DISCRIMINATION OF RESPONSE-REINFORCER AND RESPONSE-STIMULUS CONTINGENCIES IN PIGEONS

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For three pigeons (Experiment 1), the presentation of a red response key ended with a food presentation either following two responses separated by at least 10 seconds (a DRL contingency) or following a 10-second response-free period (a DRO contingency). For three other birds (Experiment 2), a brief stimulus presentation terminated the DRL and DRO contingencies. A white side key was presented next and ended with response-dependent food following one contingency and a timeout following the other. Since the contingency on the red key was unsignaled, differential responding on the white side key could indicate that the two response-reinforcer relations had been discriminated. In Experiment 1, the red-key duration and number of responses influenced white-key responding following the contingency that predicted the timeout. A response-initiated DRO was instated, and the influence of red-key duration and response number on white-key responding was diminished. In both experiments, the 10-second time criterion in both contingencies was varied from 0.34 second to 10 seconds. Even at short time intervals the DRO and DRL contingencies were readily discriminated. Pigeons tended to class the two contingencies according to a rule that did not involve simply stimulus duration, numbers of responses, or even the time between a response and its consequence.

Key words: response-reinforcer relations, response-stimulus relations, stimulus control, key peck, pigeon

In both operant and respondent conditioning it is the relationship between responses and reinforcers or between stimuli and responses that determines the course of conditioning. This paper is concerned with the extent to which organisms can detect the relationship between the events that occur in operant conditioning. Various discrimination tasks have already demonstrated that animals can discriminate the occurrence of their own responses as well as the presentation of reinforcers (Dodd, 1980; Hobson, 1975; Maki, Moe, & Bierley, 1977; Rilling & Howard, 1977; Rilling & McDiarmid, 1965; Shimp, 1976), and the relationship between neutral events has served as a discriminative stimulus (Weisman & Dodd, 1979; Weisman, Wasserman, Dodd, & Larew, 1980).

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The discriminability of the response-reinforcer relationship has also received some experimental attention. Lattal (1975, 1979) demonstrated that in a three-key choice paradigm, pigeons could distinguish between two different reinforcement schedules. Each trial contained four phases. (1) A "sample period" in which the center key was illuminated with yellow light for at least 10 s, and which terminated either when 10 s had elapsed with no response or after the first response following a 10-s response-free period. The two sample response-reinforcer relations corresponded to differential-reinforcement-of-low-rate (DRL) and differential-reinforcement-of-other-behavior (DRO) schedules. (2) A delay interval ranging from 0 to 36 s. (3) Presentation of red and green side keys. (4) Food reinforcement for a peck on the green key following a DRO sample or on the red key following a DRL sample. Choice accuracy was above 80% but declined as the delay between the completion of the DRO and DRL schedule and the presentation of the side keys increased from 0 to 36 s.

It is tempting to conclude that correct choices were cued by the response-reinforcer

contingency that had just been completed. However, simpler explanations might be offered. First, with Lattal's definition of the DRO and DRL contingencies, the birds had to make only one response for the DRL and none for the DRO. In general, if the DRL sample systematically involved more responses than the DRO sample, or if it required more time to complete, the birds could have made the correct choice on the basis of either of those two differential stimuli. Second, Killen's (1978) work suggests a more complicated account involving the temporal relation between responses and their consequences. Pigeons pecked on the left or right side key to indicate whether the presentation of the side keys had been caused by its own center-key peck or by a computer's "pseudo-peck." The time between the pigeon's last center-key peck and the presentation of the side keys greatly influenced the choice response: The greater the time, the more likely the birds were to indicate that the change had been produced by the computer's "peck." Thus, another account of Lattal's finding would be that the time between the pigeon's last response to the yellow key and the food presentation could cue the correct response.

