POSITIVE REINFORCEMENT AND THE ELIMINATION OF REINFORCED RESPONSES[1]

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Key pecking was maintained on a fixed-interval schedule while either a differential-reinforcement-of-not-responding or a fixed-time schedule was imposed simultaneously. The lower the time parameter of the not-responding schedule, the lower was the response rate. Similar effects occurred with the fixed-time schedule, if the pigeons had experience with reinforcement for not responding. Otherwise the effects were less orderly, to the extent that rate could reach maximum with the lowest-valued fixed-time schedule. The not-responding and the response-independent schedules had similar effects on rate in experienced pigeons only when the time parameter or nominal frequency of food presentation was considered. When considered in terms of obtained frequency of food presentation, reinforcement of not responding produced larger decrements in rate than did the fixed-time schedule.

Key words: response elimination, conjoint schedules, DRO schedules, fixed-time schedules, fixed-interval schedules, reinforcement frequency, experimental history, key pecks, pigeons

Positive reinforcement can eliminate responses. Skinner (1938, pp. 160-163) showed that if a rat first was given food for bar pressing and then only whenever a press had not occurred for 15 sec, the initially high response rate declined rapidly. Konorski (1967) reported that dogs given food only when one of their legs was not lifted would actively resist having their leg raised. In both Skinner's and Konorski's experiments, not emitting a certain response was the occasion for food delivery, and the response decreased in frequency. In subsequent research, the essential procedure, like Skinner's, has been to give a response a substantial rate by correlating it with reinforcer delivery. Then, the reinforcer no longer follows the response but instead occurs only when the response has not been emitted for a period of time (a DRO t schedule, where DRO is the abbreviation for differential-reinforcement-of-not-responding, and t is the time parameter). The primary intent has been to compare this procedure with extinction in the speed and durability of response elimination (e.g., Topping and Ford, 1974; Uhl, 1973; Zeiler, 1971).

Although these experiments combined reinforcement for not responding with extinc-

tion, the DRO schedule does not require that the response no longer be reinforced. The simultaneous use of a manipulation to maintain a response and one to eliminate it has its counterpart in experiments on punishment. Many studies have shown effective punishment when a stimulus such as electric shock is presented dependent on the same response that also results in food delivery. In fact, this combination results in more durable suppression of responding than does punishment combined with extinction (cf., Azrin and Holz, 1966), because it prevents the response elimination procedure from taking on discriminative stimulus properties indicating that extinction is in effect. What would be the outcome of combining the DRO schedule with maintained reinforcement for the same response? Data on the conjoint imposition of DRO schedules and schedules of reinforcement for response emission appear limited to a study by Rachlin and Baum (1972), who imposed a DRO 2-sec schedule in combination with a variable-interval schedule for key pecking. The rate of key pecking decreased. They also reported that food given independent of behavior, instead of on the DRO schedule, yielded quantitatively equivalent effects; they concluded that the availability of food in some manner for not pecking was more important than the precise nature of the alternative source. This finding contrasts with the report that when DRO or response-independent

schedules were combined with extinction, the DRO schedule reduced responding more effectively (Davis and Bitterman, 1971).

The present study further explored the conjoint reinforcement of responding and not responding. One purpose was to investigate how changes in the parameter of the DRO schedule influenced performance; a second was to compare the effects of DRO and response-independent schedules over a range of parameter values.

METHOD

Subjects

Seven White Carneaux pigeons were maintained at 80% of their free-feeding weights. Birds P-15, P-40, P-59, P-102, and P-111 had experience with a variety of reinforcement schedules, and P-111 also had experience with DRO schedules combined with extinction (Zeiler, 1971). Birds P-122 and P-127 were experimentally naive.

Apparatus

A single-key pigeon unit contained a 2-cm diameter response key (Ralph Gerbrands Co.) operated by a minimum force of 0.20 N. A 5-cm square aperture centered 8 cm below the key provided occasional access to Purina Pigeon Checkers, the birds' standard diet. The key was transilluminated by two 7-W yellow lamps, except during the 4-sec feeder cycles, when the aperture was illuminated by a 1-W white light. A relay mounted behind the panel next to the key provided auditory feedback for each response. White noise masked extraneous sounds.

