

Assessing the Contributions of S–O and R–O Associations to Differential-Outcome Matching Through Outcome Reversals

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Pigeons were trained on symbolic matching with 2 samples, 2 pairs of comparisons, and different outcomes for the correct responses within each comparison pair. For one group, the 2 samples were also associated with different outcomes, whereas for another group, they were not. When the response–outcome (R–O) relations for one pair were subsequently reversed, the group trained with differential sample–outcome (S–O) associations was significantly disrupted in its performance on both reversed- and nonreversed-outcome trials. By contrast, the group trained with just differential R–O associations was disrupted only on reversed-outcome trials. These results were replicated when the outcomes on the initially nonreversed trials were then reversed. The findings indicate that differential S–O associations, when present, have a stronger influence on matching performances than differential R–O associations. They are also consistent with hierarchical and configural models of discriminative control.

The differential-outcome procedure has been used with good success to analyze the associative structure of instrumental discriminations (Peterson & Trapold, 1980; Rescorla & Colwill, 1989; Trapold, 1970; Urcuioli & DeMarse, 1996). Unlike typical instrumental discrimination tasks in which each correct response produces the same reinforcer, each correct response in a differential-outcome task produces a discriminably different reinforcer (Goeters, Blakely, & Poling, 1992; Peterson, 1984; Trapold, 1970). One typical consequence of these contingencies is that acquisition of discriminative performance is much more rapid than it would otherwise be (e.g., Trapold, 1970; Urcuioli, 1990).

In the simplest version of the differential-outcome task, there are two discriminative stimuli (S1 and S2), two defined correct responses (R1 and R2), and two reinforcing outcomes (O1 and O2). These combinations yield the reinforced trial types S1–R1–O1 and S2–R2–O2, each of which contains a number of potentially potent associative relations. Two that have attracted a lot of theoretical and empirical attention (Colwill, 1994; Colwill & Rescorla, 1986) are those involving each discriminative stimulus and the outcome whose availability it signals (S–O relations) and those involving each correct response and the outcome it produces (R–O relations). In this article, we examine the relative impact of these relations on pigeons' delayed matching.

The role of S–O relations in mediating differential-outcome performances has been emphasized in two-process accounts of instrumental learning (Trapold & Overmier, 1972; see also Peter-

son, 1984, and Urcuioli & DeMarse, 1996). The reason for this emphasis is that when each discriminative stimulus reliably signals a particular outcome, then presentation of that stimulus permits the animal to anticipate through Pavlovian means which outcome will be contingent on subsequent responding. That outcome anticipation can, in turn, serve as another cue for instrumental performance. In other words, responding under these training conditions can be controlled not only by the discriminative stimuli themselves but also by what those stimuli signal—that is, by their associative properties. Indeed, there is considerable evidence in the literature that anticipatory cues arising from differential S–O associations effectively cue both free-operant (e.g., Colwill & Rescorla, 1988; DeLong & Wasserman, 1981; Urcuioli & Zentall, 1990, 1992) and instrumental choice (Peterson, 1984; Trapold, 1970; Urcuioli, 1991) behavior.

Despite the S–O focus of two-process theory, important and potentially potent consistencies also exist in most differential-outcome tasks between the responses the animal makes and the outcomes those responses yield. Moreover, these R–O relations typically “match” the prevailing S–O relations in the sense that the outcomes produced by responding in the presence of the discriminative stimuli are the same as those signaled by those stimuli. Thus, one can ask whether differential-outcome effects, like enhanced acquisition relative to nondifferential-outcome controls, truly reflect the impact of the S–O relations (as emphasized by two-process theory) or the concurrent R–O relations.

Rescorla and Colwill (1989) and Rescorla (1992b) have addressed this question in discriminative, free-operant conditioning and have argued that it is, in fact, the R–O relations that exert the stronger influence on performance. One of their techniques used to arrive at this conclusion is to initially arrange a discrimination task in which the outcomes produced by the animal's responses are the opposite of those ostensibly signaled by the discriminative stimuli. By their description, the animal learns a discrimination in which the “consequent” outcomes for two separately trained responses (e.g., a chain pull and a lever press) oppose the “anticipated” outcomes (i.e., the outcomes signaled by the discriminative stim-

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ulus for each response). Following this training, one of the two outcomes is devalued by making the animal sick after consuming it. Then the frequency of each previously acquired response is measured in extinction.

The rationale for this opposing-relations test is that any resulting difference in the two response rates indicates which set of relations, S-O or R-O, had exerted the greater influence on performance (cf. Colwill & Delamater, 1995; Colwill & Rescorla, 1985). Specifically, if the R-O relations are the more potent of the two, then the outcome devaluation should yield greater suppression of those responses that had previously produced the now-devalued outcome. Conversely, if the S-O relations (the anticipated outcomes) are more influential, then the responses conditioned in their presence should be more suppressed.

Rescorla and Colwill (1989, Experiments 1 and 2) and Rescorla (1992b, Experiment 1) have reported that devaluation produced greater suppression of the responses previously producing the now-devalued outcome. Stated otherwise, devaluing the consequent outcome (R-O) had a more potent effect than devaluing the presumably anticipated outcome (S-O), keeping in mind that the two italicized outcomes are the opposite of each other. In a related study, Rescorla (1992b, Experiment 3) found that devaluation suppressed responses previously producing that outcome to the same degree independently of whether the discriminative stimuli reliably signaled which reinforcing outcome was available (i.e., independently of whether the animal could anticipate the scheduled outcome). These data, too, suggest that, contrary to the two-process notion of anticipatory (S-O) mediation of instrumental responding, R-O associations are the more powerful determinants of performance.

A different picture, however, has emerged from the pigeon delayed matching literature (Sherburne & Zentall, 1998; Urcuioli & DeMarse, 1996). The typical delayed matching task is a discrete-trial procedure in which each trial begins with the appearance of a sample stimulus on the center key of a three-key display. After the sample is observed and then removed, the pigeon chooses between two comparison alternatives appearing on the adjacent side keys. Responding to one alternative is reinforced after one sample, whereas responding to the other alternative is reinforced after a different sample stimulus. With differential-outcome contingencies, each reinforced choice response produces a different outcome. In this paradigm, then, *S-O associations* refer to the relations between the sample stimuli and the outcomes available for correct comparison responses, whereas *R-O associations* refer to the relations between those responses and the outcomes they yield.

Because outcome devaluation is not a viable procedure with pigeons, the usual method for assessing outcome-specific effects on matching performance has been transfer of control (see also Colwill & Delamater, 1995, and Colwill & Rescorla, 1988). One issue here is the extent to which choice responding will transfer across different samples that give rise to the same outcome anticipation, a test of S-O potency. Another issue is the extent to which a given pair of samples will control new responses with which they share common outcomes, a test of R-O potency. The impact of S-O relations has been shown by the finding that novel stimuli immediately control existing comparison responses providing that those novel stimuli signal the same outcomes as the samples they replace. Moreover, this transfer effect occurs even when the novel

S-O relations are established off the matching baseline (Peterson, 1984; Urcuioli, 1990). Similarly, results from response-substitution tests have shown that pigeons are clearly sensitive to R-O relations as well. For instance, Urcuioli, DeMarse, and Lionello (1998; see also Urcuioli & DeMarse, 1997) showed that comparison responses acquired in a matching task in which the samples themselves were uncorrelated with the different outcomes nonetheless readily substituted for comparison responses acquired in another matching task in which the samples did reliably signal those outcomes.

However, Urcuioli and DeMarse (1996) found evidence that, of the two sets of relations, S-O associations have a greater impact on performance (see also Urcuioli, 1991). In their study, all pigeons initially learned delayed matching with differential R-O associations but with S-O associations that were either differential (correlated) or nondifferential (uncorrelated) with respect to two outcomes. When new stimuli were later substituted for the original samples, they immediately cued the comparison responses with which they shared a common outcome, and this was true following both training conditions. More important, however, every bird matched more accurately in transfer when the choice responses learned in training were acquired in a task in which the samples reliably signaled the different outcomes. In other words, with differential R-O associations held constant, transfer was stronger after training with differential than with nondifferential S-O associations. This suggests that in this paradigm the S-O relations exert the more powerful influence.

