ELIMINATIÓN OF REINFORCED BEHAVIOR: INTERMITTENT SCHEDULES OF NOT-RESPONDING[1]

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Pigeons' key pecking resulted in food according to either a variable-ratio or a variable-interval schedule. At the same time, food was available for not pecking for a specified time. The required time of not-pecking was segmented into not-responding units, and these units were followed by food according to a fixed-ratio schedule. Both unit duration and the number required were varied. In general, the shorter the time unit or the smaller the ratio, the lower was response rate. When total required not-responding time was constant, but changes in unit duration and the number required altered how the total was achieved, shorter units produced lower rates. Other conditions involved substitution of food delivered independent of responding for the not-responding schedule. With low and moderate total times to food presentation, the not-responding schedule produced lower rates; with the longest times, the response-independent schedule generated less responding. When considered in terms of relative frequency of food presentation available from a source other than pecking, the not-responding schedule reduced rate more effectively than did the response-independent schedule. Comparisons with other research suggested that food presented dependent on not responding compared favorably with punishment as a procedure for reducing response rate. Transient effects differed. Although punishment temporarily depresses rate when first imposed and temporarily enhances it when first removed, food given for not responding quickly generated steady-state rates.

Key words: response elimination, conjoint schedules, DRO schedules, fixed-time schedules, fixed-ratio second-order schedules, variable-ratio schedules, variable-interval schedules, key peck, pigeons

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When the occurrence and the nonoccurrence of the same response are eligible for reinforcement simultaneously, the response may decrease in frequency or even stop altogether (Rachlin and Baum, 1972; Zeiler, 1976; Zeiler and Fite, 1975). The effects reported to date resemble those found when a punisher and a positive reinforcer are available concurrently for the same response. They suggest the possibility that positive reinforcers delivered dependent on response omission may have effects like those of aversive stimuli presented dependent on response emission.

Research on punishment (Azrin, Holz, and Hake, 1963) has indicated that if fewer responses result in electric-shock delivery, re-

sponding is decreased less. In previous research on simultaneous (conjoint) schedules of response emission and omission, pigeons received food based on not pecking for a specified period of time (a differential-reinforcement-of-not-responding, or DRO, schedule). The required period of not pecking defined the DRO unit. Either the first unit completed at irregular intervals (Rachlin and Baum, 1972) or every one (Zeiler, 1976) resulted in food. In either study, only one period of not-responding was required, even though in the first, every such unit was not followed by food presentation. No information exists about how DRO schedules requiring multiple periods of not responding would influence performance. The present experiment provided such information by varying the number of DRO units that had to be completed per food delivery. The resulting series of fixed-ratio (FR) schedules of DRO units combined with a schedule for response emission was analogous to the FR schedules of punishment studied by Azrin *et al.*

The time parameter of the DRO unit plays an important role in determining response rate

(Zeiler, 1976). When key pecking was maintained by a fixed-interval schedule at the same time that not-pecking for 10, 20, 30, 60, or 100 sec also resulted in food delivery, the lower the time requirement the lower was the response rate. These results are in a sense paradoxical, because the schedules requiring the shorter pauses established lower rates than did those requiring longer pauses. Consider, though, that the potential frequency of food presentation in time derived from not-responding increases with shorter DRO units (*i.e.*, food can be delivered every 10 sec under a DRO 10-sec schedule, but it can occur at most only once every 30 sec under a DRO 30-sec schedule). If that aspect of the schedules is responsible, a schedule not specifying a pause as prerequisite for food delivery might have the same effects as DRO. Indeed, Rachlin and Baum (1972) found that food given independent of responding resulted in the same frequency of food delivery and in the same response rate as did food given dependent on not-responding. In subsequent research, however, this equivalence was parameter-dependent (Zeiler, 1976). The shortest time values of the two schedules produced comparable response rates, but with higher values, DRO established lower rates across a range of food presentation frequencies. Thus, a pause as prerequisite for food delivery is an important determinant of the effects of all but the shortest DRO schedules.

Would shorter DRO units continue to produce lower rates if food delivery required the same minimum time spent pausing as did longer units? Previous research could not answer this question, because unit time and minimum total pause time per food presentation were identical. However, by varying fixed-ratio size together with DRO unit time in second-order FR(DRO) schedules, minimum time of not responding could be equated while the units were changed. For example, FR 1(DRO 30-sec), FR 3(DRO 10-sec), FR 10(DRO 3-sec), and FR 30(DRO 1-sec) all specify a minimum of 30 sec of not responding before food can be given, but they involve 30-, 10-, 3-, and 1-sec units respectively. Manipulation of how the same total time could be attained indicated whether unit duration and number required mattered, or whether total not-responding time was critical. Also, the present experiment compared once again the rates established by DRO and fixed-time (FT) schedules of response-independent food presentation.

