

THE RESPONSE-REINFORCEMENT DEPENDENCY IN FIXED-INTERVAL SCHEDULES OF REINFORCEMENT¹

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Pigeons were exposed to four different schedules of food reinforcement that arranged a fixed minimum time interval between reinforcements (60 sec or 300 sec). The first was a standard fixed-interval schedule. The second was a schedule in which food was presented automatically at the end of the fixed time interval as long as a response had occurred earlier. The third and fourth schedules were identical to the first two except that the first response after reinforcement changed the color on the key. When the schedule required a peck after the interval elapsed, the response pattern consisted of a pause after reinforcement followed by responding at a high rate until reinforcement. When a response was not required after the termination of the interval, the pattern consisted of a pause after reinforcement, followed by responses and then by a subsequent pause until reinforcement. Having the first response after reinforcement change the color on the key had little effect on performance. Post-reinforcement pause duration varied with the minimum interreinforcement interval but was unaffected by whether or not a response was required after the interval elapsed.

A fixed-interval (FI) schedule of reinforcement reinforces the first response after an interval of time has elapsed since some event, usually the termination of the preceding reinforcement. Fixed-interval schedules characteristically generate a pause after each reinforcement (the post-reinforcement pause) that is followed by an acceleration to a high rate of responding until the next reinforcement.

The average duration of the post-reinforcement pause increases with the FI value (Sherman, 1959). Several recent studies have sought to identify the features of FI schedules responsible for post-reinforcement pause durations and response rates after the post-reinforcement pause is terminated (running rates). The procedures used in these studies allowed the experimenter to manipulate the response rates just before the reinforced response without changing the amount of time between reinforcements. These procedures included imposing a brief blackout after each unreinforced response (Neuringer and Schneider, 1968), requiring a minimum pause between the reinforced response and the preceding re-

sponse (Farmer and Schoenfeld, 1964), and requiring a small fixed ratio after the interval elapsed (Killeen, 1969). Although these operations changed response rates after the post-reinforcement pause terminated, they had virtually no effect on post-reinforcement pause durations. Apparently the dependencies arranging that certain response rates prevail at the moment of reinforcement determine how fast the animal responds after the post-reinforcement pause terminates. However, the duration of the post-reinforcement pause seems to be independent of these dependencies and to be determined by the amount of time between reinforcements.

By requiring a response after the interval elapses to produce reinforcement, FI schedules necessarily specify the response that immediately precedes reinforcement. The present paper considers the possibility that specifying the response-reinforcement dependency may be important for determining response rates after the post-reinforcement pause terminates but irrelevant for determining post-reinforcement pause duration. The logic of the experiment was to compare post-reinforcement pause duration and running response rates obtained under FI schedules with equivalent performance measures obtained under a schedule that provided reinforcement automatically at the end of a fixed time interval as long as a response had occurred earlier during

¹This research was supported by Grant #MH-11917 from the Public Health Service (NIMH) to Arizona State University, Dr. S. S. Pliskoff, principal investigator and by a grant from the UNC-G Research Council. Reprints may be obtained from the author. Department of Psychology, University of North Carolina at Greensboro, Greensboro, North Carolina 27412.

the interval. Thus, once the post-reinforcement pause had been terminated, no particular response was required subsequently for reinforcement. This latter schedule is similar to an FI schedule in requiring a response and an elapsed time interval for reinforcement. However, since the schedule made reinforcement depend on a response and the termination of a time interval without regard to order, the schedule may be designated a conjunctive fixed-ratio fixed-time (*conj* FR FT) schedule (Powers, 1968; Zeiler, 1968). Powers (1968) studied the effect of *conj* FR FT schedules on overall response rate, but did not report data on post-reinforcement pause durations and running response rates.

Additionally, the present study examined the effects of more clearly differentiating the post-reinforcement pause from the period after the termination of the post-reinforcement pause until the next reinforcement. This was done by having the first response after reinforcement change the prevailing exteroceptive stimuli. Thus, the experiment studied FI and *conj* FR 1 FT schedules in which the key color remained the same throughout the interreinforcement interval and the first response after reinforcement changed the key color.

METHOD

Subjects

Two adult male Silver King pigeons obtained from Palmetto Pigeon Plant were maintained at approximately 80% of their free-feeding weight. Both had previous experience with fixed-interval and variable-interval schedules of food reinforcement.