To further examine this issue and to set the stage for a later discussion of the possible reasons for the discrepant data and conclusions from these two literatures, in the present study we adopted a technique used by Peterson and Trapold (1982)—a partial outcome reversal—to evaluate the impact of S-O and R-O associations on pigeons' delayed matching. In Experiment 1, pigeons were trained concurrently on two differential-outcome tasks involving different comparison responses but the same sample stimuli. Later, the R-O associations for one of the tasks were reversed. This allowed us to see (a) if the resulting disruption in performance was confined just to that task or if it generalized to the unchanged task as well and (b) whether the pattern of disruption differed as function of the presence versus absence of differential S-O associations in training. In Experiment 2, each bird received a second partial reversal involving the originally unchanged task. This served as a replication of Experiment 1 and as another test of the relative contributions of S-O and R-O associations to performance, as described below.

Experiment 1

Table 1 shows a schematic of the training and testing procedure used in Experiment 1. Two groups of pigeons were trained on symbolic matching with two samples (S1 and S2), two pairs of comparison choice responses (R1 and R2, and R3 and R4), and different outcomes (O1 and O2) for correct (+) comparison choice. All four major trial types in this one-to-many matching task (cf. Urcuioli & Zentall, 1993) were presented in each session. The training task for both groups involved differential R-O associations: One correct choice response in each comparison pair always yielded one outcome, whereas the other correct choice response always yielded the other outcome. (The incorrect choice

Table 1
Design of Experiment 1

Training	Partial reversal testing
Congruent S-O	
S1 → R1 + (O1)	S1 → R1 + (O2)
S2 → R2 + (O2)	S2 → R2 + (O1)
S1 → R3 + (O1)	S1 → R3 + (O1)
S2 → R4 + (O2)	S2 → R4 + (O2)
Incongruent S-O	
S1 → R1 + (O1)	S1 → R1 + (O2)
S2 → R2 + (O2)	S2 → R2 + (O1)
S1 → R3 + (O2)	S1 → R3 + (O2)
S2 → R4 + (O1)	S2 → R4 + (O1)

Note. S1 and S2 represent red and green sample stimuli; R1 and R2 represent vertical and horizontal comparison choice responses; R3 and R4 represent dot and white choice responses. Correct responses following each sample are indicated by the plus sign (+). O1 and O2 represent the outcome for correct choice. Incorrect choice responses have been omitted for clarity.

for each trial type is not shown.) The groups differed in the relations between the sample stimuli and the outcomes and were labeled in a manner similar to that of Peterson and Trapold (1982). Group Congruent S-O received training with differential S-O associations such that each sample reliably signaled which outcome was available for a correct comparison response. These birds, then, could anticipate the available outcome on seeing the sample. By contrast, the S-O associations for Group Incongruent S-O were nondifferential: Each outcome occurred equally often with both samples. This was accomplished by reversing the S-O relations across the two comparison pairs. Thus, birds in this group could not determine the available outcome for correct choice during sample presentation.

Following acquisition, the R-O relations for one pair of comparison responses were reversed, as shown in the right-most column of Table 1. The trials involved in outcome reversal are shown above the space separating the four main trial types for each group. This partial reversal (cf. Peterson & Trapold, 1982) provided a test of the relative contributions of S-O versus R-O associations to performance. Specifically, if comparison response-outcome (R-O) relations exert the primary influence on performance independently of the nature of the S-O relations, then the disruption of matching accuracy on reversed-outcome trials should be similar in the two groups. Moreover, the drop in matching accuracy on reversed-outcome trials for both groups should be much greater than on trials in which the R-O associations remain the same (lines below the space).

On the other hand, if differential S-O relations, when present, exert a greater influence on performance, then matching accuracy in Group Congruent S-O should be disrupted on both reversed-outcome and same-outcome matching trials, and the size of that disruption should be comparable across trial types. The reason is that the partial reversal changes congruent (differential) S-O relations to incongruent (nondifferential) relations. This change is critical because, in training, the congruent S-O birds should be

able to anticipate the scheduled outcome prior to the appearance of the comparisons. Because this anticipation normally provides an additional cue for pigeons' choice responses (Peterson, 1984; Urcioli & DeMarse, 1996), the shift to incongruent (nondifferential) S-O relations will remove this cue for choice for both sets of comparison choices. By contrast, any disruption of matching in Group Incongruent S-O should occur only on reversed-outcome trials, because their training relations preclude the development of sample-specific outcome expectancies. Their performance on same-outcome test trials should thus be unaffected by the partial reversal, because there is no outcome expectancy cue to remove.

The design and execution of Experiment 1 were virtually identical to those of the pigeon delayed matching study of Peterson and Trapold (1982), but with the following differences and improvements. First, whereas Peterson and Trapold (1982) used a mixture of identity and symbolic matching relations during training and testing, all of the sample-comparison relations we used were symbolic. Second, the comparison responses we chose for the partial reversal were counterbalanced within each group, a methodological feature that was missing from Peterson and Trapold's (1982) study. Third, all of our birds were trained to the same criterion levels of matching accuracy prior to their outcome reversals. This was not the case in Peterson and Trapold's (1982) study, making their findings (described later) virtually impossible to interpret.

Method

Subjects

Eight experimentally naïve White Carneaux pigeons obtained from the Palmetto Pigeon Plant (Sumter, SC) participated in the experiment. Each bird was gradually reduced to 80% of its free-feeding body weight by restricted feeding prior to the start of the experiment and was maintained at that level by confining the majority of its food to the experimental sessions. Supplemental feeding was given in the home cage only on days when the experiment was not run and on days when pigeons did not obtain an adequate amount of food in a session to maintain their 80% body weights. Grit and water were available in the home cage at all times. Birds were housed individually in stainless-steel wire mesh cages in a colony room on a 14-hr light-10-hr dark cycle. Prior to the start of the experiment, birds were randomly divided into two groups of 4, with an equal number of birds in each group assigned to each experimental chamber.

Apparatus

Two pigeon chambers, each consisting of a three-key panel (BRS/LVE Model PIP-016) inside a BRS/LVE SEC-002 enclosure, were used. The three equally spaced, clear pecking keys were positioned in a horizontal row 7.5 cm from the top of the panel and were spaced 5.7 cm from each other, center to center. Behind each key was an inline stimulus projector equipped to display red, green, and white homogeneous fields; a small white dot and a small, solid inverted white triangle on black backgrounds; and three vertical or horizontal white lines on black backgrounds (BRS/LVE Pattern No. 692). Mixed grain was accessible via a food hopper located behind a 5-cm × 5.8-cm opening positioned approximately 13 cm below the center key. A 24-ESB bulb located inside the metal housing of the food hopper was lit whenever the food hopper was raised. It could also be lit independently of activation of the food hopper. A General Electric No. 1829 bulb located 7.6 cm above the center key served as a houselight. Light from the bulb was directed toward the ceiling by an opening in the metal housing that covered it. Ventilation and masking noise were provided

by a continuously running fan attached to the exterior of each chamber. All experimental events were controlled and monitored by a Zenith 286 microcomputer located in an adjacent room.

Procedure

Preliminary training. Each bird was initially trained to eat quickly and reliably from a lit food hopper. The pecking response was then shaped by the method of successive approximations to the inverted white triangle on the center response key, after which pigeons received approximately 120 reinforced trials over the course of two sessions for pecking the triangle.

Next, pigeons were taught to peck at the stimuli that would later serve as samples and comparisons in one-to-many matching-to-sample. The first two of these sessions involved an equal number of center-key presentations of red and green hues. The next four sessions involved center-key presentations of red and green along with side-key presentations of either vertical and horizontal lines (two sessions) or the dot and white stimuli (two sessions). In all of these sessions, a single peck to the lighted response key (left, center, or right) on each trial immediately turned off the stimulus and produced 3-s access to grain. Each stimulus appeared 10 times in its respective location, with successive stimulus presentations separated by a 10-s intertrial interval (ITI). The houselight was off during the first 9 s of the ITI and was turned on for the last 1 s and for the duration of the trial (i.e., until the end of the reinforcement cycle).