METHOD

Subjects

Six White Carneaux pigeons of undetermined sex were maintained at 80% of their free-feeding weights. One, P-45, had experience with a variety of reinforcement schedules, and the others were experimentally naive.

Apparatus

A single-key pigeon unit contained a 2-cm diameter response key operated by a minimum force of 0.2 N. A 5-cm square aperture centered 8 cm below the key could provide 4-sec access to Purina Pigeon Checkers, the birds' standard diet. Two 7-W blue lamps transilluminated the key while two 1-W white lamps (one located slightly above and 10 cm to either side of the key) provided dim general illumination. The only light source during feeder operations was a 1-W white lamp inside of the aperture. 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. For P-45, P-125, and P-138, a variable-ratio (VR) schedule always was in effect. Food presentations followed an irregular number of responses averaging 100 (VR 100). For P-140, P-143, and P-144, a variable-interval (VI) schedule always prevailed. The first key peck emitted at irregular intervals averaging 100 sec resulted in food delivery (VI 100-sec). The VI was a constant-probability schedule (Catania and Reynolds, 1968), and the VR was established with the same sequence of interfood periods (treating 1 sec and one response as equivalent). In some conditions these schedules prevailed alone; in others, they were accompanied by a schedule providing food if no peck occurred for a specified time. The time requirements were 1, 3, 10, and 30 sec. The number of these not-responding units that had to occur for food to be given was 1, 3, 10, or 30. Combinations of time units with number specifications are described as a fixed-ratio of DRO units, or FR(DRO) schedules. Consideration was restricted to total not-responding times (multiples of the DRO time unit and ratio value)

Table 1

Sequence of Schedules[a]