The present experiment replicated Lattal's general results, but with a delayed discrimination procedure. In this method the sample contingency was followed by illumination of a side key as a single test stimulus for 5 s. Reinforcement was available if the first part of the trial involved DRO and not if it involved DRL (or the reverse). The birds' discrimination between the two schedules would be evident if they responded on the side key only when reinforcement would be available. The roles of the duration of the DRL and DRO samples and of the number of responses to them were examined as determiners of discriminative responding. If either duration or response number could cue the birds, then differential responding to the side key would be observed when the same schedule was completed with different numbers of responses or with different sample durations. When discriminative responding had been established, the time criterion to obtain reinforcement following a response in the DRO schedule, and between responses in the DRL schedule, was varied. The DRO contingency always involves a delay between a response and the presenta-

tion of the reinforcer, whereas the DRL contingency always involves an immediate response-contingent reinforcer. Indeed, the main reason for choosing the DRL contingency was to ensure that birds would be responding to the sample stimulus at a low rate and that the temporal requirement for the DRO contingency could be readily met when it was scheduled. Varying the time criterion for the DRL contingency should not influence responding to the test stimulus, because each trial involved a response-reinforcer pairing and the duration of the preceding interresponse time was irrelevant. However, as the time requirement for the DRO schedule decreases, the delay between response and reinforcer diminishes and at very short delays the DRO contingency resembles the DRL contingency. Under these conditions discriminating between the two schedules may become difficult.

EXPERIMENT 1 DISCRIMINATION OF RESPONSE-FOOD CONTINGENCIES

METHOD

Subjects

Three experimentally naive White Carneaux pigeons served. Throughout the experiment they were maintained at about 80% of their free-feeding weights and were individually housed with free access to grit and water.

Apparatus

Two experimental chambers were used; one was 33 cm high, 32 cm wide, and 38 cm deep, and the other was 38 cm high, 38 cm wide, and 38 cm deep. The front panel of each chamber contained a 5-cm² central feeder aperture. Two response keys were mounted behind 2.5-cm circular apertures; the center key was 25 cm (28 cm in the second chamber) above the grid floor and the side key was 25 cm to the right of the center key. An Industrial Electronics Engineers stimulus projector (#4580-165) mounted behind each key could transilluminate the center key with red light and the side key with white light. A 15-W, 120-VAC bulb operated at 85 volts, mounted behind a translucent shield on the opposite wall of the chamber, served as a houselight.

Procedure

All birds were magazine trained in two sessions containing 60 4-s food presentations separated by an average interval of 60 s. Next, key pecking to the center and side keys was established with intermittent trials consisting of 8-s keylight presentations followed by 4-s food presentations. Several subsequent sessions of fixed-ratio reinforcement ensured that the birds responded reliably to both keys.

Discrimination training began next. Following a 20-s intertrial interval, the center key was illuminated red. The red key terminated with a 1.5-s food presentation after one of two response contingencies had been met. One contingency was differential-reinforcement-of-other-behavior (DRO), which required a 10-s period in which there were no responses to the center key; the other contingency was differential-reinforcement-of-low-rate (DRL), which required two responses separated by a minimum interval of 10 s. The bird had no cue to indicate the contingency in effect, and the red key remained on until the contingency was met. After the DRO or DRL contingency had been met and food had been presented, the white side key was illuminated and when 5 s had elapsed, either a 3-s timeout or a 3-s response-contingent food presentation occurred (i.e., an FI 5-s schedule). For Birds 47 and 1453, the DRL contingency was S+ and signaled food for responding on the side key, whereas the DRO was S- and signaled the timeout. These relationships were reversed for Bird 1446. The red-key DRO and DRL contingencies were equally represented in randomized blocks of four trials. Twenty blocks of trials were presented 5 or 6 days a week. Discrimination training continued for each bird until the discrimination ratio (side key responses following S+ divided by the total number of side-key responses) was at or above .80 for five of six consecutive sessions.

In the next stage, the response contingency in the DRO sample was modified; a single response to the red key was required to initiate the DRO contingency. Thus, in all the subsequent sessions, these response-initiated DRO trials involved at least one response to the red key and the DRL trials involved at least two responses. Discrimination training continued until the birds again achieved discrimination ratios above .80 for five of six sessions.