The final three preliminary training sessions involved 30 presentations each of red and green, in random order, on the center key followed equally often by the two outcomes (food and no food) that birds would experience during subsequent matching-to-sample training. Each trial began with the inverted white triangle on the center key. A single peck to the triangle immediately turned it off and, 500 ms later, produced either red or green on the center key. Five seconds after the appearance of red or green, the hue was turned off independently of responding and was followed randomly by presentation of the lit food hopper (food) or by illumination of the hopper light without raising the hopper itself (no food). As before, each trial with red or green was separated from the next trial by a 10-s ITI, with the first 9 s spent in darkness.

Differential-outcome training. The left column of Table 1 shows the one-to-many matching contingencies during training for the two groups in this experiment. S1 and S2 represent red and green sample stimuli, respectively. The two sets of comparison alternatives—vertical and horizontal lines, and the white dot and white homogeneous field—are designated R1 and R2, and R3 and R4, respectively. The reinforced comparison response following each sample is designated by the plus symbol (+). The incorrect choice response for each trial type (not shown) was the alternative comparison in each set. The food and no-food outcomes following correct comparison choice are designated O1 and O2, respectively.

For both groups, each matching trial in a 96-trial training session began with the illumination of the houselight followed 1 s later by presentation of the inverted white triangle on the center response key. A single peck to the triangle immediately turned it off and, 500 ms later, produced either red or green (S1 or S2) as the sample stimulus. The sample then went off automatically after 5 s (i.e., independently of responding) coincident with presentation of either the vertical and horizontal comparison alternatives (R1 and R2) or the dot and white alternatives (R3 and R4) on the adjacent side keys. A single peck to either comparison then turned off both and yielded the food or the no-food outcome if the correct comparison was pecked, or a time-out period of equal duration with the houselight turned off if the incorrect comparison was pecked. For all birds, pecking the vertical comparison (R1) or the dot comparison (R3), whichever was available, was correct on red-sample (S1) trials, whereas pecking the horizontal comparison (R2) or the white comparison (R4), whichever was available, was correct on green-sample (S2) trials. When the incorrect comparison was chosen on any trial, that trial was repeated until the bird chose the correct comparison, although these correction-trial choices did not enter into the computation of matching accuracy.

The eight possible trial types (2 samples \times 2 comparison sets \times 2 left- vs. right-key configurations of each comparison set) appeared equally often in each successive block of 48 trials in a session. Trial order was randomized with the additional constraint that no single sample-comparison configuration could appear on more than two successive trials. All trials were separated by a 10-s ITI, the first 9 s of which was spent in darkness. The duration of access to the lit food hopper was constant within a session for each bird but varied from 2 s to 6 s across birds and sessions so as to maintain each bird's body weight as close to the 80% value as possible. On no-food-outcome trials, the hopper light duration was equal to the food access duration for that session.

The two groups differed in the arrangement of the food and no-food outcomes (O1 and O2) for correct choice across the various trial types. For Group Congruent S-O, one of the two outcomes (food or no food) always followed both possible correct comparison choices on trials beginning with one sample, and the other outcome always followed both possible correct choices on trials beginning with the other sample. For half of the birds in this group, food was the outcome on correct red-sample trials, and no food was the outcome on correct green-sample trials; for the other half of these birds, these relations were reversed. For Group Incongruent S-O, each outcome occurred equally often following both hue samples (i.e., the S-O relations were nondifferential). This was accomplished by scheduling different outcomes for correct vertical (R1) and dot (R3) choice responses on S1 trials and, likewise, for correct horizontal (R2) and white (R4) choice responses on S2 trials. For half of the birds in this group, food followed correct responses to vertical and white (R1 and R4) and no food followed correct responses to horizontal and dot (R2 and R3); for the remaining incongruent S-O birds, these relations were reversed. Note, however, that for both groups, the two correct choices within a comparison dimension (lines and dot-white) yielded different outcomes—that is, both were trained with differential R-O associations.

Each bird was trained on its respective one-to-many task for a minimum of 10 sessions and until it reached a criterion of 90% or better overall accuracy plus 87.5% correct with each set of comparisons for five of six consecutive sessions. At that point, outcome reversal testing began.

Partial outcome reversal testing. On the day following each bird's last criterion training session, the outcomes for one of the two comparison sets were reversed, as shown in the right column of Table 1. The reversed-outcome trials are listed above the space separating the pairs of matching trials for each group. For half of the birds in each group, the outcome reversal was in effect for the line comparison responses (R1 and R2), as shown in Table 1; for the other half of the birds, the reversal was in effect for the dot and white comparison responses (R3 and R4; not shown). In addition, the reversal was counterbalanced across the sample-outcome training relations in Group Congruent S-O. All birds were tested with the reversed outcomes for a minimum of 10 sessions and until they met the aforementioned performance criteria.

The net effect of the outcome reversal was to convert the formerly differential sample-outcome relations in Group Congruent S-O to nondifferential relations, and vice versa in Group Incongruent S-O. In other words, each hue sample was now followed equally often by the food and no-food outcomes in Group Congruent S-O, whereas each hue sample was followed by only one outcome (either food or no food) in Group Incongruent S-O. Other than this change, the sample-correct choice contingencies in both groups were exactly the same as they had been in training, and the outcomes for correct choice responses on the remaining matching trials (those shown below the space) were also exactly the same as before.

Statistical analyses. We initially used analysis of variance (ANOVA) to evaluate overall within- and between-group differences. When ANOVA indicated a significant overall effect, we evaluated post hoc contrasts across the various group means using the methods, tabled *F* values, and inferential procedures described by Rodger (1975a, 1975b). Rodger's tabled *F* values ensure that the expected proportion of all null contrasts rejected in error

will not exceed α , the Type I error rate. For all analyses reported here, $\alpha = .05$.

Results

The rates of one-to-many matching acquisition were comparable in the two groups, although they were more variable in Group Incongruent S-O than in Group Congruent S-O. The average number of training sessions necessary to reach criterion levels of performance was 5.75 in Group Congruent S-O (range: 5–7 sessions) versus 8.75 in the Group Incongruent S-O (range: 4–14 sessions), $F(1, 6) = 1.65$.

Figure 1 shows each group's matching performance with the line orientation and dot-white comparisons over the first 10 acquisition sessions. Matching accuracy averaged over comparison sets and sessions did not differ significantly between groups, $F(1, 6) = 5.52$. There was, however, a significant overall effect of comparison dimension, $F(1, 6) = 33.09$, reflecting generally higher accuracies with the dot-white comparisons than with the vertical and horizontal lines. In addition to the obvious overall effect of session, $F(9, 54) = 43.58$, there were significant Group \times Session and Comparison Dimension \times Session interactions, $F_s(9, 54) = 1.87$ and 2.60, respectively, as well as a Group \times Comparison \times Session interaction, $F(9, 54) = 1.88$. These interactions appear to reflect (a) a performance advantage of Group Congruent S-O over Group Incongruent S-O during Sessions 2–6, (b) faster overall rates of acquisition with the dot-white than with the line comparisons, and (c) a somewhat larger comparison dimension effect early in acquisition in Group Congruent S-O than in Group Incongruent S-O.

Despite these differences, the two groups were nearly indistinguishable in their performances over the last five training sessions

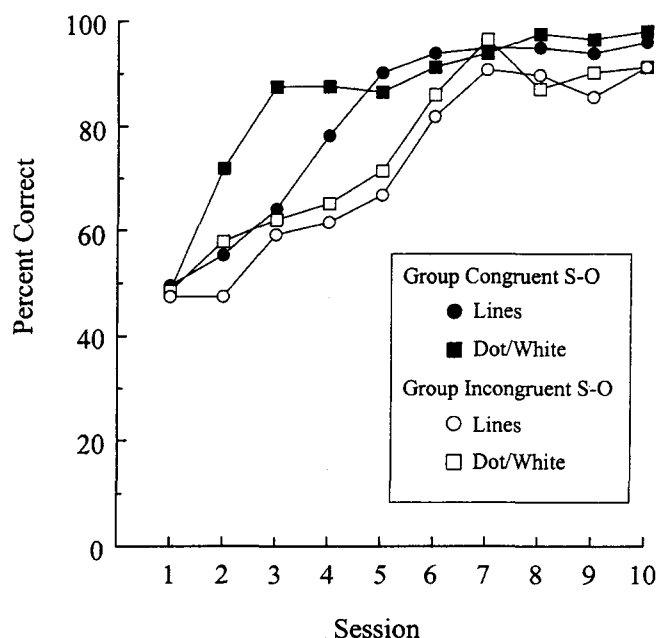


Figure 1. Percentage of correct choice responses by comparison set for each group over the first 10 one-to-many acquisition sessions in Experiment 1. S = sample; O = outcome.

that preceded the outcome reversal test. Overall matching accuracy for these sessions averaged 95.4% correct in Group Congruent S-O versus 94.7% in Group Incongruent S-O, $F(1, 6) = 0.73$. Choice accuracies with the line comparisons were 94.8% and 92.6%, respectively, for the two groups, $F(1, 6) = 3.60$, and 96.1% and 97.3% correct, respectively, with the dot and white comparisons, $F(1, 6) = 0.60$.