Procedure

Table 1 shows the sequence of schedules. A fixed-interval (FI 3-min) schedule was always in effect: the first key operation occurring after 3-min was followed by food presentation. In some conditions, the FI 3-min schedule prevailed alone; in others, it was accompanied by another schedule. This other schedule either provided food when a specified time (t) elapsed without a response (DRO t-sec schedule) or at a fixed time independent of behavior (a fixed-time, or FT t-sec schedule). Thus, the prevailing schedule was either FI 3-min, conjoint FI 3-min DRO t-sec, or conjoint FI 3-min FT t-sec. The t values were 10, 20, 30, 60, or 100 sec. In both DRO and FT components, t was timed

from session onset and from the end of food presentations earned via either component of the conjoint schedule; in the DRO, it was also reset by each response. Resets after food presentations derived from the FI schedule were appropriate for the DRO component, since these were always preceded by a key peck (on the assumption that the duration of that peck extended through the feeder cycle). It did interfere with the independence of the two components in conjoint FI FT schedules, but the procedure was maintained in order that the two types of conjoint schedule be as similar as possible. Each conjoint schedule was studied at least twice and as many as six times, sometimes after the simple FI 3-min schedule and sometimes after a different conjoint schedule. Number of conditions ranged from 38 to 61.

Birds P-40, P-59, P-122, and P-127 had conjoint schedules with DRO components at t values of 10, 20, 30, and 60 sec before encountering FT components (P-40 also had DRO 100-sec), and P-15, P-102, and P-111 had FT before DRO components. Finally, the types of schedule occurred in a mixed sequence, and the 100-sec values were incorporated.

Each schedule was maintained until responding met a stability criterion based on overall response rate for each session. The median rate of successive groups of three sessions was computed. A condition continued until three consecutive medians (based on nine consecutive sessions) neither increased nor decreased monotonically. The mean number of sessions per condition was 14.7 (standard deviation = 4.3). Sessions were conducted five days per week and terminated after 30 food presentations. The total number of sessions per bird ranged from 521 to 904.

RESULTS

Response rates were recoverable with each conjoint schedule, except for the initial series of conjoint FI FT schedules for P-15 and P-102. These are not considered in the following discussion but will be treated separately. Excluding the exceptions, the median rates of the last three sessions of each exposure to a particular schedule varied from each other by less than 10%. Consequently, the rates in each of the last five sessions of each exposure were used to calculate the means and standard deviations shown in Figure 1. These data stem

Table 1

Sequence of Schedules and Obtained Reinforcement Frequency[a]