In the test sessions that followed, the time criterion in both the DRO and DRL contingencies was varied. This provided, in effect, a generalization test on the temporal dimension that governed the sample response contingency. In each block of 16 trials, time criteria of 1.25, 2.5, 5, and 10 s occurred twice each for both DRO and DRL contingencies. For example, if the DRO contingency was in effect with a 2.5-s criterion, food would be presented after a 2.5-s response-free period following a response. Likewise, in the case of DRL, the food presentation occurred after an interresponse interval of 2.5 s or more. As in discrimination training, the white side key was presented following the sample contingency and the trial ended with reinforcement following S+ contingencies or a timeout following S- contingencies. The order of presentation was randomized within each block. Five such blocks were presented in each of the six test sessions.

Discrimination training then was reinstated, with the DRO and DRL time criterion set at 5 s; this training continued until the discrimination ratios had met the same criterion as before. Two more test sessions took place next, but with time criteria of 0.34, 0.68, 1.25, and 2.50 s instead of the values used in the previous test sessions.

RESULTS

The discrimination ratio was calculated by dividing the number of side-key responses following the positive red-key contingency by the total number of side-key responses. A ratio of 1.0 indicates that the DRO and DRL contingencies were perfectly discriminated; a ratio of .5 indicates nondifferential responding.

Birds 1453, 47, and 1446 met the discrimination criterion, a ratio of .80 or greater for five of six consecutive sessions; after 26, 35, and 24 sessions (mean = 28.3), respectively. When the DRO contingency was redefined to be a response-initiated DRO, the birds took another 24, 16, and 34 sessions (mean = 24.7) to meet the discrimination criterion. In the third phase, when the time requirement for the DRL and DRO schedules was reduced from 10 s to 5 s, the birds met the criterion in 18, 30, and 6 sessions (mean = 18).

Comparison of the effects of differing numbers of sample responses and sample durations on test stimulus responding was made by ex-

Fig. 1. The mean number of test-stimulus (side-key) responses following the DRO (dashed lines) and DRL (solid lines) sample contingencies. The means are plotted as a function of sample duration (left panels) and sample response numbers (right panels). The squares, triangles, and circles represent means based on 30 or more, 10 to 29, and 9 or fewer trials, respectively.

pressing the mean number of test-stimulus (side-key) responses as a function of the number of responses in the sample contingency and also as a function of the sample duration. Figure 1 shows the results of this analysis for each bird. Because both the number of responses in the sample and the sample duration were determined by the bird and varied from trial to trial, each point plotted is based on a different number of trials. A rough guide to the sample size is given by the symbol in the figure, with the largest symbols (squares) showing means based on 30 or more trials, medium-sized symbols (triangles) showing means based on 10 to 29 trials, and the smallest symbols (circles) showing means based on 9 or fewer trials. The panels in the left column show the mean number of side-key responses for each sample duration by 5-s intervals. The panels on the right show the means for each number of sample responses from 0 to 10. For each number of sample responses or sample durations, the difference between the mean number of side-key responses on DRO or DRL trials indicates the extent to which the bird discriminated between the two contingencies when that source of stimulus control was constant. The upper panels for each of the three birds show results from the last five sessions (400 trials) of the first phase of discrimination training, and the lower panels show results from the last five sessions with the response-initiated DRO. For Birds 1453 and 47, the mean number of side-key responses was relatively constant for all sample durations and response numbers on trials involving the positive sample contingency (DRL) during both phases of training. However, as the number of responses or the time to complete the negative sample contingency increased, the mean number of side-key responses increased somewhat. For Bird 1446 particularly, but for all birds in general, the DRO sample contained fewer responses and was completed in shorter time than the DRL sample. When the response-initiated DRO was instated (lower panels for each bird), the difference between the mean number of side-key responses following the DRO and DRL samples was generally independent of the number of responses or time taken to complete the contingency.

Figure 2 shows the results of the two test sessions, in which the time criteria for the DRO and DRL were varied. Because the responding

Fig. 2. The mean number of test-stimulus (side-key) responses following the DRO (dashed lines) and DRL (solid lines) sample contingencies with varying time criteria in test sessions (Experiment 1). The circles represent data from the first test, the triangles data from the second test.

on the successive test days was extremely variable, the data shown are from the first test day in each case. In the first test, differential responding following the DRO and DRL samples was observed across the range of time criteria from 1.25 to 10 s, and there was little evidence of a temporal gradient. In the second test, Bird 1446 exhibited differential responding across the entire range of values tested. Birds 1453 and 47 did not respond differentially at the shortest time, 0.34 s, and showed a gradient across the range 0.34 to 2.5 s. For

Bird 1453, as the criterion time increased, the number of side-key responses increased after the DRL trials and decreased after the DRO trials. For Bird 47, the number of responses following DRL trials remained constant, but decreased after DRO trials as the criterion time increased.