Figure 2 shows the performance of each group during the first 10 outcome reversal sessions. Accuracies are plotted separately for matching trials in which the comparison R-O contingencies were reversed and those in which the contingencies remained the same (cf. Table 1). For Group Congruent S-O, the outcome reversal caused a nearly identical drop in matching accuracy on reversed-outcome and same-outcome matching prior to recovery of performance. By contrast, for Group Incongruent S-O, the disruptive effects of the outcome reversal were confined to the reversed-outcome trials. Moreover, the drop in matching accuracy on these trials was comparable in size to that observed in Group Congruent S-O.

Figure 3 summarizes the effects of the outcome reversal by plotting matching accuracy on same-outcome and reversed-outcome trials averaged over the first five reversal sessions (stippled bars) with accuracy on those trial types averaged over the five sessions immediately prior to the reversal (solid bars). Prereversal (baseline) accuracies were uniformly high across trial types in both groups (range: 94.8%–96.2%). The outcome reversal produced a substantial, and comparably sized, drop in matching accuracy on reversed-outcome trials in both the congruent S-O group (73.8%) and the incongruent S-O group (73.8%) and on same-outcome trials in the congruent S-O group (79.1%). By contrast, accuracy on same-outcome matching trials in the incongruent S-O group (94.3%) was nearly identical to its corresponding baseline.

Statistical analyses confirmed this pattern of results. First, a split-plot ANOVA on the same- versus reversed-outcome test-trial data only, averaged over the first five test sessions, showed a significant effect of group, $F(1, 6) = 7.67$; trial type, $F(1, 6) = 29.15$; and their interaction, $F(1, 6) = 10.05$. Second, separate randomized-block ANOVAs on each group's data, including its baseline performances, yielded significant overall effects of trial type for both the congruent S-O group and the incongruent S-O group, $F_s(3, 9) = 20.42$ and 67.14. Post hoc contrasts on the congruent S-O group data showed no significant difference between baseline accuracies for the same- and reversed-outcome trials, $F(3, 9) = 0.05$, and no significant difference on same- and reversed-outcome test trials, $F(3, 9) = 0.76$. However, accuracies on the combined test trials were significantly lower than the combined baseline accuracies, $F(3, 9) = 19.61$. These statistical decisions imply the following ordering of accuracies in the congruent S-O group: baseline-same = baseline-reversed > same outcome = reversed outcome (Rodger, 1975b, Equation 23). For the incongruent S-O group data, post hoc contrasts showed that the baseline accuracies did not significantly differ, $F(3, 9) = 0.01$, neither did they differ from that observed on the same-outcome test trials, $F(3, 9) = 0.06$. Accuracy on the reversed-outcome test trials, however, was significantly lower than on the remaining trial types, $F(3, 9) = 67.06$. These statistical decisions imply the following ordering of accuracies in the incongruent S-O group: baseline-same = baseline-reversed = same outcome > reversed outcome.

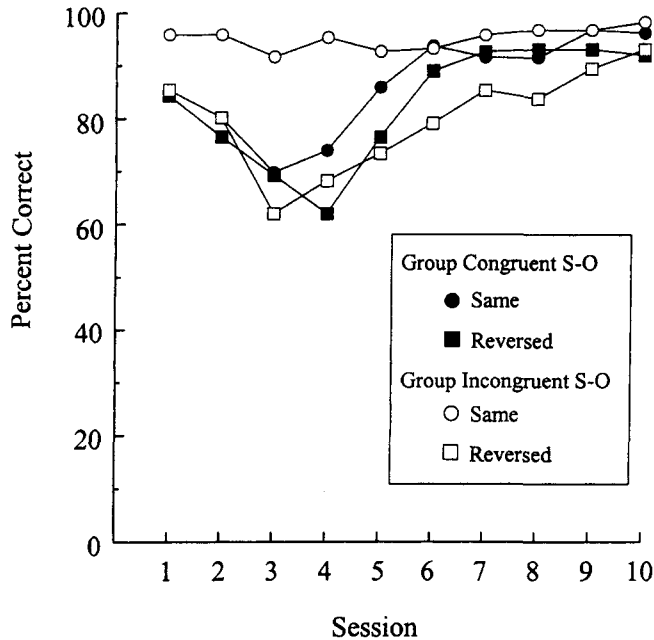


Figure 2. Percentage of correct choice responses by comparison set for each group over the first 10 outcome reversal sessions in Experiment 1. S = sample; O = outcome.

Finally, we used one-way ANOVAs to compare matching accuracy across groups on same-outcome and reversed-outcome trials averaged over the first five test sessions. On reversed-outcome trials, the congruent S-O and incongruent S-O groups performed at comparably low levels of accuracy, $F(1, 6) = 0.00$, whereas on same-outcome trials, the incongruent S-O group was more accurate in its choices than the congruent S-O group, $F(1, 6) = 13.02$.

Discussion

Experiment 1 was virtually identical in design to that reported by Peterson and Trapold (1982), although our pattern of results differed considerably from theirs. First, we found that a partial outcome reversal had an equally large disruptive effect on reversed- and same-outcome matching trials when pigeons had been trained with differential (congruent) S-O relations. By contrast, Peterson and Trapold (1982) reported greater disruption on reversed- than on same-outcome trials after congruent training. Second, we found that a reversal following training with nondifferential (incongruent) S-O relations produced a drop in accuracy only on the trials in which the R-O relations were reversed. By contrast, Peterson and Trapold (1982) reported that a partial outcome reversal following incongruent training had little or no effect on matching performances on either reversed- or same-outcome trials.

As indicated earlier, however, Peterson and Trapold's (1982) findings may have been compromised by a number of factors. First, they did not counterbalance across comparison sets. Thus, it is unclear if the differences they observed on same- versus reversed-outcome trials following congruent S-O training may have arisen solely for that reason. Second, matching accuracy in

Peterson and Trapold's (1982) incongruent group prior to its reversal was 20%–30% lower than in the congruent group. Consequently, the ineffectiveness of the partial reversal on matching performance in their incongruent group may simply reflect the fact that those birds had not completely learned the baseline relations prior to testing (i.e., the associations involved in the reversal had not fully formed). By contrast, in the present experiment all birds were trained to the same high level of baseline accuracy, and the outcome reversal in each group was balanced over the two pairs of comparisons. Our results, then, provide a clearer, more interpretable picture of the effect of partial outcome reversals on pigeons' differential-outcome matching.

Although the comparably sized drop in accuracy in the two groups on reversed-outcome trials suggests that R-O relations were dominant, the additional finding of an equally large drop in matching accuracy in Group Congruent S-O on the same-outcome trials indicates that their differential S-O relations were, in fact, the more influential of the two. On same-outcome trials, the outcomes for correct choice were unchanged relative to baseline. Despite this, and despite the fact that the sample-comparison response relations themselves were unchanged, the ability of the congruent S-O birds to maintain high levels of performance accuracy on these trials was seriously compromised by the outcome reversal on the other matching trials. Moreover, this effect occurred only in this group: Group Incongruent S-O's performances on same-outcome trials remained fully intact. Clearly, then, the presence versus absence of differential S-O associations during training made a huge difference in how widespread the effects of the outcome reversal were on matching performances.