	P-15	P-59	P-122	P-127	P-102	P-111	P-15
FI 3	1, 4, 6	1, 3, 5	1, 3, 5	1, 3, 5	1, 3, 5	1, 3, 5	1, 3, 5
	8, 10, 12	7, 9, 11	7, 9, 11	7, 9, 11	7, 9, 15	7, 9, 11	7, 9, 11
	14, 16, 18	13, 15, 17	13, 15, 17	13, 15, 17	17, 19, 21	14, 18, 20	13, 17, 19
	20, 22, 24	19, 21, 23	19, 21, 23	19, 21, 23	25, 38	22, 27, 40	21, 23, 26
	26, 28, 30	25, 27, 29	25, 27, 29	25, 27, 29			
	32, 34, 36	31, 33, 36	31, 33, 36	31, 33, 35			
	38, 40, 42	38, 40, 42	38, 40, 43	38, 40, 42			
	44, 46, 49	45, 59	46, 59	44, 47, 60			
	(20, 0)	(20, 0)	(20, 0)	(20, 0)	(20, 0)	(20, 0)	(20, 0)
conjoint FI 3:							
DRO 10	9, 13, 15 41, 51	6, 16, 39	4, 14, 42	2, 16, 41	16, 27	19, 25	22, 31, 33
	(14, 324)	(16, 288)	(13, 212)	(12, 343)	(12, 343)	(12, 350)	(12, 337)
DRO 20	3, 11, 43	4, 10, 18 37, 51	8, 12, 44 48	6, 14, 43 49	22, 32	17, 24, 36	24, 34
	(17, 126)	(18, 117)	(17, 108)	(19, 169)	(18, 165)	(17, 149)	(15, 136)
DRO 30	5, 17, 39	8, 12, 43 47	2, 6, 18 37, 52	8, 12, 18 39, 52, 54	18, 34	23, 29	20, 28
	(18, 35)	(18, 50)	(18, 54)	(17, 55)	(15, 95)	(18, 88)	(19, 64)
DRO 60	7, 19, 45 48	2, 14, 41	10, 16, 39 41	4, 10, 45	20, 23	21, 32, 34	18, 35
	(19, 7)	(19, 3)	(18, 16)	(19, 7)	(19, 7)	(19, 11)	(18, 16)
DRO 100	2, 47, 57 59	44, 50, 55 57	45, 51, 57	46, 55	24, 33	26, 35, 38	25, 36
	(20, 2)	(19, 5)	(19, 3)	(19, 1)	(19, 2)	(19, 2)	(19, 4)
FT 10	23, 31, 50 52	20, 30, 54	20, 28, 58	26, 34, 59	2, 8, 14 26, 28	4, 15, 37	2, 10, 32
	(12, 348)	(12, 348)	(12, 348)	(12, 348)	(12, 348)	(12, 348)	(12, 348)
FT 20	21, 29, 37	26, 28, 58	26, 30, 35 47, 49	22, 32, 48 50	10, 13, 31	6, 10, 16	8, 14, 40
	(20, 180)	(20, 180)	(20, 180)	(20, 180)	(20, 180)	(20, 180)	(20, 180)
FT 30	27, 33, 56	22, 32, 35 46, 48	24, 32, 53	20, 28, 30 37, 53	4, 11, 30	8, 12, 28 30	4, 12, 16 27, 29
	(18, 116)	(18, 116)	(18, 116)	(18, 116)	(18, 116)	(18, 116)	(18, 116)
FT 60	25, 35, 54	24, 34, 53	22, 34, 55	24, 36, 57	6, 12, 36	2, 13, 33	6, 15, 38
	(18, 60)	(18, 60)	(18, 60)	(18, 60)	(18, 60)	(18, 60)	(18, 60)
FT 100	53, 55, 58 60	49, 52, 56	50, 54, 56	51, 56, 58	29, 35, 37	31, 39	30, 37
	(20, 20)	(20, 20)	(20, 20)	(20, 20)	(20, 20)	(20, 20)	(20, 20)

[a] Numerals outside parentheses indicate condition number, numerals inside are obtained reinforcements per hour, first for FI, then for DRO or FT component.

from 10 to 30 sessions, depending on the number of replications per condition.

Response rate increased as the DRO or FT value increased from 10 to 60 sec, but only P-111 never showed a lower rate at the 100-sec than at the 60-sec parameter value. There were no consistent differences produced by same-valued DRO and FT schedules: the DRO components produced lower rates in 20 of the 35 possible paired comparisons. In summary, when equated for parameter value, the DRO

and FT schedules had approximately the same effects on overall response rate. Session-to-session variability was small relative to effects on central tendency.

