

REINFORCEMENT CONTINGENCIES AS DISCRIMINATIVE STIMULI¹

KENNON A. LATTAL

WEST VIRGINIA UNIVERSITY

A matching paradigm was used to examine the discriminative properties of two different reinforcement contingencies. Responding according to either a differential-reinforcement-of-low-rate or a differential-reinforcement-of-other-behavior schedule produced a choice situation in which each of two keys was illuminated with a unique color. The correct choice response was defined by the contingency that was met to produce the choice. Eighty to 100% correct matching was obtained and recovered during two reversals of the choice stimuli. Introduction of a delay between completion of the reinforcement contingency and presentation of the choice stimuli resulted in decrements in matching performances similar to those obtained when other types of sample stimuli are used. The results provided evidence of the discriminative properties of the relation between behavior and other classes of stimuli.

Reinforcement contingencies specify the relations among responses and discriminative and reinforcing stimuli. The analysis of reinforcement contingencies as they directly contribute to the control of a number of behavioral processes has been an important facet of psychological research. In addition to controlling behavior directly, such contingencies may also affect behavior by serving as discriminative stimuli. The discriminative properties of the relation between behavior and stimuli are important in several recent accounts of learned behavior (*e.g.*, Maier, Seligman, and Solomon, 1969; Rescorla, 1967). Rescorla (1967) suggested that the appropriate control in respondent conditioning was "one in which the animal is taught that the CS is irrelevant to the US (p. 76)". Thus, the respondent conditioning paradigm and its proper control were conceptualized as conditions in which the organism learns to discriminate the presence, or absence, of a close consistent temporal relationship between the conditioned and unconditioned stimulus.

Other investigators (Appel and Hiss, 1962;

Staddon and Simmelhag, 1971, p. 21) have suggested that animals receiving response-independent reinforcers can distinguish between reinforcers that have a variable temporal relation to responding (*i.e.*, are response-independent) and those that have a fixed and close temporal relation to responding (*i.e.*, are response-dependent). One index of the discriminative properties of the relation between behavior and other stimuli is one in which the different relations control different responses that are not maintained by the contingencies under investigation. The present experiment examined the discriminative properties of the relation between behavior and its consequences by using a matching paradigm in which the emission and omission of a key-peck response were the discriminative stimuli for choice responses.

METHOD

Subjects

Two adult White Carneaux pigeons were maintained at approximately 80% of free-feeding weights.

Apparatus

Three translucent plastic response keys and a Gerbrands grain magazine were located on one wall of an operant-conditioning chamber with inside dimensions of 31 by 32 by 39.5 cm. The keys were separated by 9.0 cm and were 25.5 cm from the floor of the chamber. Each could be operated by a force of approximately

¹This research and the manuscript preparation were respectively supported by a NIMH post-doctoral fellowship to the author at the University of California, San Diego and a faculty research grant from West Virginia University. I thank Dr. G. S. Reynolds for his support and for providing the facilities and equipment used in this experiment and Dr. Paul Weisberg for his helpful comments on the manuscript. Reprints may be obtained from the author, Department of Psychology, West Virginia University, Morgantown, West Virginia 26506.

0.14 N. The center key was transilluminated by a yellow stimulus light and the keys on either side of the center key were transilluminated by red or green stimulus lights. The food magazine, located behind an aperture 14 cm below the center key, provided 3-sec access to grain. General chamber illumination was provided by a 7-W, 110-V ac bulb. A continuously operating ventilating fan and white noise were used to mask extraneous noise. Standard electromechanical control and recording equipment were located in an adjacent room.

Procedure

After the birds were trained to peck all three keys, a modified matching-to-sample procedure was introduced. At the beginning of each trial, the center key was yellow and the two side keys were dark. During this sample component, one of two schedules of reinforcement for pecking the center key was in effect. In one of these, presentation of the choice stimuli was dependent upon the absence of key pecking for 10 sec (differential-reinforcement-of-other-behavior; DRO 10-sec). In the other, presentation of the choice stimuli was dependent upon the emission of a single key peck on the center key after a 10-sec period in which pecking did not occur (differential-reinforcement-of-low-rate; DRL 10-sec). These contingencies were selected in an attempt to equate, as closely as possible, the number of nonreinforced responses emitted and amount of time spent in each condition. These two response-reinforcer relations occurred an equal number of times in each daily session and were randomly presented on different trials.