Apparatus

The experimental chamber was enclosed in an ice chest. A ventilation fan provided masking noise. A translucent plastic response key was mounted 8.5 in. (22 cm) above the floor behind a 0.75 in. (2 cm) diameter hole through one wall of the chamber. The key could be transilluminated by either a blue or red light. When the key was transilluminated, a force exceeding 20 g (0.18 N) applied to the key broke an electrical contact that operated control and recording circuits and also produced a click by activating a relay mounted behind the front wall of the chamber. The key was disconnected from the control circuit when

darkened. The reinforcing event was a 5-sec presentation of mixed grain which was accessible through an opening below the key. When grain was available, the feeder opening was illuminated and the key darkened. The key light and the feeder light were the only sources of illumination in the chamber. Power for the key light was obtained from a transformer isolated from the main power supply.

Procedure

Because of their prior training, the birds did not need preliminary key training. The experiment employed four different reinforcement schedules that arranged reinforcement opportunity at fixed time intervals from the termination of the preceding reinforcement.

(A) The first condition was a standard FI schedule. The first response after a fixed interval of time had elapsed was followed immediately by food. The color on the key was blue throughout the session except during reinforcement.

(B) The second procedure was implemented to study the effects of not requiring a response after the interval elapsed. With this procedure, if a key peck occurred before the end of the interval, food was presented automatically at the end of the interval regardless of responding after the termination of the post-reinforcement pause. If the interval had timed out before the post-reinforcement pause had been terminated, the termination of the post-reinforcement pause was followed immediately by food. The color on the key was blue throughout the session except during reinforcement. This procedure permitted a substantial delay to occur between a key peck and reinforcement.

(C) The third condition arranged a standard FI schedule with the additional feature that the first response after reinforcement changed the color on the key from blue to red. Thus, the key was blue during the post-reinforcement pause and red following the termination of the post-reinforcement pause until the next reinforcement.

(D) The fourth condition was the same as Condition B with the additional feature that the blue and red key colors were correlated with the periods before and after the post-reinforcement pause terminated. Thus, the first response after reinforcement changed the key color from blue to red and food was presented at the end of the fixed time interval

timed from the termination of the preceding reinforcement regardless of responding while the key was red. If the post-reinforcement pause exceeded the fixed-interval, the response that terminated the post-reinforcement pause produced food immediately.

Each of these schedules was studied with the minimum interreinforcement interval set at 300 sec. Also, two of the schedules were studied with the minimum interreinforcement interval set at 60 sec. These latter two schedules were the standard FI 60-sec schedule (Condition E) and the schedule in which a response was not required after the 60-sec interval had elapsed and in which the first response after reinforcement changed the key color (Condition F).

Daily sessions terminated automatically after the sixty-first reinforcement. Data were not recorded in a session until after the first reinforcement. From 15 to 35 sessions were allowed for stabilization at each condition. Two determinations were made with the standard FI 300-sec schedule and with the standard FI 60-sec schedule. Specifically, the various conditions were scheduled in the following sequence, where the letters correspond to the conditions described above. The numbers in parentheses indicate the number of sessions devoted to each condition: E (35), A (30), B (20), A (15), C (25), D (20), F (20), E (15).

RESULTS

Figure 1 presents representative cumulative records from each of the experimental conditions for P1. The records were selected from one of the last five sessions of a condition. The two conditions in which a response was required after the FI had elapsed (records A and C) produced qualitatively similar response patterns consisting of a post-reinforcement pause and responding at a high rate after the post-reinforcement pause terminated. In one condition (record A), the first response did not change the key color; in the other condition (record C) it did. The two conditions that did not require a response after the interval had elapsed if a response had occurred earlier (records B and D) generated response patterns consisting of a pause after reinforcement, responding, and a second pause until reinforcement. When the first response after reinforcement did not change the key color (record B),

the record for P1 appeared more erratic than when the first response after reinforcement did change the key color from blue to red (record D).

The records from the two conditions with the interval set at 60 sec paralleled the effects noted with the interval set at 300 sec. When the schedule did not require a response after the interval elapsed and when the first response changed the color on the key, the response pattern consisted of a pause, a response, and a subsequent pause (record F). The standard FI 60-sec schedule (record E) produced characteristic break-and-run patterns.

The cumulative records for P2 in Fig. 2 are essentially similar to those for P1. For both birds, characteristics of the response pattern appeared to depend more on whether or not a response was required after the interval had elapsed than on whether the first response after reinforcement changed the key color.