	P-45	P-125	P-138	P-140	P-143	P-144
1.	VR 100	VR 100	VR 100	VI 100	VI 100	VI 100
2.	FR 3(DRO 1)	FR 10(DRO 1)	FR 316(DRO 1)	FR 32(DRO 1)	FR 10(DRO 1)	FR 100(DRO 1)
3.	VR 100	VR 100	FR 100(DRO 1)	VI 100	VI 100	VI 100
4.	FR 10(DRO 1)	FR 32(DRO 1)	VR 100	FR 3(DRO 1)	FR 3(DRO 1)	FR 32(DRO 1)
5.	VR 100	VR 100	FR 10(DRO 3)	VI 100	VI 100	VI 100
6.	FR 10(DRO 3)	FR 3(DRO 3)	VR 100	FR 10(DRO 3)	FR 32(DRO 3)	FR 3(DRO 3)
7.	VR 100	VR 100	FR 32(DRO 3)	VI 100	VI 100	VI 100
8.	FR 3(DRO 3)	FR 10(DRO 3)	VR 100	FR 3(DRO 3)	FR 10(DRO 3)	FR 32(DRO 3)
9.	VR 100	VR 100	FR 10(DRO 1)	FR 30(DRO 1)	FR 3(DRO 10)	FR 10(DRO 3)
10.	FR 1(DRO 30)	FR 30(DRO 1)	FR 3(DRO 10)	FR 3(DRO 10)	FR 30(DRO 1)	FR 3(DRO 10)
11.	FR 30(DRO 1)	FR 3(DRO 3)	FR 30(DRO 1)	FR 1(DRO 30)	FR 1(DRO 30)	FR 30(DRO 1)
12.	FR 3(DRO 10)	FR 3(DRO 10)	VR 100	FR 10(DRO 1)	FR 1(DRO 10)	FR 1(DRO 30)
13.	FR 1(DRO 30)	FR 1(DRO 30)	FR 10(DRO 3)	FR 3(DRO 1)	FR 1(DRO 3)	FR 1(DRO 10)
14.	FR 1(DRO 10)	FR 30(DRO 3)	FR 30(DRO 3)	FR 1(DRO 10)	FR 30(DRO 3)	FR 10(DRO 1)
15.	FR 30(DRO 3)	FR 1(DRO 10)	FR 30(DRO 1)	FR 30(DRO 3)	FR 3(DRO 3)	FR 30(DRO 3)
16.	FR 1(DRO 3)	FR 1(DRO 3)	FR 1(DRO 10)	FR 1(DRO 3)	FR 30(DRO 1)	FR 1(DRO 3)
17.	FR 3(DRO 3)	FR 3(DRO 10)	FR 30(DRO 3)	FR 3(DRO 1)	FR 30(DRO 3)	FR 3(DRO 1)
18.	FR 3(DRO 1)	FR 3(DRO 1)	FR 10(DRO 1)	FR 10(DRO 1)	FR 10(DRO 3)	FR 1(DRO 10)
19.	FR 1(DRO 10)	FR 10(DRO 3)	FR 10(DRO 3)	FR 30(DRO 1)	FR 3(DRO 10)	FR 10(DRO 1)
20.	FR 3(DRO 10)	FR 30(DRO 1)	FR 3(DRO 3)	FR 10(DRO 3)	FR 3(DRO 3)	FR 1(DRO 3)
21.	FR 30(DRO 1)	FR 1(DRO 10)	FR 30(DRO 3)	FR 3(DRO 10)	FR 10(DRO 1)	FR 1(DRO 30)
22.	FR 10(DRO 1)	FR 30(DRO 3)	FR 1(DRO 30)	FR 1(DRO 3)	FR 1(DRO 30)	FR 3(DRO 1)
23.	FR 10(DRO 3)	FR 10(DRO 1)	FR 3(DRO 10)	FR 3(DRO 3)	FR 1(DRO 10)	FR 3(DRO 10)
24.	FR 1(DRO 3)	FR 1(DRO 30)	FR 30(DRO 1)	FR 3(DRO 30)	FR 3(DRO 30)	FR 10(DRO 3)
25.	FR 3(DRO 30)	FR 3(DRO 3)	FR 3(DRO 30)	FR 1(DRO 30)	FR 3(DRO 1)	FR 30(DRO 1)
26.	FR 1(DRO 30)	FR 32(DRO 1)	FR 1(DRO 30)	FR 10(DRO 10)	FR 1(DRO 30)	FR 3(DRO 30)
27.	FR 30(DRO 3)	FR 3(DRO 30)	FR 1(DRO 30)	FR 10(DRO 1)	FR 1(DRO 3)	FR 3(DRO 3)
28.	FR 10(DRO 3)	FR 3(DRO 1)	FR 3(DRO 10)	FR 3(DRO 30)	FR 30(DRO 1)	FR 30(DRO 3)
29.	FR 3(DRO 30)	FR 30(DRO 1)	FR 3(DRO 3)	FR 30(DRO 3)	FR 3(DRO 30)	FR 3(DRO 30)
30.	FR 3(DRO 1)	FR 1(DRO 3)	FR 3(DRO 30)	FR 10(FT 3)	VI 100	FR 10(FT 3)
31.	FR 1(DRO 10)	FR 3(DRO 30)	FR 10(DRO 1)	FR 10(FT 1)	FR 30(FT 3)	FR 10(FT 1)
32.	VR 100	FR 30(DRO 3)	VR 100	FR 3(FT 1)	FR 10(FT 1)	FR 3(FT 1)
33.		VR 100	FR 10(FT 1)	FR 30(FT 1)	FR 30(FT 1)	FR 30(FT 1)
34.		FR 1(FT 10)	FR 30(FT 1)	FR 1(FT 10)	FR 1(FT 10)	FR 1(FT 10)
35.		FR 10(FT 1)	FR 1(FT 10)	FR 3(FT 10)	FR 10(FT 3)	FR 3(FT 10)
36.		FR 3(FT 1)	FR 3(FT 10)	FR 3(FT 30)	FR 3(FT 10)	FR 30(FT 3)
37.		FR 30(FT 1)	FR 30(FT 3)	FR 1(FT 30)	FR 1(FT 30)	FR 3(FT 30)
38.		FR 10(FT 3)	FR 3(FT 1)	FR 30(FT 3)	FR 3(FT 30)	FR 1(FT 30)
39.		FR 3(FT 10)	FR 1(FT 30)	FR 1(FT 3)	FR 3(FT 1)	FR 3(FT 3)
40.		FR 30(FT 3)	FR 3(FT 30)	FR 3(FT 3)	FR 1(FT 3)	FR 1(FT 3)
41.		FR 1(FT 3)	FR 1(FT 10)	VI 100	FR 3(FT 3)	VI 100
42.		FR 3(FT 30)	FR 10(FT 3)		VI 100	
43.		FR 1(FT 30)	FR 3(FT 3)			
44.		FR 3(FT 3)	FR 10(FT 3)			
45.		VR 100	VR 100			

[a]All FR(DRO) and FR(FT) schedules were imposed conjointly with VR 100 for P-45, P-125, and P-138, and conjointly with VI 100-sec for P-140, P-143, and P-144.

ranging from 3 to 90 sec. All of these schedules were studied at least twice, sometimes preceded by simple VR or VI and sometimes by a different FR(DRO) schedule in conjunction with VR or VI. Programming errors also produced FR 32 schedules with DRO 1-sec and/or DRO 3-sec for all birds but P-45, FR 100 (DRO 1-sec) for P-138 and P-144, and FR 316 (DRO 1-sec) for P-138.

The FR 3(DRO 10-sec) schedule serves to illustrate the not-responding aspect of the procedure. Whenever a continuous 10-sec period elapsed without a response, one unit was credited. After three such units, food was delivered. The requirement could be met in any of four ways: one continuous 30-sec pause, one pause of more than 20 but less than 30 sec followed by one of 10 sec, one pause of more than 10 but less than 20 sec followed by one of 20 sec, or two pauses each more than 10 but less than

20 sec followed by one of 10 sec. At the same time, any pecks that occurred could produce food according to the VR or VI schedule.