Table 1 shows further details of the test sessions. The mean sample duration, the mean number of responses to complete the sample contingency, and the mean number of side-key responses are listed for each of the time and schedule contingencies. The table shows that sample durations and response numbers do vary with the time and schedule requirements. The differential responding to the side key after DRO and DRL contingencies is generally maintained when the two measures are similar. This would indicate that the differential responding on the side keys was not simply

Table 1

Mean number of sample responses, sample seconds, and side-key pecks during test sessions for the various time and schedule requirements in Experiment 1.

	Crit (sec)	Sample		Side	Sample		Side
		Resp	Sec	pecks	Resp	Sec	pecks
Bird 1453		DRO (S-)			DRL (S+)		
Test 1	1.25	3.2	3.6	3.4	3.5	6.8	13.8
	2.50	3.0	4.5	0.6	4.2	8.8	14.0
	5.00	5.6	9.1	0.0	5.3	13.3	12.5
	10.00	6.2	27.2	2.6	10.6	39.0	11.1
Test 2	0.34	1.0	4.0	7.0	2.0	8.8	9.5
	0.68	1.2	3.7	7.0	2.3	5.0	11.5
	1.25	1.7	5.6	6.6	3.7	5.2	12.8
	2.50	3.7	7.9	5.3	7.1	12.5	13.5
Bird 0047		DRO (S-)			DRL (S+)		
Test 1	1.25	1.0	9.5	1.8	2.4	17.0	5.5
	2.50	1.6	13.7	2.1	2.5	15.4	5.1
	5.00	1.8	12.9	0.7	2.4	16.7	6.6
	10.00	5.0	35.1	3.8	6.4	38.7	5.3
Test 2	0.34	1.3	1.8	13.6	2.2	0.7	13.4
	0.68	3.5	1.9	5.9	4.5	2.6	12.9
	1.25	4.2	3.1	4.1	6.4	6.0	15.0
	2.50	8.6	7.0	0.5	8.3	8.5	13.7
Bird 1446		DRO (S+)			DRL (S-)		
Test 1	1.25	1.9	15.4	15.5	2.5	21.8	3.0
	2.50	1.7	13.9	16.3	2.4	21.5	2.2
	5.00	1.2	14.6	13.3	2.8	21.7	3.5
	10.00	3.2	26.7	12.7	4.3	29.8	1.1
Test 2	0.34	1.0	2.9	11.7	2.1	6.1	4.2
	0.68	1.0	4.7	12.3	2.6	9.2	3.6
	1.25	1.5	6.4	13.7	2.9	7.6	6.8
	2.50	3.4	9.1	13.0	3.1	8.3	3.9

a function of changed sample durations or response numbers during the test sessions.

EXPERIMENT 2 DISCRIMINATION OF RESPONSE- STIMULUS CONTINGENCIES

Experiment 1 involved a discrimination of the contingency between responding and a motivationally salient event, namely food. The presentation of food between the sample and the test stimulus may have made the relationship between responses and their consequences more relevant and therefore more discriminable. On the other hand, it may have degraded the memory for the relationship by interpolating an eating period between the sample period and the test period, with the result that poorer discriminative responding was observed. Experiment 2 was therefore carried out as a systematic replication of Experiment 1, in which the relationship to be discriminated was the response-contingent onset of a keylight, rather than food presentation. If birds do learn generally about relationships between their behavior and environmental events, then the results should resemble those obtained in Experiment 1.

METHOD

Subjects

Three experimentally naive White Carneaux pigeons served. They were maintained throughout the experiment at 80% of their free-feeding weights and had free access to grit and water in their home cages.

Apparatus

The apparatus was the same as in Experiment 1.