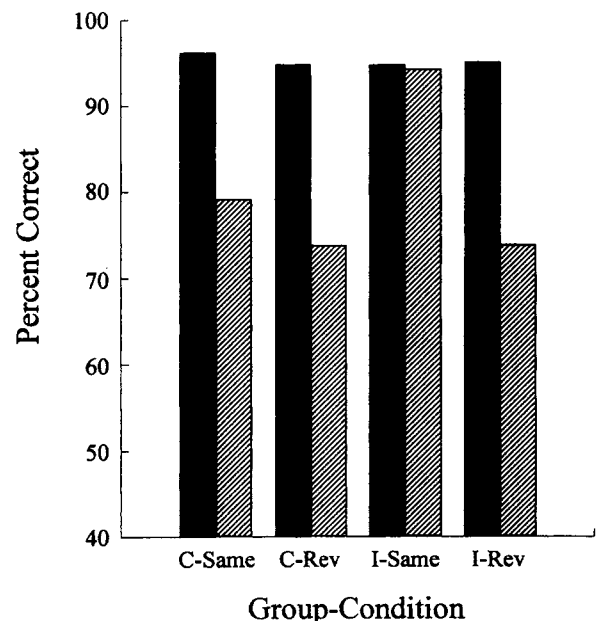


Figure 3. Percentage of correct choice responses averaged over the first five outcome reversal sessions in Experiment 1 by Group C (congruent sample-outcome [S-O]) and Group I (Incongruent S-O) on same-outcome and reversed-outcomes matching trials (stippled bars). Prereversal accuracies on each trial type averaged over the last five baseline sessions preceding the outcome reversal are shown by the solid bars. Rev = reversed.

These between-group differences make sense when considered in terms of anticipated outcomes. When each sample reliably signals the availability of one particular outcome, as in the congruent S-O group, birds are able to anticipate which outcome is scheduled to occur from one trial to the next on the basis of the sample stimulus. This outcome anticipation can provide an additional cue for comparison choice (Trapold, 1970; Urcuioli, 1991; see also Urcuioli & Zentall, 1992, Experiments 2 and 3). By reversing the consequent outcomes for one pair of choice alternatives in one-to-many matching, each sample no longer reliably signals one particular outcome, thus removing any differential-outcome expectancies. With the deterioration of those expectancies, accuracy of the choice responses previously cued by them should drop even though some of those choices continue to have exactly the same differential consequences as in training.

Independent evidence for this account can be seen in the way the congruent S-O pigeons responded to the samples themselves. The left panel of Figure 4 shows the average peck rate to each sample stimulus by this group over the last five acquisition sessions (left pair of bars) and over the last five reversal sessions (middle pair of bars). S1 and S2 designate the samples associated with the food and no-food outcomes, respectively, for correct choice during acquisition. By the end of acquisition, the congruent S-O pigeons pecked the food-associated sample very rapidly but seldom pecked at the no-food-associated sample. When outcomes were later reversed for one of the comparison sets in this group, food and no food now followed each sample equally often, and sample-response rates changed accordingly: By the end of the reversal, these birds pecked the formerly no-food-associated sample far more often, and peck rates to S1 and S2 were now more nearly equal. In short, sample responding by Group Congruent S-O tracked the changing S-O associations from acquisition to reversal.

The right panel of Figure 4 shows the corresponding data for Group Incongruent S-O. Although the S-O associations during

acquisition were nondifferential in this group, there was a large overall difference in peck rates to the two samples (left pair of bars), primarily because 2 of the 4 birds had a very strong bias for pecking one sample. Nonetheless, this difference in sample response rates reversed when, as a consequence of the outcome reversal, the S-O associations became differential (middle pair of bars). For the two birds showing the initial sample bias, the "preferred" sample in acquisition now signaled no food during the reversal phase, whereas the originally "nonpreferred" sample now signaled food. The net result was that these birds pecked the former sample much less frequently than the latter, again tracking the changing S-O associations.

Experiment 2

To provide an additional assessment of the relative contributions of S-O (sample-outcome) and R-O (comparison response-outcome) associations to pigeons' matching performances, we conducted a second partial reversal test immediately after performances on the initial reversal test stabilized at criterion levels of accuracy. For each bird, the second outcome reversal involved the comparison dimension that was not subject to the outcome reversal in Experiment 1.

It is important to note that the S-O contingencies resulting from the reversal in Experiment 1 effectively changed each group's assignment. In other words, the Group Congruent S-O pigeons in Experiment 1 were now matching under incongruent conditions, and vice versa (cf. Table 1). For exposition purposes, the group designations used in Experiment 2 reflect their S-O relations at the end of Experiment 1 (viz., after the prior outcome reversal).

If the effects seen in Experiment 1 are replicable, then a second reversal should, once again, disrupt performances on reversed-outcome matching trials by all pigeons. By contrast, the reversal should disrupt same-outcome matching accuracy for Group Congruent S-O but not for Group Incongruent S-O.

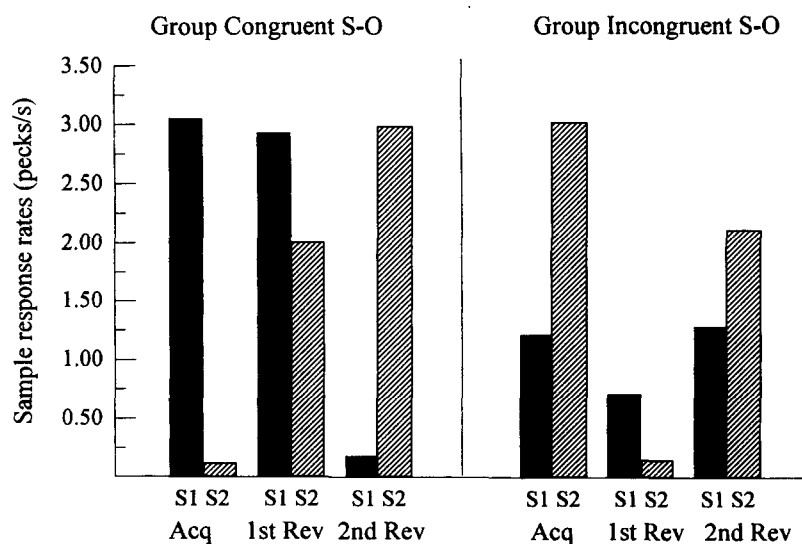


Figure 4. Sample response rates (in pecks/s) for each group to the two samples (S1 and S2) averaged over the last five acquisition (Acq) sessions and last five reversal (1st Rev) sessions in Experiment 1, and the last five reversal sessions (2nd Rev) in Experiment 2. S = sample; O = outcome.

Method

Subjects and Apparatus

All pigeons from Experiment 1 participated in this experiment. They were housed and maintained as before. The same apparatus was used.

Procedure

After each bird had reached criterion levels of one-to-many matching accuracy on the outcome reversal of Experiment 1 (i.e., 90% or better overall matching accuracy plus at least 87.5% correct with each comparison set for 5 of 6 consecutive sessions), the food and no-food outcomes for the formerly "unchanged" comparison set were now reversed. Again, counterbalancing of the training relations in Experiment 1 ensured that an equal number of pigeons in each group experienced the reversal with the line and with the dot-white comparisons. As in Experiment 1, each pigeon was tested for a minimum of 10 sessions and until its matching performance reached the aforementioned criterion levels of accuracy. All other details about these matching sessions were identical to those previously described.

Results and Discussion

Figure 5 shows matching performances by each group during the first 10 reversal sessions of this experiment. The asterisks by each group's name designate the one-to-many contingencies effective at the end of Experiment 1 (i.e., immediately prior to the reversal in this experiment). The reversal results resemble those previously observed. Specifically, reversing the food and no-food outcomes for correct choice with one comparison set disrupted performance on both reversed- and same-outcome matching trials in Group Congruent S-O. By contrast, the disruption of perfor-

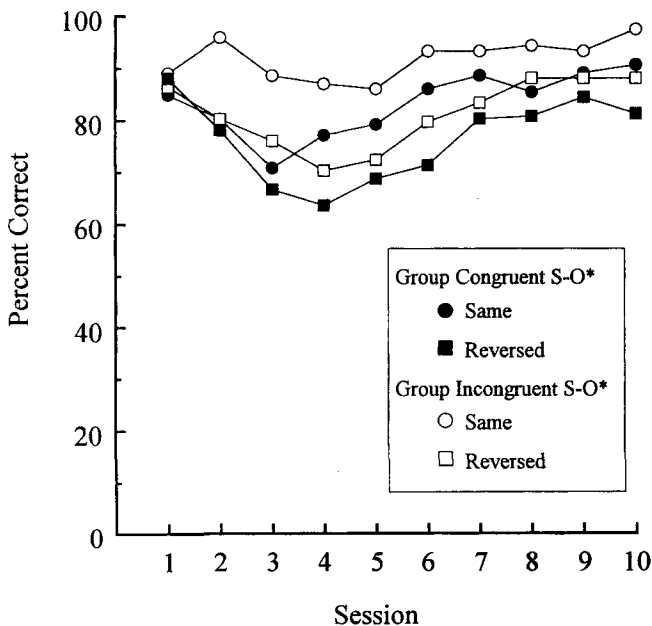


Figure 5. Percentage of correct choice responses by comparison set for each group over the first 10 outcome reversal sessions in Experiment 2. Asterisks designate the sample-outcome contingencies effective at the end of Experiment 1 and prior to the outcome reversal. S = sample; O = outcome.

mance in Group Incongruent S-O was specific to the reversed-outcome trials.