The timers controlling the VI and DRO schedules stopped during food cycles. In addition, every peck reset the DRO timer. Since the peck resulting in food delivery re-initiated the DRO interval, the DRO began anew after each food presentation and after each response.

Conditions involving the VR or VI schedules combined with response-independent food presentation followed the series of FR(DRO) schedules. Once again, either 1, 3, 10, or 30 units had to be completed, but now each unit ended after 1, 3, 10, or 30 sec without reference to either responding or not responding (a fixed-time, or FT, schedule). These arrangements generated a series of FR(FT) second-order schedules. Total times per food delivery (multiples of ratio and FT values) from 3 to 90 sec were studied. Although all combinations of ratio and time yielding the same multiple were nominally identical in arranging food delivery, they did provide controls for possible idiosyncracies in the programming circuitry.

The FT timer was unaffected by responses. It reset only after food presentations derived from the FR(FT) schedule, and it stopped timing (without resetting) during food presentations derived from the VR or VI schedule.

Each condition continued until responding met a stability criterion based on overall response rate for each session. The median rate was computed for successive groups of three sessions, excluding the first. A condition ended when three consecutive medians (based on nine consecutive sessions) neither increased nor decreased monotonically. The only exception was that sometimes a condition was terminated after five consecutive sessions with rates of 0.00 responses per second. Sometimes a condition was continued after the criterion was met to determine if the criterion was representative of rates occurring after more prolonged exposure. Sessions were conducted five days per week and terminated after 20 food presentations. The total sessions per bird ranged from 574 to 778.

RESULTS

The effects of the time parameter of the FR(DRO) and FR(FT) schedules are seen in Figures 1 and 2 by comparing the array of points at each fixed-ratio value. For all birds, the lower the duration of the DRO unit, the lower the response rate. The only exceptions occurred at FR 3, where 1- and 3-sec units produced the same rates in several birds. Otherwise, with either the VR or VI baseline schedule, food simultaneously available for not-responding decreased response rate, with the amount of decrement inversely related to the time value of the DRO unit. The same general relations appeared with FT, except that they were less consistent.

The effects characterized individual sessions, as well as the means across sessions. Expressed in terms of percentage of the means, the standard deviations for the sessions entering into the means were 0% with means of 0.00, from 0% to 50% with means from 0.01 to 0.04, from 20% to 25% with means from 0.05 to 0.16, and from 5% to 11% with means larger than 0.16. The only aberrant data were for the first exposure to FR 10(DRO 3-sec) for P-138. In contrast to later exposures, the initial one eliminated responding completely. That condition, therefore, was excluded from the means and standard deviations. Thus, the mean response rates shown in Figures 1 and 2 were recovered in each exposure to the VR and VI schedule imposed alone or in conjunction with a particular FR(DRO) or FR(FT) schedule, and they characterized individual sessions as well. It made no difference whether a particular FR(DRO) or FR(FT) schedule was or was not preceded by the VR or VI schedule in effect alone. The same constancy described the effects of the simple VR and VI schedules.

The influence of the fixed-ratio schedule is apparent from the changes in rate with each DRO time value as a function of ratio size. As ratio size increased, response rate did as well. Thus, increasing the intermittency of food presentation diminished the rate-reducing influence of the DRO schedules. Once again, the FT schedules revealed similar but less consistent relations.