Procedure

The initial training was the same as in Experiment 1, but discrimination training differed in two ways. First, the DRO 10-s and DRL 10-s samples terminated not with a 1.5-s food presentation, but with a 1.5-s presentation of a green light on the center response key. Second, the DRO sample was always response initiated, as in the later stages of Experiment 1. Following initial training, Birds 1139 and 1167 were trained with the DRO sample signaling that food would be available for responding on the side key, and the DRL

sample signaling the timeout; for Bird 1060, these relationships were reversed with food available after the DRL sample, and the timeout available after the DRO sample. Training continued until a bird had a discrimination ratio of .8 or greater for five out of six consecutive sessions. Then, the first test took place; for one session the time criterion in the DRO and DRL samples was varied as in Experiment 1, with interresponse or interevent times of 1.25, 2.50, 5.00, and 10 s. Next, discrimination training was reinstated, with the time criterion held constant at 5 s in both the DRO and DRL samples. Training continued until the birds again had discrimination ratios of .80 for five of six sessions or until 40 sessions had elapsed. Finally, a second test took place in which the DRO and DRL time criteria were 0.34, 0.68, 1.25, and 2.50 s.

RESULTS

Birds 1139, 1167, and 1060 met the first discrimination criterion in 31, 54, and 58 sessions (mean = 47.7), respectively. The second criterion was met only by Bird 1139, in eight sessions; the other birds were trained for the full 40 sessions.

Figure 3 shows the results of the two test sessions. Birds 1139 and 1167 exhibited the same differential responding following the DRO and DRL contingencies regardless of the time criterion involved. Bird 1060 responded at about the same rate following all DRL trials, but after DRO trials, the bird responded somewhat more when the time criterion was short than when it was long.

Table 2 shows mean sample durations, mean number of sample responses, and mean number of side-key pecks for the various time and schedule requirements. As in Experiment 1, these data seem to indicate that differential responding to the side key does not depend entirely on the sample duration or response number.

GENERAL DISCUSSION

Experiment 1 supports the view that a bird's discrimination between response contingencies does not necessarily rely upon discriminating the passage of time or the number of responses emitted. When those cues were differential, however, discriminative performance was somewhat related to specific sample durations

Fig. 3. The mean number of test-stimulus (side-key) responses following the DRO (dashed lines) and DRL (solid lines) sample contingencies with varying time criteria in test sessions (Experiment 2). The circles represent data from the first test, the triangles data from the second test.

and response numbers. Thus, Lattal's conclusions about the basis for his subject's choice performance may be open to question, inasmuch as he did not report choice accuracy as a function of time or response numbers. Nevertheless, the differential performance following DRL and response-initiated DRO contingencies provides a convincing demonstration that birds can discriminate between response contingencies. These data are clearly in agreement with Lattal's general conclusions and should lay to rest any lingering concerns about

Table 2

Mean number of sample responses, sample seconds, and side-key pecks during test sessions for the various time and schedule requirements in Experiment 2.

	Crit (sec)	Sample		Side pecks	Sample		Side pecks
		Resp	Sec		Resp	Sec	
Bird 1139		DRO (S+)			DRL (S-)		
Test 1	1.25	1.9	39.2	17.3	2.5	123.5	4.1
	2.50	1.7	6.7	16.5	2.9	41.3	5.7
	5.00	2.8	16.7	17.3	3.0	45.1	4.1
	10.00	2.6	20.3	14.1	3.3	33.3	2.8
Test 2	0.34	2.1	3.6	17.5	3.0	17.9	1.9
	0.68	2.1	2.2	17.8	3.0	13.7	1.1
	1.25	2.1	22.0	17.7	3.0	14.5	2.2
	2.50	2.2	9.3	18.2	3.3	25.1	1.8
Bird 1167		DRO (S+)			DRL (S-)		
Test 1	1.25	1.3	8.6	16.4	2.1	18.2	6.7
	2.50	1.4	9.1	15.5	2.2	19.0	5.6
	5.00	1.3	11.7	17.6	3.1	38.4	6.9
	10.00	3.5	21.0	17.2	3.5	32.3	6.7
Test 2	0.34	1.0	7.3	16.8	2.0	52.4	6.1
	0.68	1.1	6.3	16.9	2.4	42.2	7.1
	1.25	1.2	8.6	16.7	2.2	45.5	4.4
	2.50	1.4	6.8	16.3	2.3	25.3	5.4
Bird 1060		DRO (S-)			DRL (S+)		
Test 1	1.25	3.8	4.0	5.3	5.4	7.2	11.2
	2.50	7.7	9.4	5.6	8.5	9.4	10.7
	5.00	15.0	25.0	0.3	29.9	44.9	11.5
	10.00	39.4	93.1	3.1	61.9	134.9	8.4
Test 2	0.34	1.0	2.0	8.9	2.0	2.2	11.7
	0.68	1.6	1.8	6.2	2.9	2.8	11.3
	1.25	4.0	4.2	7.6	6.3	6.1	11.8
	2.50	13.8	15.4	5.2	16.6	18.6	11.4