The FT schedule guaranteed that food would be presented at regular time intervals, but the DRO schedule did not. Table 1 shows the actual frequency of food presentation (reinforcements per hour) derived from the two components of the conjoint schedule in the sessions entering into Figure 1. The birds re-
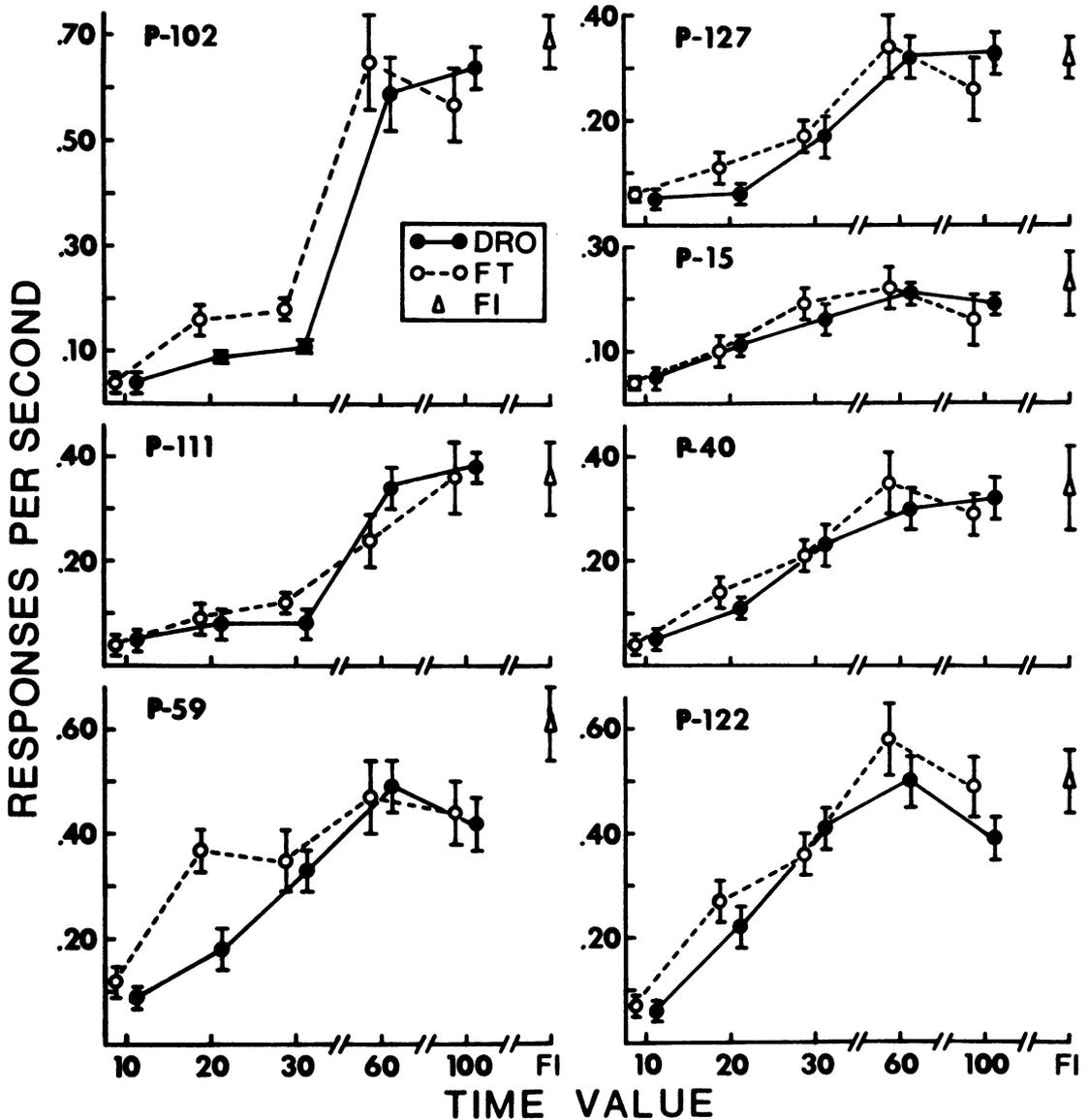
Fig. 1. Mean response rate in the FI 3-min (triangles), the conjoint FI 3-min DRO *t*-sec (filled circles), and the conjoint FI 3-min FT *t*-sec (open circles) schedules. Vertical lines show the mean plus and minus one standard deviation. Points are displaced from their proper location above the horizontal axis to avoid overlap.

sponded sufficiently often to obtain all of the food presentations arranged by the FI 3-min component on time; however, they did not obtain the maximum frequency of food presentation possible via the DRO components (maximum was the same as the obtained frequency derived from the FT components). The frequency associated with the FI 3-min component was lower than 20 food presentations per hour in some cases, because sessions terminated by a food delivery via the other

component could end the sessions in the midst of an interval. For example, suppose the thirtieth food presentation occurred 1 sec before the end of the interval, and previously the bird had completed five fixed intervals. The frequency correlated with the FI component (in seconds), would be 5/1079, or 17 per hour.