The dashed lines of each panel connect points involving a total of 30 sec of not-responding time (the DRO schedules) or 30 sec between successive food presentations (the FT schedules). The curves connect points differing in both time unit and fixed ratio, with the ratio increasing and time unit decreasing as the curve moves from left to right. Shorter times produced the lower rates with the FR(DRO) schedules. This effect was replicated
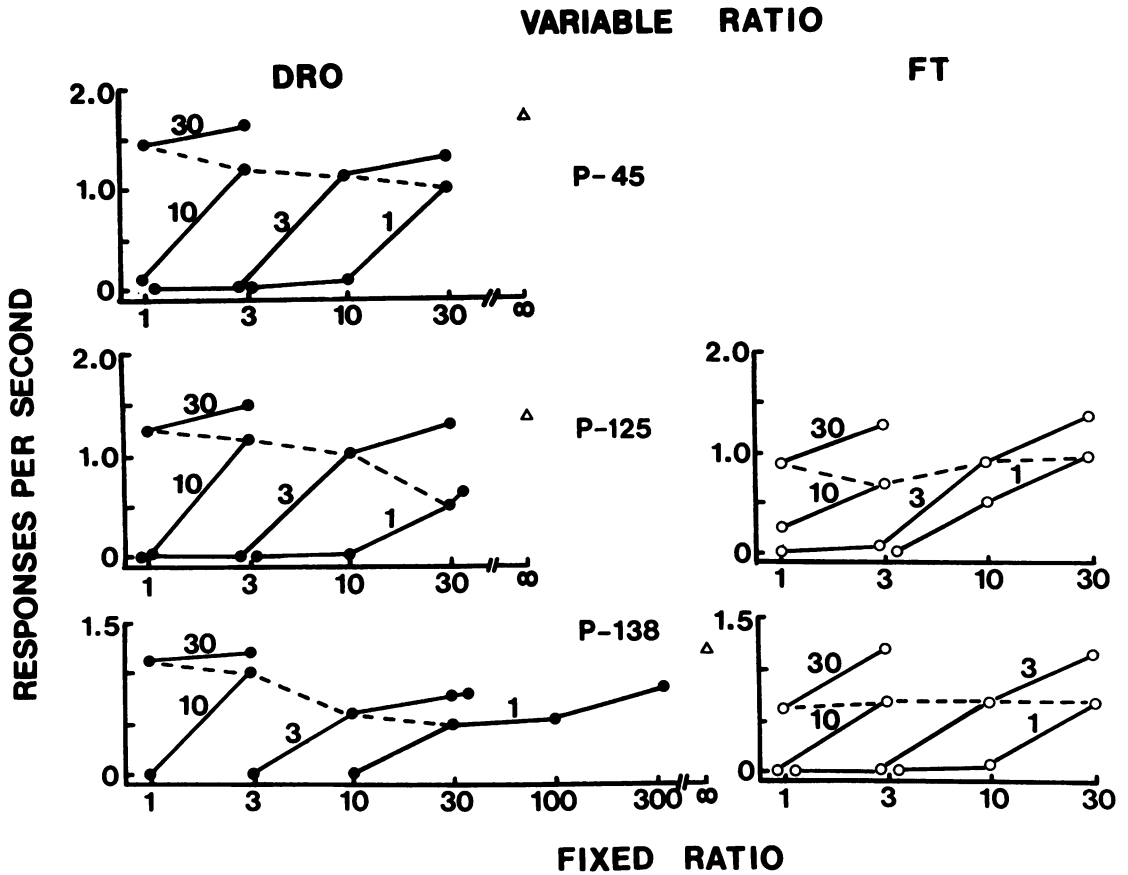
Fig. 1. Response rate under each schedule for birds having the variable-ratio baseline schedule. These means are the averages over the last five sessions of each exposure; they involve five to 35 sessions, depending on the number of replications. Numerals adjacent to each curve indicate the duration of the time unit. The dashed lines connect points involving a total time requirement of 30 sec. Triangles indicate rate in the absence of either the FR(DRO) or FR(FT) schedule, *i.e.*, with an infinite ratio. Bird P-45 did not have the FR(FT) conditions. For the other birds, the FR(DRO) conditions appear on the left and the FR(FT) on the right.

with the 90-sec overall requirement, that is, the FR 30(DRO 3-sec) schedule produced lower rates than did the FR 3(DRO 30-sec) schedule. It also was replicated in several instances involving the 10-sec total time. In the remaining cases, and with 3-sec total time, different time units and ratios yielded no consistent differences. With FR(FT), equal total times meant identical times between food presentations (excluding the possibility of timing errors). As anticipated, they produced similar effects regardless of time units and ratios.

A total of 53 paired comparisons were possible between FR(DRO) and FR(FT) schedules having identical time and ratio values. Five of the six equal rates occurred with rates of 0.00 responses per second, the sixth with a rate of 0.02 responses per second. In the re-

mainder, the FR(DRO) schedule produced lower rates in 24 of the 28 pairs involving 1- and 3-sec time units. The FR(FT) schedules produced lower rates in 16 of 19 comparisons involving 10- and 30-sec units.