When the contingency in effect in the presence of the yellow center key was completed, the choice component was initiated by turning off the yellow center-key light and, simultaneously, illuminating the two side keys (0-sec delay) (Cumming, Berryman, and Cohen, 1965). Red and green stimulus lights were randomly presented on the left and right response keys on different choice trials. If the DRL 10-sec requirement had been in effect during the sample component, a single response on the red side-key resulted in 3-sec access to the grain reinforcer. If the DRO 10-sec requirement had been in effect during the sample component, a single response on the green side-key produced 3-sec access to the grain. Responses to the incorrect choice key produced a 15-sec

blackout period, during which all lights in the chamber were off. A new trial began immediately after a grain presentation or a blackout period. A correction procedure was used so that an incorrect response on the choice keys resulted in re-exposure to the same contingency in the sample component until a correct choice response occurred (*cf.* Blough, 1959). Each session was terminated after 80 (Bird 62) or 100 (Bird 54) reinforcements. Data from the first trial in each sequence were included in the analysis; data from the correction trials were not included. Pecks on dark keys did not produce either the choice component or access to grain. Such responses rarely occurred.

After 34 such training sessions, the choice stimuli were reversed. Under the reversal condition, a response on the red key produced grain if the DRO 10-sec schedule was in effect in the sample component and a response on the green key produced grain if the DRL 10-sec schedule was in effect in the sample component. A second reversal occurred 30 sessions after the first reversal.

The effects of imposing a delay between completion of the sample component and illumination of the choice keys were studied in the final condition. During the delay, all lights in the chamber were off and key-peck responses had no effect. Blackout durations of 0, 1.5, 3, 6, 12, 24, 36, 6, and 0 sec were studied in that order for both birds, except that the 36-sec blackout condition was omitted for Bird 54. Each delay value was in effect for 12 sessions.

RESULTS

Figure 1 shows that the two response-reinforcer relations controlled the choice responses of both birds in the presence of the red and green choice stimuli. Following both stimulus reversals, the percentage of correct responses gradually increased to the values observed during the preceding condition.

The contribution of several variables to the discriminative properties of the two schedules was examined. Each response in the presence of the yellow light produced an auditory stimulus (relay closure). It was possible that this stimulus controlled choice responding, since it consistently occurred when the DRL 10-sec requirement was met (*i.e.*, the key-peck response produced both the auditory stimulus and the component change) and never occurred when the DRO 10-sec requirement was met. The ses-