Figure 6 summarizes these effects by plotting matching accuracy on same- versus reversed-outcome trials (stippled bars) averaged over the first five reversal sessions in this experiment alongside accuracy on those trials during the last five criterion-level test sessions in Experiment 1 (solid bars). The latter provided the baseline accuracies against which to assess the effect of the current outcome reversal. Again, the asterisk by each group's abbreviated name indicates the S-O contingencies in effect at the end of Experiment 1 and prior to the present reversal.

Baseline accuracies were again very high in both groups (range: 93.5%–98.8%). Moreover, a substantial and comparably sized drop in matching accuracy was again observed on reversed-outcome trials both in the congruent S-O group (73.0%) and in the incongruent S-O group (77.1%). By contrast, the outcome reversal had virtually no effect on same-outcome trials in the incongruent S-O group (89.2%), whereas it produced considerable disruption in the congruent S-O group (78.0%).

A split-plot ANOVA on the same- versus reversed-outcome test-trial data only, averaged over the first 5 test sessions, showed significant effects of group, $F(1, 6) = 6.73$; and trial type, $F(1, 6) = 7.54$; although no interaction, $F(1, 6) = 1.12$. However, post hoc contrasts on the mean accuracy data from each group, including the baseline performances, showed a different pattern for the congruent S-O group than for the incongruent S-O group. For the congruent S-O group, baseline accuracies did not differ, $F(3, 9) = 1.26$, neither did accuracies differ on the same- and reversed-outcome trials over the first five reversal sessions, $F(3, 9) = 1.14$. However, combined performances on the latter (test) trials were significantly less accurate than their corresponding baselines, $F(3, 9) = 39.42$. Once again, these statistical decisions imply the following ordering of accuracies in the congruent S-O group: baseline-same = baseline-reversed > same outcome = reversed outcome (Rodger, 1975b, Equation 23). By contrast, matching accuracies on the same-outcome test trials for the incongruent S-O group were comparable to those of the two baseline trial types, which did not differ from each other, $F(3, 9) = 0.14$ and 0.53 , respectively. Accuracy on the reversed-outcome test trials, however, was significantly lower than on the former three trial types, $F(3, 9) = 8.05$. These statistical decisions imply that the ordering of matching accuracies in the incongruent S-O group was as follows: baseline-same = baseline-reversed = same outcome > reversed outcome.

One-way ANOVAs comparing accuracies across groups on same-outcome and on reversed-outcome trials showed no significant between-group difference on the latter, $F(1, 6) = 0.78$, but did show significantly more accurate same-outcome performance in the incongruent group than in the congruent group, $F(1, 6) = 7.42$.

To statistically evaluate whether the partial reversal following each type of training generated the same between-trial differences in this experiment as in Experiment 1, we calculated an accuracy difference for same- versus reversed-outcome trials for each bird over its first and second five test sessions in each experiment. We then compared difference scores across experiments for the congruent training condition and for the incongruent training condition. Although these comparisons are confounded with amount and type of prior matching training, they do provide a rough sense of how similar the partial reversal effects were. In all cases, there

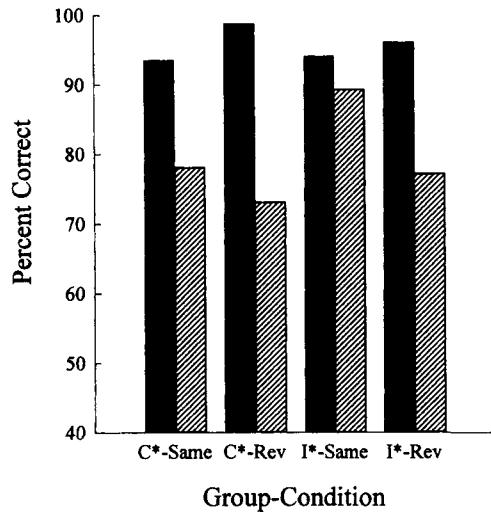


Figure 6. Percentage of correct choice responses averaged over the first five outcome reversal sessions in Experiment 2 by each group on same-outcome and reversed-outcomes matching trials (stippled bars). Baseline accuracies on each trial type averaged over the last five sessions preceding the outcome reversal are shown by the solid bars. The asterisk by each group's label (C = congruent sample-outcome [S-O]; I = incongruent S-O) indicates the nature of the S-O relations created by the partial reversal in Experiment 1.

were no significant differences across experiments in same- minus reversed-trial accuracies following either congruent or incongruent training, all $F(1, 6) < 4.01$. So, for example, the large performance difference between the two trial types during the initial test sessions following incongruent training was equally large whether birds received that type of training initially (in Experiment 1) or after they had undergone a previous partial reversal that had switched their S-O relations from congruent to incongruent (i.e., their incongruent training was the baseline for Experiment 2).

The only possible exception to this was an indication of a larger accuracy difference during the second five test sessions following congruent training in Experiment 2 than in Experiment 1, as seen by the greater separation between the filled-symbol functions over Test Sessions 6–10 in Figure 5 than in Figure 2. Although the difference-score analysis described earlier returned a nonsignificant result, $F(1, 6) = 4.10$, every congruent S-O group bird in Experiment 2 matched more accurately on same- than on reversed-outcome trials over those later test sessions, $F(1, 3) = 32.52$. This slower recovery of performance on reversed-outcome trials was not seen in the congruent S-O group in Experiment 1. Its implications are addressed in the General Discussion.

Finally, the rightmost pairs of bars in Figure 4 show how sample responding changed in reaction to the second outcome reversal. Here, the group labels correspond to each bird's original group assignment in Experiment 1 and the nature of the S-O associations resulting from the second outcome reversal. When the second reversal re-created differential S-O associations (left panel), birds pecked at very high rates to the sample (S2) that was now consistently followed by food and at very low rates to the sample (S1) that was now consistently followed by no food. By contrast, when the reversal re-created nondifferential S-O associations (right

panel), the differential pattern of sample responding evident at the end of the first reversal (i.e., at the end of Experiment 1) dissipated. Again, the higher overall rates observed to S2 at the end of the second reversal in this group primarily reflected the reappearance of the sample-response bias seen in acquisition. It is clear, however, that the shift back to nondifferential S-O associations in Group Incongruent S-O produced a large corresponding shift in their sample peck rates.

General Discussion

Rescorla (1992b) and Rescorla and Colwill (1989) have argued that in differential-outcome discriminations, R-O associations have a greater influence on performance than S-O associations. By contrast, the conclusion we draw from the results reported here is quite different: When pigeons' conditional discriminations involve both differential S-O and differential R-O associations, the former exert stronger control over performance than the latter. The main finding supporting this conclusion is that, after training of this sort, reversing the R-O associations on some matching trials adversely affects performance on other matching trials on which the R-O associations are unchanged.

Just as important, this generalized disruption occurred only when training involved differential S-O associations (Group Congruent S-O). By contrast, when pigeons learned one-to-many matching with nondifferential S-O associations (Group Incongruent S-O), their reversal-test performances were disrupted only on trials directly involved in the outcome reversal. Although this latter effect confirms pigeons' sensitivity to R-O associations (Urcuioli & DeMarse, 1997; Urcuioli et al., 1998), the specificity of the effect in the incongruent S-O group clearly shows that the generalized disruption observed in the congruent S-O group cannot be explained simply by this or by procedural changes per se that were experienced during the reversal.