Table 2 shows the food presentations per hour obtained from each of the schedules. These data are based on the same sessions entering into the mean response rates. The maximum frequency possible under FR(DRO) was the same as the obtained frequency under the equal valued FR(FT) schedule. Slight errors in the timing circuits resulted in departures from nominal values. Since sessions could end with a food presentation from either source, frequency via the VI and FR(FT) schedules could be lower than that programmed. The frequency correlated with VI also could be
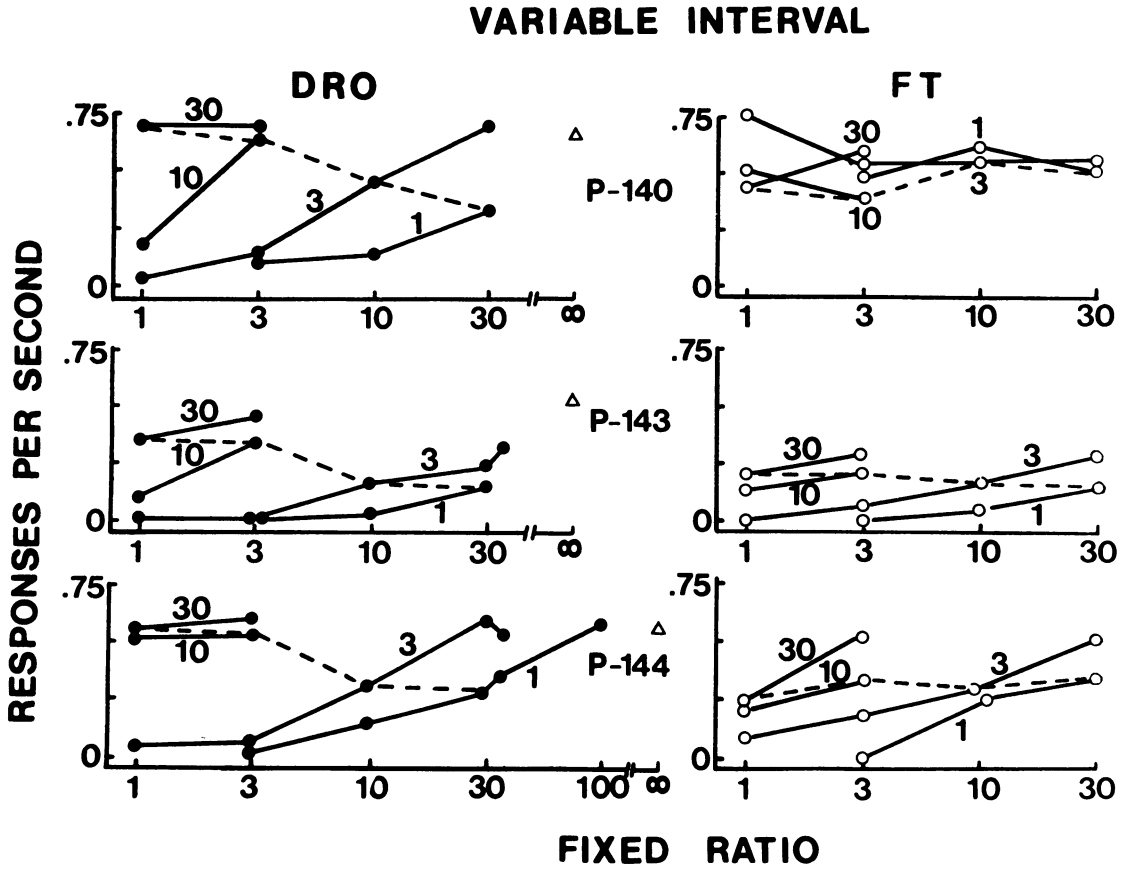
Fig. 2. Response rate under each schedule for birds having the variable-interval baseline schedule. Details as in Figure 1. The vertical axes do not have the same scale as do those of Figure 1.

less than that programmed if there were few responses, or it could exceed the programmed maximum if there was a series of short sessions (low ratios and time units) in which the VI programmer happened to arrange one or more successive intervals averaging less than 100 sec.

Figure 3 shows response rate as a function of the relative frequency of food presentation correlated with the VR or VI (food presentations per hour from these schedules divided by the total from both sources). Curves for FR (DRO) lie below those for FR(FT) for all birds over much of the range. Except at the extremes, a given relative frequency of food presentations was correlated with larger rate reductions if it was derived from the FR(DRO), rather than the FR(FT) schedule.

The relation between relative frequency, response rate, and schedules was evaluated further by means of paired comparisons. The members of each of the 53 pairs of same-valued

FR(DRO), and FR(FT) schedules sometimes produced the same relative frequencies, but often did not. The FR(FT) produced the higher relative frequency in 37 pairs, the FR (DRO) did so in 10, and the members were equal in six. In 33 pairs, response rate was lower with the member that generated the higher relative frequency or was equal when relative frequencies were equal. Of these, the FR(FT) produced higher relative frequency and lower rates in the 15 pairs involving FR 3 of 10-sec units and FR 1 and 3 of 30-sec units, as well as in four others. The FR(DRO) schedule showed this same correspondence in nine cases, and frequencies and rates were equal in five. In 19 of the remaining 20 pairs, the FR (FT) schedule produced a higher relative frequency than did FR(DRO) or relative frequencies were equal, yet FR(DRO) generated the lower response rate. In short, food given dependent on not-responding frequently con-