Figure 2 shows response rate replotted as a function of the relative reinforcement frequency obtained from the FI 3-min schedule (reinforcements per hour from the FI sched-
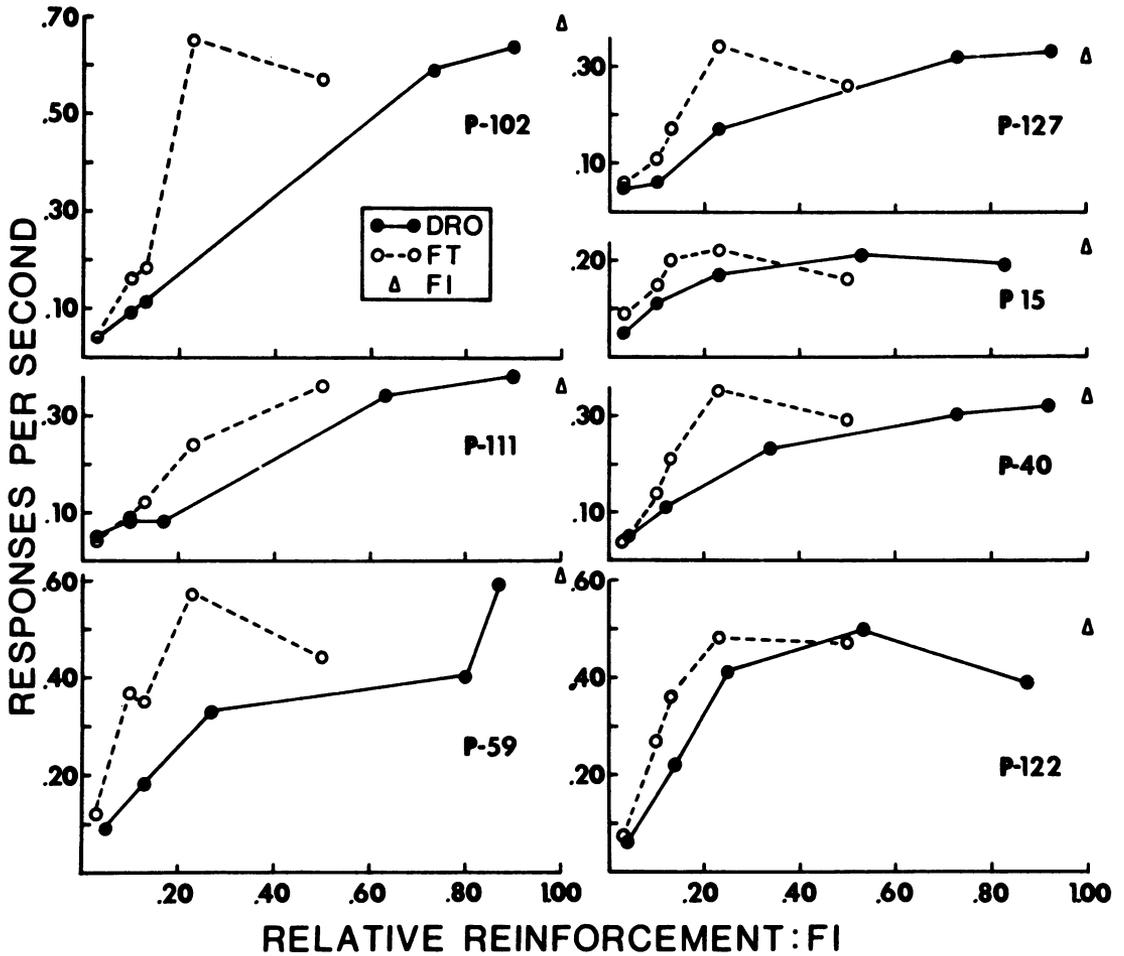
Fig. 2. Response rate as a function of proportion of food presentations occurring from the FI 3-min schedule. Symbols as in Figure 1.

ule divided by total reinforcements per hour). Except for P-59, for which the FI component produced a higher relative reinforcement frequency with the DRO 60-sec than with the DRO 100-sec component, as t increased so did the proportion of food presentations occurring with the FI 3-min schedule. Only when $t = 10$ sec did same-valued DRO and FT components generate nearly equal reinforcement rates. The functions describing rate under the DRO components consistently lay below those from the FT components over much of the range, approaching each other at both ends. Except at the lowest points, a given relative reinforcement frequency earned via the DRO component reduced response rate more than did that earned from the FT component.