Figure 3 permits more detailed comparisons of the effects of the various conditions on response rates after the post-reinforcement pause terminated (running rate) and on post-reinforcement pause duration. All data in Fig. 3 represent median values based on the last five sessions under a particular condition. Running rates (top panel) were much higher when a response was required after the end of the interval than when a response was not required, regardless of whether the first response after reinforcement changed the key color (compare A with B and C with D) and regardless of the minimum interreinforcement interval (compare E with F). Running rates were consistently low for those conditions in which a response was not required after the interval had elapsed (conditions B, D, and F). For P1, however, running rates were higher when the first response did not change the key color than when it did (for P1 compare B with D).

With the minimum interreinforcement interval set at 300 sec, median post-reinforcement pause durations (bottom panel) ranged from 141 sec to 188 sec for P1 and from 152 sec to 219 sec for P2. When the first response after reinforcement did not change the key color, post-reinforcement pause durations increased when the requirement that a response occur after the interval elapsed was eliminated (A to B). The equivalent change for the condition in which there was a key color change produced virtually no change in post-rein-

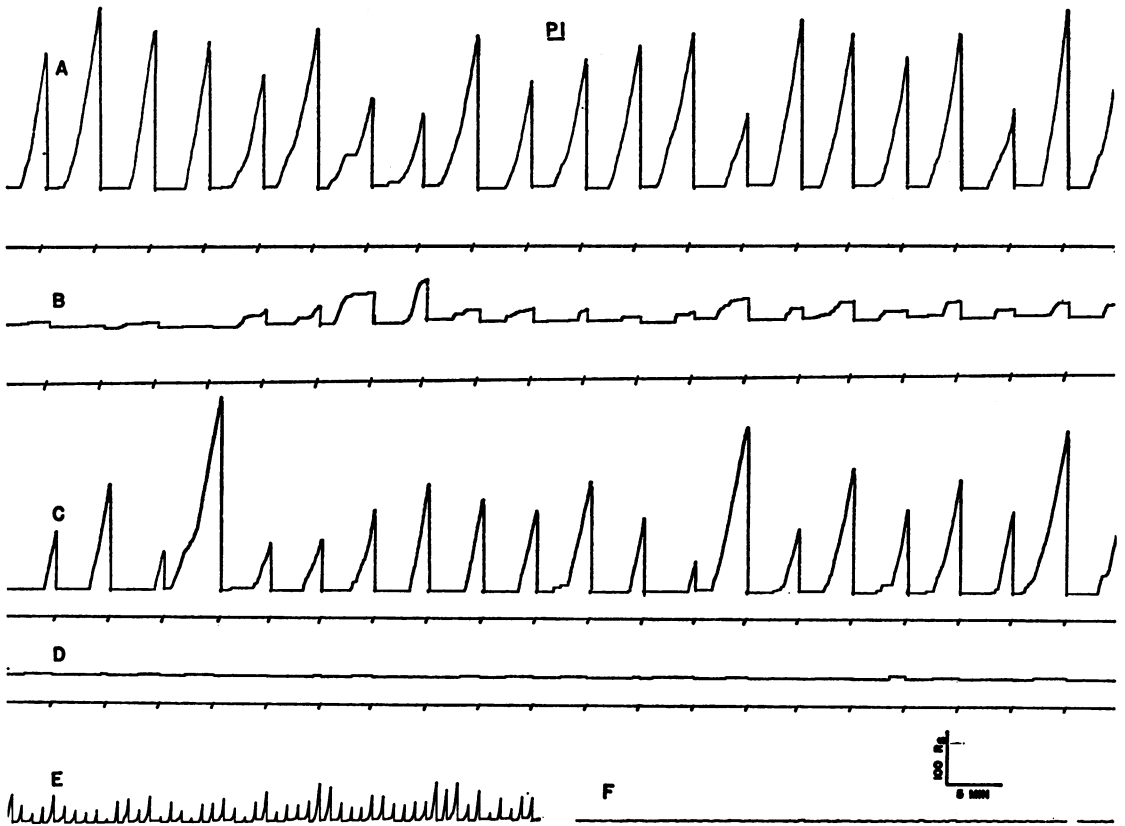


Fig. 1. Representative cumulative record strips for P1. Records were selected from one of the final five sessions under a condition. Reinforcement opportunity is indicated by the downward deflection of the lower event pen. Reinforcement delivery is indicated by resetting the stepping pen. Record A—No key color change; response required after end of 300-sec interval (standard FI 300-sec). Record B—No key color change; no response required after end of 300-sec interval. Record C—First response after reinforcement changed key color; response required after end of 300-sec interval. Record D—First response after reinforcement changed key color; no response required after end of 300-sec interval. Record E—No key color change; response required after end of 60-sec interval (standard FI 60-sec). Record F—First response after reinforcement changed key color; response not required after end of 60-sec interval.

forcement pause duration (C to D). These latter two conditions produced post-reinforcement pause durations only slightly longer than were produced by the standard FI 300-sec schedule.