Table 2

Obtained Food Presentations per Hour

	P-45		P-125		P-138		P-140		P-143		P-144	
	VR	DRO	VR	DRO	VR	DRO	VI	DRO	VI	DRO	VI	DRO
VR 100	67	0	49	0	42	0						
VI 100							36	0	36	0	36	0
FR 3(DRO 1)	10	1088	0	1171			36	266	0	1185	17	1124
FR 10(DRO 1)	3	334	5	350	0	348	34	150	26	346	36	36
FR 30(DRO 1)	40	55	18	85	20	87	35	87	32	108	41	96
FR 32(DRO 1)			31	83			36	79			36	74
FR 100(DRO 1)					18	27					35	24
FR 316(DRO 1)					29	6						
FR 1(DRO 3)	0	1091	0	1173			19	947	0	1181	25	802
FR 3(DRO 3)	0	323	2	393	0	391	36	284	0	398	36	354
FR 10(DRO 3)	44	28	41	32	16	67	34	39	31	98	37	69
FR 30(DRO 3)	46	3	43	4	26	16	35	1	35	19	35	4
FR 32(DRO 3)					27	15			36	7	34	8
FR 1(DRO 10)	7	330	8	305	0	349	36	144	34	199	35	2
FR 3(DRO 10)	45	10	46	9	29	15	35	1	35	1	36	1
FR 1(DRO 30)	51	3	44	2	28	35	36	0	36	1	36	0
FR 3(DRO 30)	60	0	50	0	37	1	36	0	36	0	36	0
			VR	FT	VR	FT	VI	FT	VI	FT	VI	FT
FR 3(FT 1)			0	1187	0	1181	36	1160	0	1196	23	1152
FR 10(FT 1)			18	348	7	351	31	350	30	349	47	353
FR 30(FT 1)			37	118	10	116	34	116	36	120	35	118
FR 1(FT 3)			0	1186			35	1185	0	1181	36	1181
FR 3(FT 3)			0	392	0	395	34	392	25	391	39	395
FR 10(FT 3)			35	119	19	118	36	116	32	116	35	117
FR 30(FT 3)			40	37	30	39	36	38	32	38	35	38
FR 1(FT 10)			11	352	0	356	42	344	43	348	38	350
FR 3(FT 10)			27	116	20	115	35	116	33	118	30	119
FR 1(FT 30)			14	116	17	115	36	114	38	115	36	114
FR 3(FT 30)			47	37	36	38	36	38	36	38	35	39

trolled lower response rates than did a higher relative frequency of food presented independent of behavior.

Cumulative records gave the impression of generally steady response rates with simple VR and VI and of periods of responding separated by pauses when FR(DRO) or FR(FT) schedules were added (when responding was maintained at all). Neither the FR(DRO) nor the FR(FT) schedules seemed to control patterning consistently. The ability of the DRO schedules to contact behavior, that is, for the requirements ever to be met, indicated that the generally steady response rate could not have been representative of individual interresponse times under the VR and VI schedules. Consider P-45, the bird showing the highest baseline rate (1.7 responses per second). The average interresponse time was 0.6 sec. If rates were truly steady, the DRO requirement of 1 sec never would have been fulfilled. Yet, even 10- and 30-sec requirements resulted in food presentations. The overall impression of steady rates occurred because the pauses engendered by the VR and VI schedules were distributed throughout the sessions. Addition of FR(DRO) and FR(FT) schedules increased the frequency of the pauses, but their location continued to be unpredictable.

Steady-state response rates were established quickly. Rate in the second sessions was always within the range of those of the last five sessions. In fact, cumulative records suggested that rate stabilized after the first one or two food presentations via the FR(DRO) or FR (FT) schedules, or by the middle of the first session with VR or VI in effect alone. The mean rates, therefore, approximated performance throughout each session after the first and in most of the first as well.