Moreover, these between-group differences were replicated with the same pigeons that had earlier shown the contrasting pattern of results. In other words, when the pigeons trained with differential S-O associations in Experiment 1 (Group Congruent S-O) were "retrained" on the same task with nondifferential S-O associations (via the first outcome reversal), their same-outcome matching performances during the partial reversal of Experiment 2 remained intact, while their performances on reversed-outcome trials collapsed. By contrast, when pigeons initially trained with nondifferential S-O associations (Group Incongruent S-O) were "retrained" with differential S-O associations in Experiment 2, their second partial reversal now produced as much disruption on same-outcome as on reversed-outcome trials, at least initially.

It is important, then, that the pattern of test results consistently coincided with, and is understandable in terms of, the changes in the prevailing S-O associations caused by the partial reversal. For instance, a shift from differential to nondifferential S-O associations did, and would be expected to, have an impact on all matching trials if baseline performances were at least partly cued by the anticipated outcomes arising from the differential S-O associations. Conversely, the opposite shift did not, and would not be expected to, have an effect on all trials because the nondifferential S-O associations in baseline would not engender a sample-specific anticipatory cue.

Other researchers have reported effects, and offered interpretations, similar to ours. For example, Peterson and Trapold (1982) found that following one-to-many matching with differential S-O associations, reversing R-O associations with one comparison set disrupted pigeons' choice accuracy with the other, unchanged set. Likewise, Honig, Matheson, and Dodd (1984) found that reversing the outcomes for one of two concurrent matching tasks decreased discriminative test-stimulus responding on both tasks if the anticipated outcomes conditioned to the samples (via differential S-O associations) provided a valid cue for responding during training. In addition, the performance disruption Honig et al. observed was comparable in size on both changed- and unchanged-outcome trials. The authors of both of these studies interpreted their findings in terms of performance mediation by sample-specific outcome expectancies.

Data reported by Sherburne and Zentall (1998) and Urcuioli and DeMarse (1996) also support the argument that differential S-O associations, when present, have a discernible impact on matching performances over and above that of R-O associations. As mentioned earlier, the latter study showed that although differential R-O associations were sufficient to support transfer of choice responding to novel stimuli with which they shared a common outcome (cf. Urcuioli et al., 1998), the effect was clearly and consistently enhanced when training also involved differential S-O associations.

An Alternative Interpretation of the Devaluation Findings

Why, then, do the outcome devaluation results reported by Rescorla (1992b) and Rescorla and Colwill (1989) indicate the apparent primacy of R-O associations? Again, these authors reported that devaluation of the consequent outcome, the outcome in the R-O relation, produced greater suppression of those responses than of the other responses presumably cued by anticipation of the now-devalued outcome (i.e., the one in the S-O relations). There are certainly many procedural differences between devaluation studies with rats and conditional discrimination studies with pigeons that make across-literature comparisons difficult and that may contribute to the different patterns of results. Nonetheless, we

suggest that the devaluation findings can reasonably be interpreted in terms of S-O associations—in other words, in terms of devaluing the *anticipated* outcome for responding. We base our contention on the belief that the design and execution of the devaluation experiments introduce the possibility that the different response options present during the different training phases cue different sets of S-O associations. This point is perhaps made clearer in Table 2, which is a diagram of a simple (but representative) devaluation design along with our assumed theoretics.

Note that when the R1 and R2 response alternatives are present during Phase 2 training, the S-O relations are the opposite of those during Phase 1 in which a different response alternative, Rc, is present. In other words, in the presence of the R1 and R2 manipulanda, S1 signals O2 and S2 signals O1, whereas just the opposite signaling relations hold in the presence of Rc. Thus, if animals discriminate different sets of S-O relations on the basis of available response options, then the outcomes they actually anticipate in Phase 2 would be congruent with the obtained (consequent) outcomes, rather than conflicting with them as is often assumed. For example, the animals would expect O2 on S1 trials in Phase 2, the same outcome that their R1 responses produce. This point is also made at the bottom of Table 2, which shows the hypothesized outcome expectancies (E2 and E1) arising from S1 and S2 during Phase 2. Note that these expectancies correspond to the outcomes (O2 and O1, top of Table 2) produced by responding in the presence of those stimuli. If the assumed correspondence between anticipated and consequent outcomes is correct, then subsequent devaluation of one of the outcomes would not distinguish between S-O and R-O associations, because those associations would not oppose one another. Stated in a different way, animals may have shown relatively greater suppression of R1 after devaluation of O2 because they had learned to anticipate O2 (not O1) when presented with S1 during Phase 2 training. If so, then the reported test results would be equally consistent with an interpretation emphasizing S-O relations.

Rescorla's (1992b, Experiment 3) results also can be interpreted in this fashion. His experiment is of particular interest because it involved one-to-many training and a between-group comparison much like that of the present experiment (cf. Table 1). Separate

Table 2

A Basic Devaluation Design for Evaluating the Contributions of S-O and R-O Associations to Instrumental Performances and Theoretical Outcome Expectancies (Italicized) Assuming That Response Options Define the Signaling Properties of the Discriminative Stimuli

Training			
Phase 1	Phase 2		Testing
S1—Rc → O1	S1—R1 → O2	Devalue	R1 vs. R2
S2—Rc → O2	S2—R2 → O1	O1 or O2	
Theoretics			
S1 → E1	S1 → E2		
S2 → E2	S2 → E1		

Note. S1 and S2 are different discriminative stimuli; Rc, R1, and R2 are different responses; O1 and O2 are different reinforcing outcomes; and E1 and E2 are expectations (anticipations) of those outcomes.

groups of rats were trained with two discriminative stimuli (S1 and S2), two pairs of response alternatives (R1 and R2, and R3 and R4), and differential R-O associations (the correct responses within each pair of alternatives yielded different outcomes). One group was trained with differential S-O associations (each stimulus always signaled one particular outcome for its correct responses), whereas the other group was trained with nondifferential S-O associations (each stimulus yielded each outcome, depending on the response). After subsequently devaluing one outcome, Rescorla (1992b) found equal suppression of the responses producing that outcome (the consequent outcome) in both groups, a finding he interpreted as favoring the primacy of R-O associations.

Here, too, however, the pairs of responses were trained in separate sessions, unlike in the present study. Consequently, in Rescorla's (1992b) "nondifferential" S-O condition, the available alternatives could potentially cue which *differential* S-O associations were in effect. (Moreover, the first reinforced trial in a given session could also cue the prevailing set of S-O relations for this group—cf. Jenkins, 1965.) Thus, the devaluation results in both groups of Rescorla's (1992b) Experiment 3 are potentially explicable in terms of anticipated outcomes (i.e., in terms of differential S-O relations).

Admittedly, there is no independent evidence within the Rescorla and Colwill (1989) paradigms that response alternatives effectively disambiguate which differential S-O relations are in effect. However, the general notion that contextual factors can define the "meaning" of a stimulus—what event it signals—is not foreign to the conditioning literature as shown, for instance, by the renewal effect (e.g., Bouton, 1994; Bouton & Peck, 1989). In addition, there is very clear evidence in pigeons' one-to-many matching for the sort of contextual control hypothesized here. Specifically, Urcuioli and DeMarse (1996) trained pigeons on separate differential-outcome matching tasks in which only one of two possible pairs of comparison alternatives appeared in a session. Across comparison pairs and sessions, the differential S-O relations reversed, as in Rescorla's (1992b) Experiment 3. Even though the S-O relations were nondifferential overall (viz., collapsed across pairs of responses), pigeons pecked the two samples in each session at different rates, and this rate difference reversed across sessions as a function of the available alternatives. Thus, the available comparison responses effectively signaled which differential S-O relations were operating.

The incongruent training procedure of the present study, by contrast, ensured that S-O associations were truly nondifferential. In other words, given that both pairs of comparison alternatives appeared in each session, and that each scheduled pair could not be determined at the time of sample presentation, the incongruent S-O pigeons could not use those alternatives to discriminate the particular S-O relations in effect. Thus, our design permits a valid comparison of how pigeons' differential-outcome performances are affected by their ability (Group Congruent S-O) versus inability (Group Incongruent S-O) to anticipate the scheduled outcome at the time of sample presentation. As predicted from two-process theory (Peterson, 1984; Trapold & Overmier, 1972; Urcuioli & DeMarse, 1996), performances were more sensitive overall to a partial outcome reversal when pigeons could anticipate outcomes at the beginning of each matching trial.