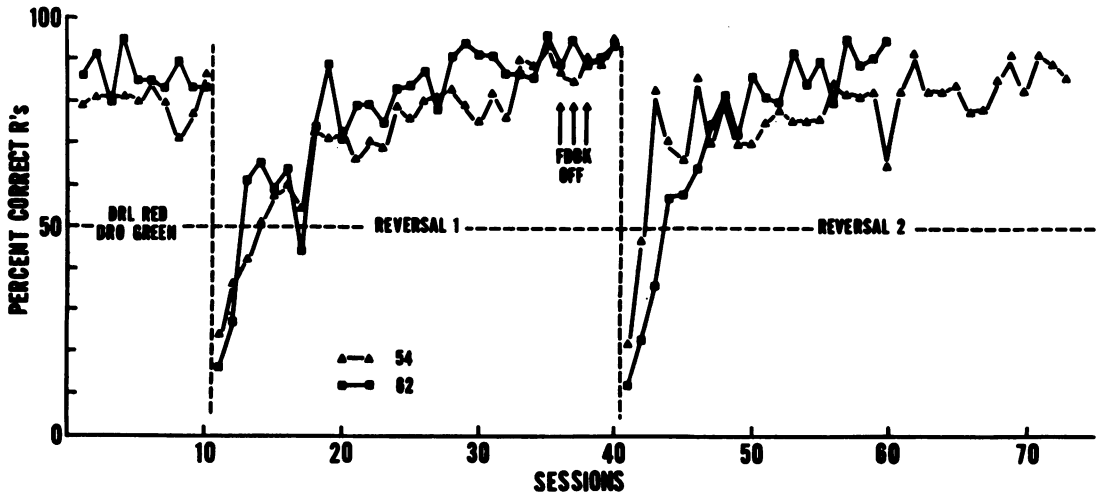


Fig. 1. Per cent correct responses for Birds 54 and 62 during successive sessions of the experiment. The last 10 sessions of the initial conditioning procedure and all sessions during the two stimulus reversals are shown. "Fdbk off" refers to removal of the auditory feedback click following each response on the center key.

sions in Figure 1 labelled "fdbk off", show that removal and re-instatement of the auditory stimulus had no effect on choice behavior.

Figure 2 shows several measures of performance in the sample component during the last five sessions of training and stimulus-reversal conditions. The top graph shows the mean number of responses emitted during the DRL and DRO schedules. Since a single key peck was required during each DRL schedule trial, and the omission of the key peck was required during each DRO trial, only responses that did not produce the change to the choice component were compared. Such a comparison shows that no systematic relation existed between the number of responses emitted during the two schedules in the sample component and the choice behavior shown in Figure 1. The middle graph shows that the amount of time spent in the DRL schedule was somewhat longer than the amount of time in the DRO schedule. Incorrect choices occurred approximately equally in DRL and DRO during the training and reversal conditions. Visual observations suggested that the latency from the onset of the choice component to the choice response was quite short following either schedule. Thus, the mean time per component may also be taken as an index of rate of positive reinforcement in the two schedules. The lower graph shows that overall response rates (total responses in each schedule/total time in each schedule) were consistently higher during the DRL schedule.

There was a general decrease in the per cent of correct responses, with increasingly longer delay intervals between completion of the requirement on the center key and presentation of the choice keys (Figure 3). Relatively accurate matching was maintained in Bird 54 through the 6-sec delay interval, but the accuracy of Bird 62 began to decline with introduction of the 1.5-sec delay interval. Visual observation of Bird 54 revealed the development of a stereotyped behavior pattern during the delay interval. When the yellow light was illuminated, the bird would position itself at the rear of the chamber. If DRO was in effect in the sample component, the bird was observed in the choice component to be at this location at the end of the delay interval. If DRL was in effect in the sample component, the bird would remain at the rear of the chamber until approximately 10-sec had elapsed in the first component and would then move toward the work panel and emit a response. After the delay interval, the bird was observed to be consistently in close proximity to the work panel.

Figure 4 shows the conditional probabilities of pecking the correct key in the choice component, given the DRL contingency on the center key in the sample component, $P(\text{DRL}|\text{DRL})$, and of pecking the incorrect key in the choice component, given the DRO contingency in effect in the sample component, $P(\text{DRL}|\text{DRO})$. Each data point is the mean of the last five sessions at each delay value. During the last sessions of the second reversal (0-sec delay), choice