the role of sample time and response numbers as artifactual cues for correct responding.

Experiment 1 also showed that after extended training on two different response-reinforcer contingencies, some characteristic of the two schedules exerted stimulus control over side-key responding even though the temporal requirements of the schedules were modified to make the DRO schedule more closely resemble the DRL schedule.

Experiment 2 replicated the general results of Experiment 1, and also illustrated that the stimulus control observed in Experiment 1 was not specific to response-reinforcer relationships, but also to response-stimulus relations, since the birds exhibited similar levels of stimulus control in the two experiments.

A strict description of the sample contingencies reveals that the primary difference between the response-initiated DRO and the DRL contingencies was simply one of delay

of reinforcement. The DRL contingency involves an immediate food presentation, whereas the DRO involves a 10-s (and later 5-s) delay of reinforcement. Thus, one might argue, the differential performance is due to a discrimination of the duration of the delay of reinforcement. However, if the birds were indeed sensitive to the delay of reinforcement, varying that delay, as in the test sessions of both Experiment 1 and Experiment 2, should have produced gradual and orderly changes in differential performance as a function of the duration of the delay. This assumption is based partly on Reynolds' (1966) work. Here, a red response key was presented, and after two responses, the key color was changed to blue; the birds were reinforced for responding to the blue key if the interval between successive responses on the red key had been greater than 18 s, and were not reinforced otherwise. The rate of responding on the blue key was related to the duration of the preceding interval, suggesting a smooth gradient on the dimension of time. Killeen's (1978) work, described earlier, also suggests that a delay-of-reinforcement account would have predicted a more pronounced gradient over the range of delays tested in the present work.

The delay-of-reinforcement hypothesis is attractive because it provides a simple and straightforward mechanism by which an animal can detect whether environmental events were produced by its own behavior, and would seem to be the mechanism predicted by Killeen's (1978) results: Immediate or near-immediate events are attributable to an animal's own behavior, whereas events more temporally distant are attributable to other causes. These experiments provide scant evidence to support the hypothesis, however. When the response-reinforcer relation "immediate reinforcement" (the DRL contingency) was S- (Birds 1446, 1139, and 1167), the birds differentiated S+ from S- regardless of the delay involved during the test session, but when "delayed reinforcement" (the DRO contingency) was S- (Birds 1453, 47, and 1060), very short delays were not as well discriminated from immediate reinforcement. Thus, a slight temporal gradient was observed only when the DRO contingency was S-.

If the delay-of-reinforcement hypothesis is true, then the differential responding after DRL and very short DRO trials would seem

to imply that the previous training with DRL and 10-s or 5-s DRO trials established stimulus control that generalized across a very wide range of delay intervals. This would seem unlikely, given the usual results of studies on generalization of stimulus control. That there was differential side-key responding does imply that stimulus control could also have been exerted by some special aspect of either the immediate or the delayed reinforcement contingencies that cannot be simply described as temporal contiguity, response number, or stimulus duration. The salient features of a response-reinforcer relation that remain to be specified may involve the bird's physical position at the time of reinforcement, nondifferential response-produced feedback from individual responses, and the role of any other behavior the bird might exhibit during inter-reinforcement or interresponse intervals.

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