Other Considerations

One potential criticism of the across-literature comparisons made above is that there are important procedural differences that could affect an animal's ability to discriminate changing S-O relations on the basis of available response alternatives. For instance, in Urcuioli and DeMarse's (1996) study, which showed reversing sample-response rate differences as a function of the comparison alternatives, training involved multiple transitions between the two sets of alternatives. By contrast, the rats in Rescorla and Colwill's (1989) devaluation studies experienced only one transition between the two training phases during which the S-O relations reversed. If the sort of discriminative control we are postulating requires multiple transitions, then our analyses would not apply to devaluation studies of this type.

Still, the rapidity with which reversing S-O relations can be learned is uncertain, so it is possible that multiple transitions are unnecessary. Indeed, renewal effects in Pavlovian conditioning are apparent after only a single transition between conditioning and extinction training, suggesting that one contextual shift is sufficient for rats to detect changes in the signaling properties of stimuli. Moreover, the devaluation study that most closely resembles the present experiment—that of Rescorla (1992b, Experiment 3)—contained multiple (five) transitions between the pairs of response alternatives during training. At least for those results, then, the idea that rats may have detected reversing, differential S-O relations on the basis of their response options seems especially plausible.

Another potential criticism concerns the comparability of the outcomes used in this experiment (food vs. no food) and those typically used in devaluation studies (e.g., food pellets vs. sucrose). Are these different types of outcomes fundamentally different? Do they produce different types of behavioral control? We do not think so.

First, although our term *no food* suggests no reinforcer, the no-food event actually involved lighting of the food hopper. Because this light always accompanied food, when available, the "no-food" light likely served as a conditioned reinforcer for choice (Bersh, 1951; Zimmerman, 1963). Second, food versus no-food outcomes produce the same effects as reported with different types of outcomes. For instance, they yield facilitated acquisition like that observed when discriminative conditioning in rats involves sucrose versus pellets (Trapold, 1970), different delays or magnitudes of the same food reinforcer (Carlson & Wielkiewicz, 1972, 1976), or a light flash versus none (Fedorchak & Bolles, 1986), and when conditional discrimination learning in pigeons involves food versus water (Brodigan & Peterson, 1976) or different probabilities of food (DeLong & Wasserman, 1981; Urcuioli, 1990). Likewise, the food-versus-no-food manipulation supports transfer of control to novel stimuli in the same way as that obtained with food versus water (Honig et al., 1984) or different types of grain (Edwards, Jagielo, Zentall, & Hogan, 1982). Although the size of these acquisition and transfer effects varies as a function of type of outcome, this variation is probably explicable in terms of salience differences between the corresponding outcome expectancies.

Finally, it could be argued that the use of food and no-food outcomes in congruent training conditions introduces a source of discriminative control, differential sample responding, that negates any comparison to other paradigms in which no such behavior to

the discriminative stimuli is evident. However, Trapold (1970) and others (e.g. Peterson, 1984) have noted that the very notion of outcome anticipation or expectation via differential S-O associations implies an additional source of discriminative control besides that arising from the physical features of the discriminative stimuli. In other words, saying that an animal "anticipates" one outcome given one stimulus and another outcome following a different stimulus means that it is "doing something different," whatever that happens to be, to each stimulus. Moreover, that difference—whatever its form—must have discriminably different stimulus properties (i.e., give rise to a distinct cue). Thus, behavioral and ostensibly "cognitive" forms of mediation share a common feature indispensable to any analysis of the effect of differential S-O associations on instrumental performance: the introduction of a new and redundant discriminative stimulus (cf. Hull, 1931; Peterson, 1984; Trapold & Overmier, 1972).

A Hierarchical Interpretation

Despite the two-process tradition of analyzing instrumental tasks in terms of binary associations, more recent analyses (Colwill, 1994; Rescorla, 1992a; cf. Skinner, 1938) adopt a hierarchical view of instrumental contingencies, prompted in part by data from "switching" designs (e.g., Rescorla, 1992b, Experiment 3) and "biconditional discrimination" tasks (e.g. Colwill & Delamater, 1995). This view states that each sample stimulus occasions ("signals") a particular R-O relation: S_n -(R_n - O_n). For one-to-many matching with differential outcomes, each sample indicates which outcome is contingent on which response.

This hierarchical view predicts the performance disruption seen in both groups on reversed-outcome trials because the samples on those trials now signal different R-O relations than they had originally. To account for the finding that partial reversals also disrupt matching accuracy on same-outcome trials following congruent training, it is necessary to assume substantial generalization between R_1 - O_1 and R_3 - O_1 and between R_2 - O_2 and R_4 - O_2 . However, this seems reasonable given that the response members of each pair of R-O relations shared the same outcome and that each pair was occasioned by a common sample stimulus in the congruent S-O group (see Table 1). The contrasting finding of stable same-outcome performances following incongruent training requires the assumption of less generalization between comparison responses associated with the same outcome as well as between the R-O relations occasioned by the same sample stimulus. But this, too, seems reasonable given that the common-outcome responses for the incongruent S-O group were occasioned by different sample stimuli and the two R-O relations occasioned by the same sample stimuli involved different outcomes. Recent data on acquired equivalence arising from common antecedents and consequents (Johns & Williams, 1998; see also Bonardi & Hall, 1994) and on acquired relational equivalence (Honey & Watt, 1998) support this analysis.

A Configural Interpretation of Incongruent S-O Performances

Although we have interpreted the between-group differences in reversal performances in terms of mediation by outcome expectancies in the congruent S-O group but not in the incongruent S-O

group, certain assumptions would allow the results from both groups to be explained by expectancy mediation. Specifically, when pigeons are trained with incongruent contingencies, they might nonetheless learn to anticipate each trial's scheduled outcome by configural means—for instance, by combining memory of each sample with the particular set of comparisons that appear. For instance, after seeing sample S_1 , comparison set $R_1 + R_2$ predicts the availability of O_1 , whereas comparison set $R_3 + R_4$ predicts O_2 . Conversely, after seeing sample S_2 , comparison set $R_1 + R_2$ predicts the availability of O_2 , whereas comparison set $R_3 + R_4$ predicts O_1 (cf. Table 1). Thus, the incongruent S-O birds might have, in fact, anticipated each trial's outcome prior to making a choice. This idea makes some degree of sense given that the two comparison sets were quite different in their appearance, thus making the requisite discriminations relatively easy. There are also data in the pigeons' one-to-many matching literature suggesting just such a configural strategy following incongruent S-O training—in particular, differential choice latencies (DeMarse & Urcuioli, 1993) and transfer of control (Urcuioli et al., 1998, Experiment 3).

Anticipating outcomes on the basis of a combination of sample and comparison set also predicts the observed specificity in the disruption of the incongruent S-O group's performance following a partial reversal. Same-outcome performance should remain intact, because the outcomes predicted by the sample-comparison configurations on those trials were unchanged by the reversal. By contrast, reversed-outcome performances should suffer, because the configurations on those trials now signaled the opposite outcome vis-à-vis training. Moreover, if incongruently trained birds continue to anticipate outcomes on the basis of combined (sample + comparison set) information even after subsequent training with congruent S-O contingencies, then a second reversal following the latter type of training should produce a disruption in performance that, again, is mostly or solely confined to reversed-outcome trials. Although such trial-specific disruption was not observed in these birds in Experiment 2 (congruent S-O), the slower recovery of their performances on reversed- than on same-outcome trials (cf. congruent S-O performances in Figure 5) may reflect residual use of a configural strategy.

Obviously, distinguishing between configural control, hierarchical control, and binary associative control is a difficult task at best. Most probably, the particular events or combination of events that control pigeons' matching performances will vary depending on the particular training contingencies to which they are exposed, their prior training experiences, and so on. It seems likely, however, that anticipating forthcoming outcomes is both behaviorally important and potent and that pigeons will use whatever information is necessary to accurately anticipate those events.

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