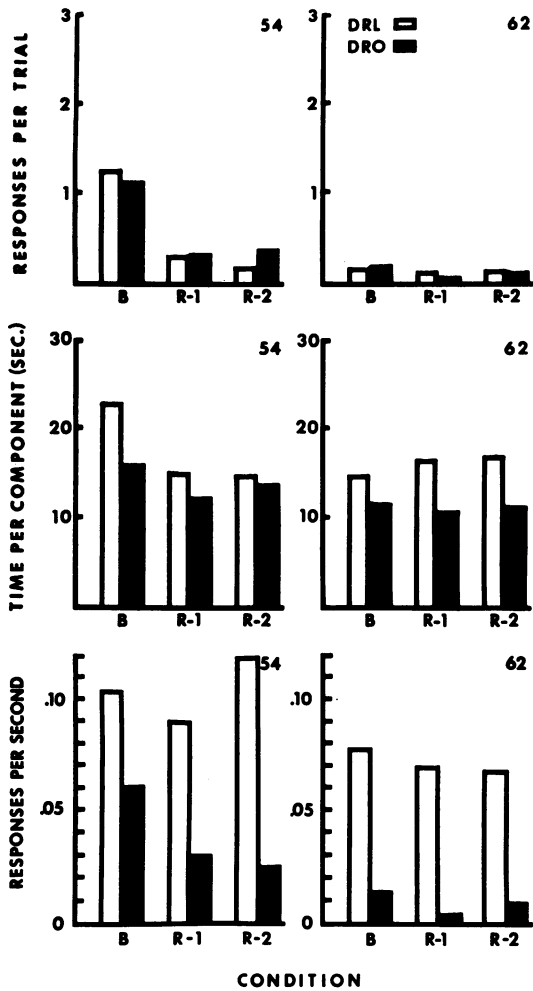


Fig. 2. Mean responses per trial, mean number of seconds per trial (component), and mean number of responses per second per trial during the last five sessions of the baseline (B) and stimulus-reversal conditions (R-1 and R-2) during DRL and DRO trials for Birds 54 and 62 are respectively shown in the top, middle, and lower graphs.

responses were accurate, as indicated by the distance of the points above the positive diagonal. Color preferences were minimal, as indicated by the proximity of the data points to the negative diagonal (Rilling and McDiarmid, 1965). With increasing delays, color preference increased somewhat as accuracy decreased. Preferences for the right- or left-side keys were also calculated. Preference for a side key was never great; but both birds showed a small increase in preference for the right key as the delay interval increased.

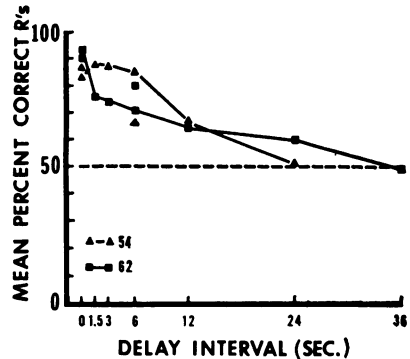


Fig. 3. Mean per cent correct choice responses for DRL and DRO trials during the last five sessions at each delay interval. The data points connected by lines indicate the increasing duration sequence (0 sec to 24 or 36 sec) and the unconnected points indicate the decreasing duration sequence (36 or 24 sec to 0 sec).

DISCUSSION

The temporal relation between a key-peck response and illumination of the side keys controlled choice responses. Previous research has shown that different values of a fixed-ratio schedule and different numbers of responses can discriminatively control choice behavior (Pliskoff and Goldiamond, 1966; Rilling, 1967; Rilling and McDiarmid, 1965). The present use of two different contingencies for presentation of choice stimuli extends information about the discriminative properties of behavior to include different reinforcement contingencies, as well as different values of the same reinforcement schedule. These results agree with the previously described suggestions of Rescorla (1967) and of Maier *et al.* (1969) concerning the discriminative properties of the relation between behavior and other stimuli.

Appel and Hiss (1962) found a difference in response rates of pigeons trained on a multiple schedule when positive reinforcers were delivered at 4-min intervals independently of responding in the presence of one stimulus (FT 4-min schedule) and were delivered after the first response after 4 min in the presence of another stimulus (FI 4-min). The consistently higher response rates in the fixed-interval condition were offered as evidence that the different response-reinforcer relations were discriminative stimuli. Lattal (1973) systematically replicated the Appel and Hiss (1962) results with rats, but also found that response rates in the two schedules were indistinguishable when identical exteroceptive stimuli were associated