Cumulative records enabled comparisons of the temporal distribution of responses. The conjoint schedules involving the DRO 10-sec and FT 10-sec components resulted in the steady low rates shown in Figure 4, sections entitled "DRO 10" and "FT 10 After DRO". These records were typical of all birds. The 20-sec values also produced steady rates. Figure 3 shows characteristic records indicating how differences occurred at longer time intervals. With FT 30-sec, the pattern continued to be a fairly steady rate. The DRO 30-sec components, however, either also generated steady rates or patterns more closely resembling those of the simple FI 3-min schedule. After an FI food presentation, there was a pause during which one or more of the 30-sec not-responding criteria were met. With DRO 60-sec, the patterns basically were the same, but there were numerous intervals with pauses too short to result in any DRO reinforcements. The FT
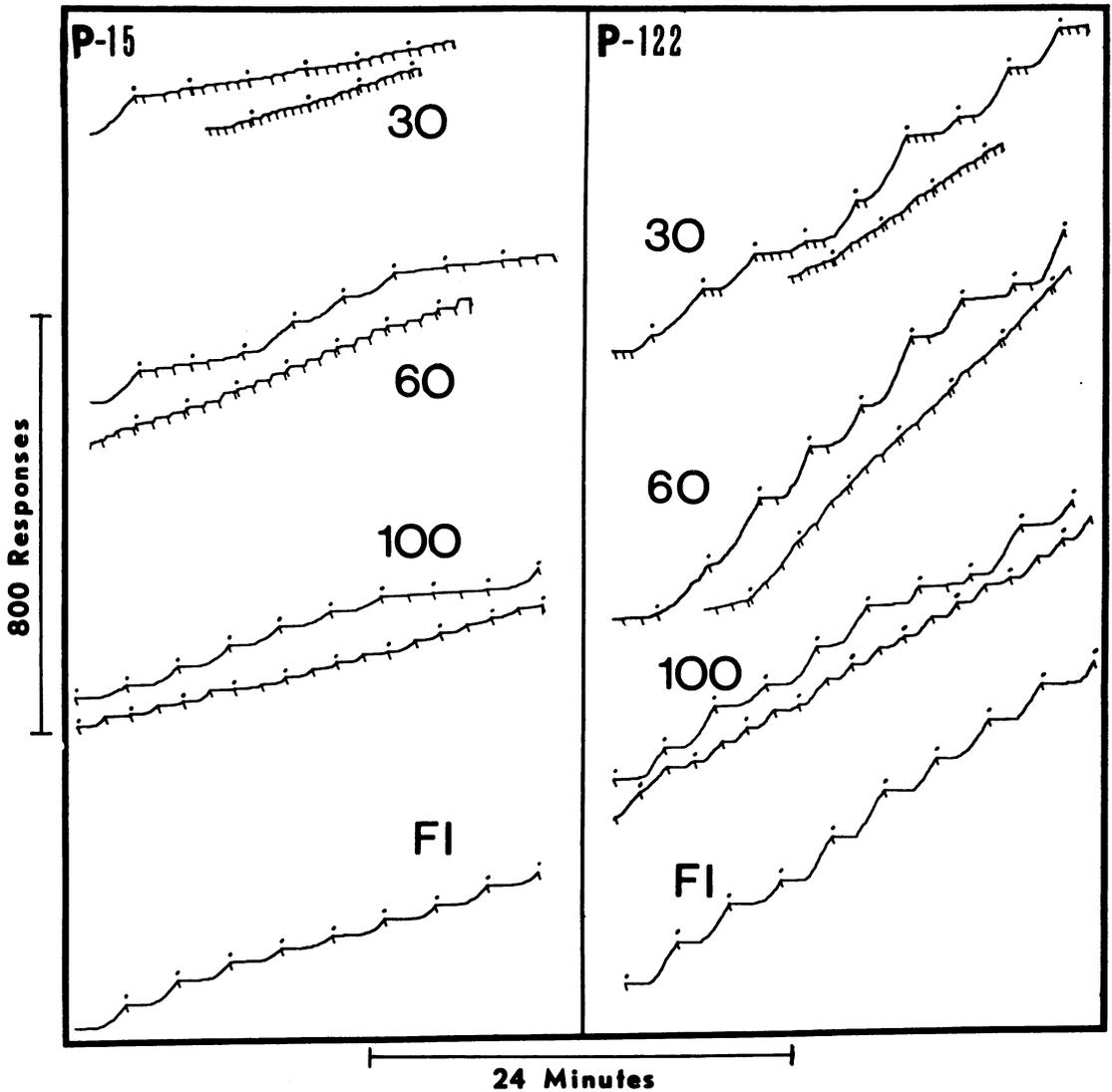
Fig. 3. Representative cumulative records. The upper member of each pair is the schedule with the DRO component, the lower member is the one with the FT component. Numerals adjacent to each pair indicate *t*-value. Offsets of the response pen indicate food presentations; dots above the offsets indicate those occurring via the FI 3-min component. Characteristics of the two timing systems resulted in a constant error producing too-short intervals with the DRO and FT schedules relative to the FI.

