcuioli, 1990) by differential outcomes simply the result of an added discriminative cue provided by the birds' differential sample behavior (cf. Urcuioli, 1984, 1985; Urcuioli & Honig, 1980)? Although the data reported here do not answer this question, the possibility gains considerably more credence given that our data show clearly that differential behaviors that develop as a consequence of differential outcomes do, in fact, enter into the control over choice.

One aspect of the data, however, appears to discourage any attempt to reduce differential outcome effects to the effects of differential sample responding—namely, the incomplete transfer of performance. Certainly, if the former were the sole consequence of the latter, then transfer should have been complete, not partial. However, as mentioned earlier, incomplete transfer could also occur for other reasons (e.g., if sample responding during the substitution tests was not identical to that occurring in training).

Another approach to this issue is to look for correspondence, or lack thereof, between differential outcome and differential sample-response effects in closely related tasks. For example, Urcuioli (1991) found that outcomes unique to particular sample stimuli but uncorrelated with correct choice retarded MTS acquisition to such an extent that birds were unable to reach consistently high levels of accuracy after as many as 60 training sessions. By contrast, Urcuioli (1985) found that although differential sample responding uncorrelated with comparison choice in MTS also yielded relatively slow acquisition, birds nonetheless reached high levels of accuracy within 12–30 sessions. In both of these experiments, birds responded differentially to the sample stimuli, and the relationship of their pecking versus nonpecking patterns to correct comparison choice was the same. Despite this, the rate of MTS acquisition was substantially different across experiments. A cautious conclusion, then, may be that differential sample behaviors contribute to differential outcome effects but probably do not provide the sole source of those effects. In line with this, Urcuioli (1990) found that pigeons' patterns of comparison choice in differential outcome tasks did not always correspond to that predicted on the assumption of control by differential sample responding. The issue warrants closer study.

It is equally important to recognize, though, that an outcome expectancy account of our data makes a prediction that was consistently disconfirmed. Specifically, if pigeons' choices had been predominantly controlled by their expectancies of food and no food, then the substitution tests should have produced a strong and consistent preference for the comparison stimulus cued by the food expectancy because all substituted samples were associated the same food outcome. That preference, in turn, should have yielded first-session test performances that were comparable in all differential outcome groups and near the level expected by chance. Clearly, that was not the case.

Finally, the finding that differential sample responding serves a mediational role in differential outcome MTS is not an entirely unanticipated result. After all, the fact that the pigeons' sample behavior might have cue properties in these situations can be easily derived from Hull's (1931) analysis of expectation and goal direction. According to that analysis, the conditioning of components of the two "goal responses" (i.e., the responses to food and no food) to antecedent stimuli (i.e., the samples) should introduce additional proprioceptive stimuli into the matching situation that would then help to direct future action (i.e., comparison choice). The analysis of expectancy effects in terms of $r_g - s_g$ has, in the past, been criticized because the purported controlling anticipatory responses were not always apparent

or, when they were, did not always behave in ways consistent with a mediational role (e.g., Rescorla & Solomon, 1967; Trapold & Overmier, 1972). We are not advocating a return to the $r_g - s_g$ analysis of expectancy learning. However, we do wish to underscore one of its implications: that behavior conditioned to stimuli signaling different outcomes can have a directive function. This is an important point because others have argued that observable anticipatory responses may be only "surface manifestations of some more primary central event" (Peterson, 1984, p. 145; see also Rescorla & Solomon, 1967). Our experiments indicate that if differential sample responses are considered to be anticipatory, they are most certainly not merely "surface manifestations" but are instead a potent source of discriminative control.

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