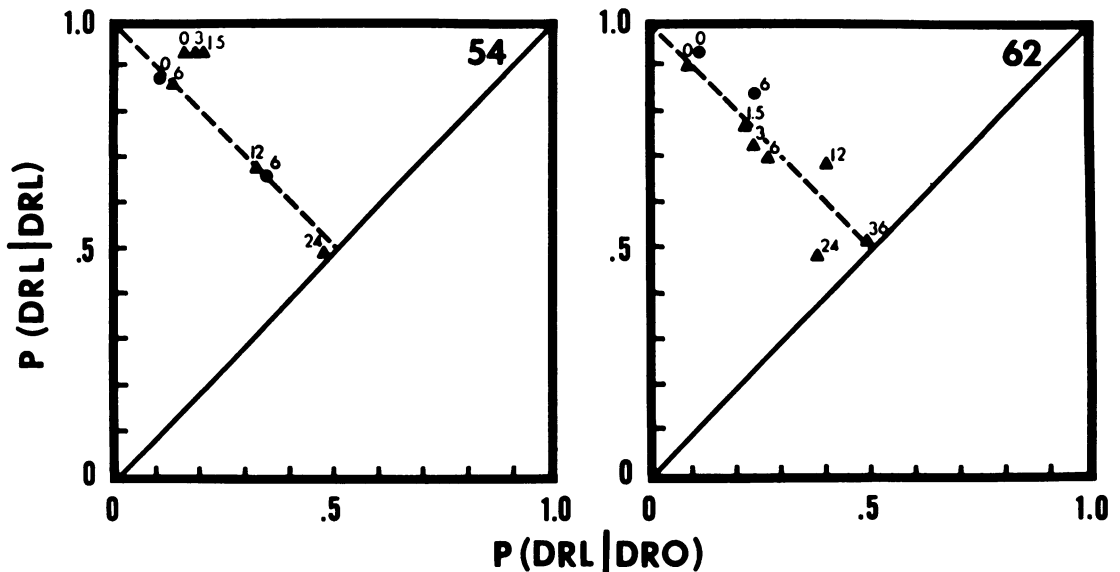


Fig. 4. Probability of a peck on the DRL choice key (red key), given a DRL or a DRO trial at each delay duration. The number above each data point is the delay duration in seconds. Triangles indicate the increasing duration sequence (0 sec to 24 or 36 sec) and circles indicate the decreasing duration sequence (36 or 24 sec to 0 sec). All points are based on the mean of the last five sessions at each condition.

with response-dependent and response-independent reinforcer delivery. It was suggested that response rates in the presence of the different multiple-schedule stimuli were an inappropriate index of the discriminative stimulus properties of the response-reinforcer relation. Since Appel and Hiss' measure of discriminative stimulus properties (response rates) could not be separated from the direct control of responding by the different response-reinforcer relations, independently of their own stimulus properties, the interpretation was equivocal. The present data, based on an independent index of discrimination, support the earlier suggestion of Appel and Hiss (1962) and of Staddon and Simmelhag (1971) that different temporal relations between a response and a stimulus are discriminable events.

Several parameters related to the peck/no-peck contingencies, and the resulting behaviors controlled by them, may be implicated in the discriminative control of the choice responses in this experiment. Whether response-rate differences of the magnitude observed during the two schedules, or the differences in reinforcement frequency suggested in Figure 2, can serve as discriminative stimuli remains an open question. This and the previously cited studies of schedule discrimination confounded response rate and reinforcement frequency by

the nature of the schedules used, precluding an analysis of the relative contribution of these two variables. Fantino (1968) reported that only one of three subjects consistently discriminated schedules that required high and low response rates for reinforcement. As Fantino observed, however, the evidence for rate discrimination was based only on response-rate differences during the two schedules, and not upon an independent index of discrimination as suggested above. Rilling (1967) presented data suggesting that the number of responses emitted was an important variable in controlling choice in a related matching task. The data in Figure 2 showed that the number of excess responses emitted in each schedule was approximately equal, and thus did not systematically contribute to the discriminative performance. Previous experiments have also shown that different temporal durations can serve as discriminative stimuli (*e.g.*, Stubbs, 1968). Temporal durations may have contributed to the present results, since during the initial baseline and the two reversals, the time in DRL was somewhat longer than that in DRO. Responding in all zero-delay conditions typically did not occur until after a minimum of 10-sec had elapsed after illumination of the center key. If, after the 10-sec interval the choice stimuli were not presented as a result of

the omission of responding, then a response was emitted. This pattern of behavior seems to account for the different amounts of time spent in DRL and DRO trials shown in Figure 3. It should be noted that with Bird 54 (R-2), a mean difference of approximately 1 sec between DRO and DRL trials was found while discriminative control of choice behavior was maintained. This difference is less than the just-noticeable difference for temporal stimuli in the range of temporal durations observed in this experiment (Stubbs, 1968).