60-sec components resulted in either a steady rate or in responding immediately after food presentation followed by a pause. With DRO 100-sec, the pause requirement was met infrequently, and the essential pattern was that of the FI 3-min schedule. The FT 100-sec components generated positively accelerated rates between successive food presentations. The records indicate that performance was like that appropriate to FI 100-sec and FI 80-sec schedules, rather to an FI 3-min schedule.

For two birds, P-15 and P-102, response rate was not simply related to the value of *t* in the initial series of exposures to FT components. For P-102, FT 10-sec generated mean rates of 1.64, 0.63, and 0.57 responses per second in the first three exposures (see Figure 4), FT 20-sec produced 0.36 and 0.32 responses per second, and FT 30-sec yielded 0.55 and 0.50 responses per second. For P-15, mean rates under FT 10-sec were 0.27 and 0.24 responses per second, under FT 20-sec were
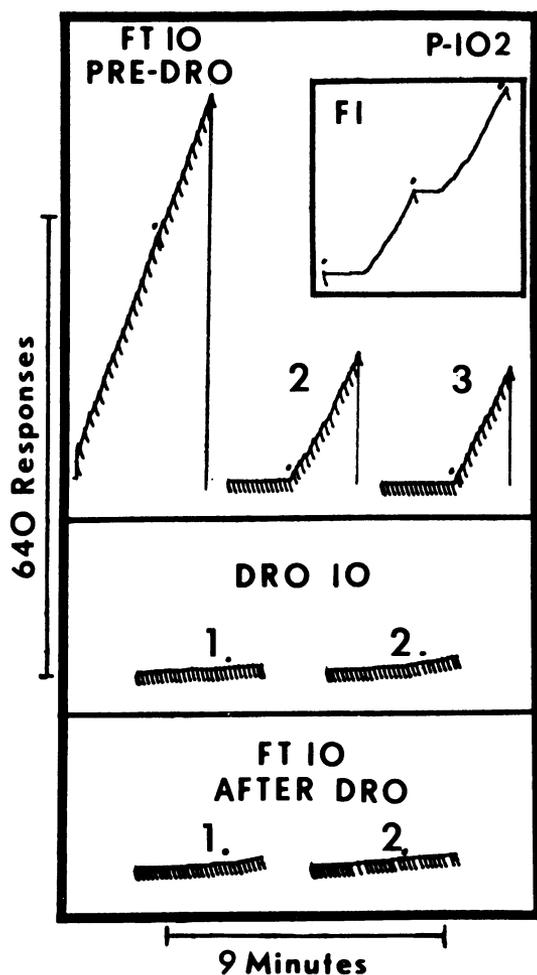
Fig. 4. Representative cumulative records for P-102. The upper panel shows performance with the conjoint FI 3-min FT 10-sec schedule in the three exposures before experience with DRO components, and the inset shows characteristic performance with the simple FI 3-min schedule. The middle panel shows the two exposures to the conjoint FI 3-min DRO 10-sec schedule, and the bottom panel shows the two exposures to the conjoint FI 3-min FT 10-sec schedule following experience with DRO components. Other details of recording as in Figure 3.

0.14 and 0.17 responses per second, and under FT 30-sec were 0.32, 0.17, and 0.22 responses per second. For both birds, FT 60-sec and FT 100-sec resulted in rates like those shown in Figure 1. The performances then changed drastically. Figure 4 illustrates the largest change, that exhibited by P-102 with FT 10-sec. Initially, that schedule maintained a rate higher than ever occurred with the simple FI 3-min schedule. In the second and third exposures, the bird paused until the first FI

reinforcement and then maintained a high steady rate. After experience with DRO, however, FT 10-sec resulted in the low steady rates typical of the other birds. All of the high rates occurred before P-15 and P-102 experienced the DRO schedules. The only bird beginning with FT components that did not show these changes was P-111, the one with experience with DRO schedules before the present study. None of the other four birds showed similar effects. In short, after experience with DRO schedules, rates were related in an orderly manner to parameter value under every FT schedule. Without such a history, rates were less predictable.