When the interval was shortened to 60 sec, post-reinforcement pause durations decreased to approximately 30 sec. Post reinforcement pause durations were approximately equal under the two 60-sec interval conditions, despite large differences in response rate.

For post-reinforcement pause duration, re-determined values closely approximated initial values. There were larger discrepancies between initial and second determinations for running rates.

In general, running rates were most corre-

lated with the presence or absence of requiring a response after the interval elapses. Post-reinforcement pause durations were most clearly correlated with the minimum interreinforcement interval.

DISCUSSION

How fast the pigeons pecked the key after termination of the post-reinforcement pause depended on whether or not a key peck was required after the interval elapsed. These observations support the data reported by Powers (1968) with schedules similar to those used here. How long the pigeon paused after reinforcement before pecking the key did not depend on whether or not a key peck was re-

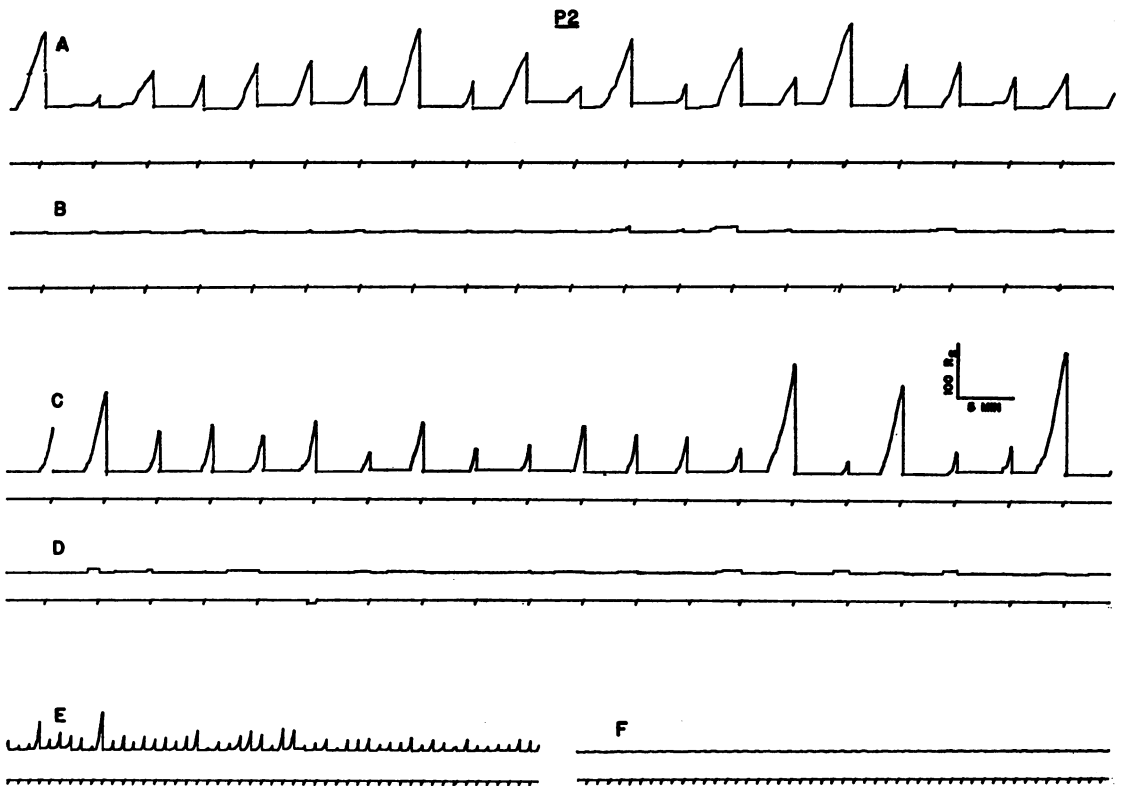


Fig. 2. Representative cumulative record strips for P2. Same condition code as in Fig. 1.