The delayed-matching data further suggest the similarity of the stimulus properties of different reinforcement contingencies to other types of stimuli that can control behavior (Blough, 1959; Pliskoff and Goldiamond, 1966). Utilizing different rates of flicker of a light as the stimulus to control delayed-matching-to-sample performance of pigeons, Blough (1959) described a pattern of behavior during the delay intervals that resembled the behavior of Bird 54 during the delay intervals in the present experiment.

Investigations of the control of behavior by reinforcers delivered independently of responding have attributed such control to the response-eliciting properties of the positive reinforcer (Rescorla and Skucy, 1969) and to the action of adventitious temporal proximity of the response and the delivery of the reinforcer (Herrnstein, 1966). The delivery of response-independent reinforcers implies a variable relation between responding and their delivery, *i.e.*, reinforcers occur along a continuum of temporal proximity to responses, with some temporally close to a response and others temporally removed from a response. The present experiment may be taken as a model of performance in which the response-reinforcer relation was dichotomized by requiring a response either to precede immediately the illumination of the choice keys or to be omitted for a period of time before illumination of the keys. One consideration arising from Herrnstein's analysis, and supported by these data, is that the responding in the presence of response-independent reinforcers may reflect in part a failure to discriminate the independence of responding and reinforcer delivery. Utilizing a procedure similar to the one employed in the present experiment, it might be possible to investigate more extensively the discriminative properties of the response-reinforcer rela-

tionship and its contribution to maintained behavior in the presence of response-independent reinforcers.

REFERENCES

- Appel, J. B. and Hiss, R. H. The discrimination of contingent from non-contingent reinforcement. *Journal of Comparative and Physiological Psychology*, 1962, **55**, 37-39.
- Blough, D. S. Delayed matching in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1959, **2**, 151-160.
- Cumming, W. W., Berryman, R., and Cohen, L. R. Acquisition and transfer of zero-delay matching. *Psychological Reports*, 1965, **17**, 435-445.
- Fantino, E. Effects of required rates of responding on choice. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 15-22.
- Herrnstein, R. J. Superstition: a corollary of the principles of operant conditioning. In W. K. Honing (Ed.), *Operant Behavior: areas of research and Application*. New York: Appleton-Century-Crofts, 1966. Pp. 33-51.
- Lattal, K. A. Response-reinforcer dependence and independence in multiple and mixed schedules. *Journal of the Experimental Analysis of Behavior*, 1973, **20**, 265-271.
- Maier, S. F., Seligman, M. E. P., and Solomon, R. L. Pavlovian fear conditioning and learned helplessness: effects on escape and avoidance behavior of (a) the CS-US contingency and (b) the independence of the US and voluntary responding. In B. A. Campbell and R. M. Church (Eds.), *Punishment and aversive behavior*. New York: Appleton-Century-Crofts, 1969. Pp. 299-342.
- Pliskoff, S. S. and Goldiamond, I. Some discriminative properties of fixed-ratio performance in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 1-9.
- Rescorla, R. A. Pavlovian conditioning and its proper control procedures. *Psychological Review*, 1967, **74**, 71-80.
- Rescorla, R. A. and Skucy, J. C. Effect of response-independent reinforcers during extinction. *Journal of Comparative and Physiological Psychology*, 1969, **67**, 381-389.
- Rilling, M. Number of responses as a stimulus in fixed interval and fixed ratio schedules. *Journal of Comparative and Physiological Psychology*, 1967, **63**, 60-65.
- Rilling, M. E. and McDiarmid, C. G. Signal detection in fixed-ratio schedules. *Science*, 1965, **148**, 526-527.
- Staddon, J. E. R. and Simmelhag, V. L. The "superstition" experiment: a reexamination of its implications for the principles of adaptive behavior. *Psychological Review*, 1971, **78**, 3-43.
- Stubbs, A. The discrimination of stimulus duration by pigeons. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 223-238.

Received 25 February 1974.
(Final Acceptance 30 October 1974.)