DISCUSSION

Although key pecks continued to result in food delivery, they could be decreased by also presenting food dependent on not pecking. This was positive reinforcement, since the behavior (not pecking) that produced the reinforcer (food) increased in frequency.

A comparison of these results with those of Azrin and Holz (1961) shows similarities between reinforcement of not responding and punishment. In both experiments, responding was maintained by a fixed-interval schedule of food presentation while a procedure for response elimination—reinforcement of not responding or electric shock following each response—occurred simultaneously. Both experiments revealed sensitivity to a parameter inherent in the particular procedure: the higher the intensity of shock or the higher the frequency of food presentation provided by the DRO schedule, the lower the rate of responding. (Comparisons of the most analogous parameters of the two situations, *i.e.*, between frequency of shock presentation and DRO reinforcement or between shock intensity and magnitude of DRO reinforcement cannot be drawn at this time, because the necessary experiments involving fixed-interval baselines do not seem to have been conducted.) Also, both experiments found that rate shifted immediately when the parameters were changed and that response suppression was restricted to periods in which electric shock or food presentation for not responding occurred. The suppression did not generalize to the simple fixed-interval schedule in either case.

There were differences as well. Although moderate shock intensities initially produced

large decrements in response rate followed by increased responding, rates did not change with prolonged exposure to any DRO component. Also, DRO, but not punishment, often disrupted the fixed-interval pattern. This last difference perhaps occurred because food presentation occurred in both the FI and DRO components of the present study but only via the fixed-interval schedule in the Azrin and Holz experiment.

Overall, therefore, the response-reducing effects of the DRO schedule were comparable in some ways, and perhaps stronger in others, to those of punishment, when responding was maintained by a fixed-interval schedule. Whether the similarities or the differences will hold with other baseline schedules is unknown.

Rachlin and Baum (1972) found that intermittently imposed DRO 2-sec and FT 2-sec schedules in effect conjointly with a variable-interval schedule for pecking produced equal rate reductions. Although the present functions based on *t*-value indicated a comparable correspondence, those involving obtained reinforcement frequency did not. Rachlin and Baum used the nominal (maximum programmed) rather than the obtained frequencies in comparing the schedules quantitatively, and they noted that programmed and obtained frequency differed only slightly. In the present study, equal programmed and obtained frequencies occurred only with FT 10-sec and DRO 10-sec components, the schedules having the *t* values closest to theirs. The other DRO schedules produced substantial differences between nominal and obtained reinforcement frequency. The present data showed that the source of reinforcement for not pecking (DRO or FT) indeed made a difference in the degree of response reduction, at least when scaled in terms of obtained reinforcement frequency.

The DRO and FT schedules also differed in their apparent sensitivity to experimental history. Without a DRO history, response rate was complexly related to *t* in the FT schedules and could be enhanced rather than decreased by the FT 10-sec components. However, once the bird had been exposed to DRO components, the FT schedules always generated predictable and recoverable functions, with FT 10-sec controlling the lowest rate. With a history of reinforcement dependent on not pecking the key, FT schedules showed the same relation of response rate to *t* displayed by

DRO schedules. The sensitivity of performance under FT schedules to experimental history has been pointed out previously (Alleman and Zeiler, 1974). The concept of adventitious reinforcement leads to the expectation that the nature of ongoing behavior will determine what will be manifested under response-independent reinforcement and could explain the initial rate increase seen in P-102 or any irregular unpredictable function. But it is not evident that this concept could easily cope with orderly unchanging effects, *i.e.*, how it could explain stable performance developing from a variety of baselines. The FT schedule produced such stable performance in the present study after the history with DRO, and it has also been shown to generate different, but consistent, rates and patterns of responding after a history with other schedules (Alleman and Zeiler, 1974). Systematic changes attributable to experimental history seem to be independent of behavior that happens to be temporally contiguous with the reinforcing stimulus.

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