quired after the interval elapsed. Instead, the interreinforcement interval appeared to control the duration of the post-reinforcement pause. Considering the response pattern in more detail, when the schedule required a peck after the interval elapsed, the pattern consisted of a pause after reinforcement followed by a rapid acceleration to a high and essentially constant response rate until reinforcement. When a peck was not required after the interval had elapsed, the running response rates were low. Moreover, the few responses that did occur were clustered around the middle of the interreinforcement interval. Thus, the pattern consisted of a pause, a response or group of responses and a subsequent pause until reinforcement. Most likely, the secondary pause resulted from some behavior other than key pecking being strengthened by an adventitious correlation with reinforcement (Skinner, 1948; Herrnstein, 1966; Powers, 1968; Zeiler, 1968). Correlating a different key color with the post-reinforcement pause and the post-pause portion of the interreinforcement interval seemed to have little effect on

the response patterns. These data extend the functional independence of the post-reinforcement pause and responding after termination of the post-reinforcement pause that was suggested by the findings of Farmer and Schoenfeld (1964), Neuringer and Schneider (1968), and Killeen (1969). Such data are especially consistent with suggestions that the performance on FI schedules consists of two behavioral states (Sherman, 1959; Schneider, 1969). According to this analysis, the interreinforcement interval controls the duration of the first state (the post-reinforcement pause) and the responding that prevails at the moment of reinforcement determines the rate and topography of responding in the second state.

The observation that one set of variables controls the initiation of responding in a FI schedule and another set of variables controls responding once initiated has parallels in other situations. For example, Drew (1939) and Zeaman (1949) found that a number of factors affected the tendency to start running in a straight alley but did not affect the speed of running once started.

As Dews (1969, P. 191) observed recently, most systematic attempts to account for the patterns of responding engendered by schedules of reinforcement "have sought to explain all the effects of schedules in terms of the characteristics of responding at the moment

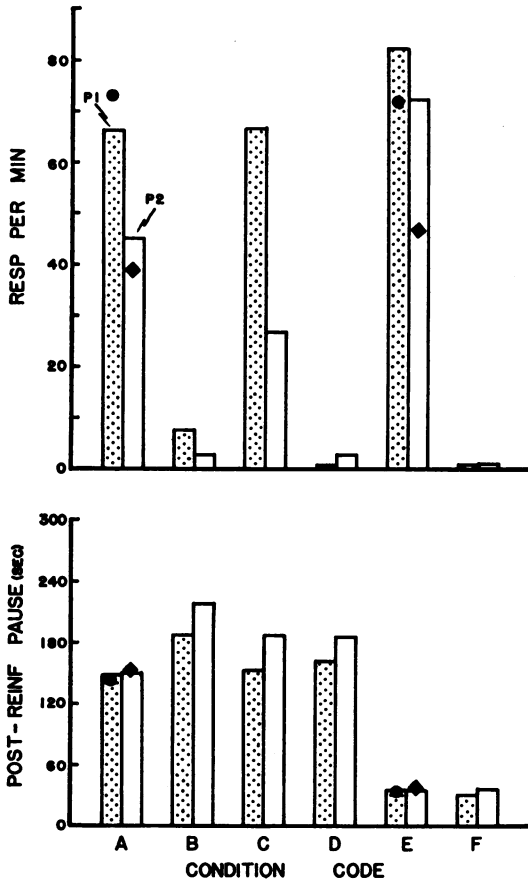


Fig. 3. Running rates (top panel) and post-reinforcement pause duration (bottom panel) for each experimental condition. The heights of the bars indicate median values, based on the last five sessions of a condition, from initial determinations. The closed symbols indicate median values from second determinations. Running rates were computed by dividing the number of responses made after termination of the post-reinforcement pause by the session time minus post-reinforcement pause time. Condition Code: A—No color change; response required after end of 300-sec interval (standard FI 300-sec). B—No key color change; no response required after end of 300-sec interval. C—First response after reinforcement changed key color; response required after end of 300-sec interval. D—First response after reinforcement changed key color; no response required after end of 300-sec interval. E—No key color change; response required after end of 60-sec interval (standard FI 60-sec). F—First response after reinforcement changed key color; response not required after end of 60-sec interval.

of reinforcement . . .". However, recent studies have revealed that significant features of the response pattern maintained by FI schedules are independent of the response rates just before reinforcement (Dews, 1969) and are even independent of the response-reinforcement dependency (Zeiler, 1968). These investigations were mainly concerned with the general pattern of accelerated response rates throughout the interreinforcement interval. The studies that have been more specifically concerned with post-reinforcement pause duration and post-pause response rate (including the present study) also demonstrate the inadequacy of theories of FI performance that consider only the responding just before reinforcement.

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Received 22 December 1969.