DISCUSSION

Reductions in the time parameter of the DRO schedule lowered the rate of responding. Larger rate reductions with shorter required
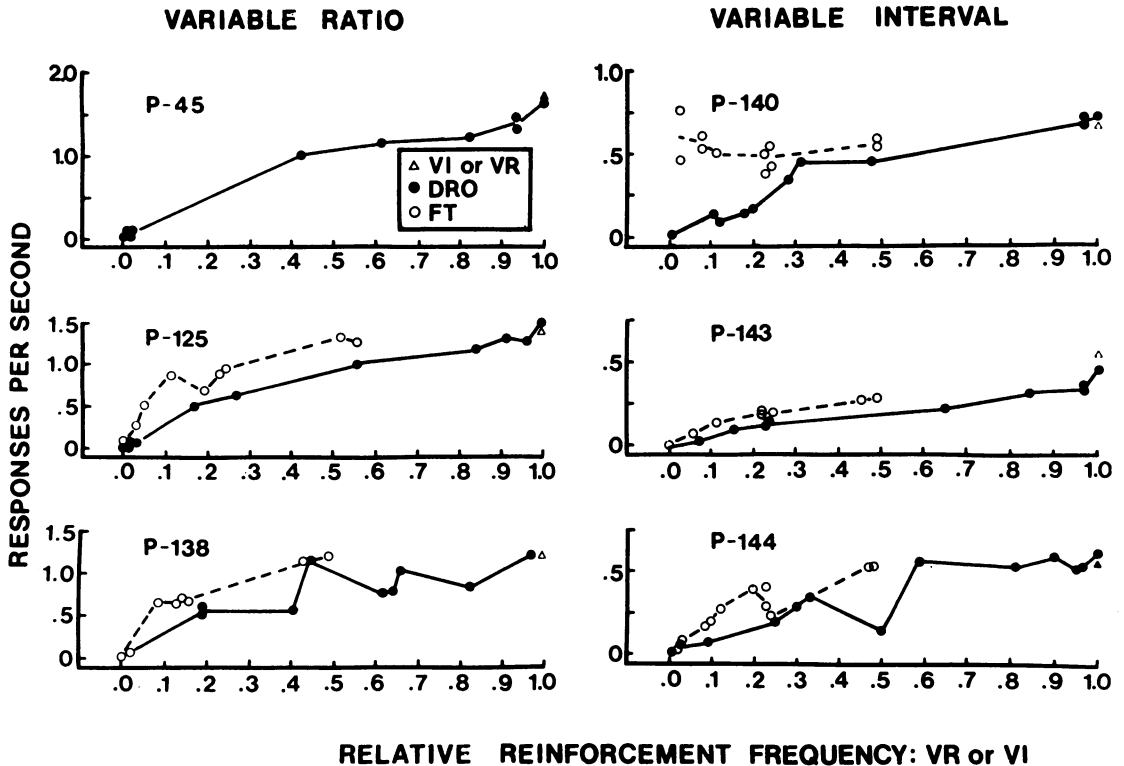
Fig. 3. Response rate as a function of the proportion of food presentations delivered via the variable-ratio (left panels) and variable-interval (right panels) schedules. Filled circles are for the FR(DRO) conditions, open circles are for the FR(FT) conditions, and triangles are for the VR and VI schedules in effect alone. When two or more points coincided exactly for a given condition, only one point is shown. The lines either connect individual points or are drawn to the approximate averages of multiple points involving the same relative frequency of food presentation. The vertical axes are scaled differently for the variable-ratio and variable-interval schedules.

pause times now have characterized performance maintained by variable-ratio and variable-interval schedules, as well as that maintained by a fixed-interval schedule (Zeiler, 1976); the phenomenon appears to be independent of the baseline schedule. The present experiment also emphasized the importance of unit duration in another way. When the total required time of not responding was held constant while varying how that total was achieved, except with very short total times the smaller the DRO unit the more responding was decreased. Apparently, shortening the unit time more than compensated for increases in units required for food delivery. The following generalization emerges: the shorter the required pause, the more responding is reduced.

In addition to highlighting the effects of DRO unit duration, the present data showed that a given duration reduced responding more the fewer units necessary for food delivery.

This aspect of fixed-ratio schedules of DRO units can be related to that of fixed-ratio schedules applied to response emission. If rate increases in the present experiment are construed as indicating less frequent occurrence of the required pause, increases in ratio size resulted in fewer pauses of the specified duration, i.e., a lower rate of occurrence of the behavior correlated with the fixed-ratio schedule. The question then arises of which data provide the most suitable comparisons. When FR schedules are in effect alone and their value is increased, response rate increases and then decreases (Felton and Lyon, 1966; Powell, 1968). A symmetrical finding would be an initial increase and then a decrease in pausing; that is, response rate in the present study should have decreased as the ratio was raised to moderate values and decreased thereafter. As no such nonmonotonic function was evident, FR schedules of response omission and

emission would not seem comparable. On the other hand, the present FR schedules were not in effect alone, but were embedded in the context of food presented for responding. The appropriate comparison, then, would be with a conjoint schedule involving an FR varied in size together with either VR or VI. No such conditions seem to have been studied. The closest situations have involved concurrent schedules with FR and fixed-interval components. As FR size was increased, response rate correlated with the FR schedule decreased (LaBounty and Reynolds, 1973; Wood, Martinez, and Willis, 1975). These findings are indeed symmetrical to the present ones. In either case, the response related to the FR schedule occurred less frequently as the FR was raised. In this respect, therefore, pausing and responding revealed equivalent effects of ratio size.

The data confirm previous ones showing that DRO and FT schedules have equivalent effects over only a limited range of time values. Even at low time requirements where the schedules operate most similarly, the DRO is likely to establish the lower rate. With still larger times, DRO consistently generates less responding. Then, with the longest times, FT may establish lower rates than DRO, because the DRO requirements are rarely if ever met. In short, when food given for responding is combined either with food given for pausing or independent of responding, the effects are parameter-dependent in almost every respect. These phenomena are not readily integrated by considering obtained frequency of food delivery for not responding. The DRO schedule has generated lower rates even when it and response-independent food delivery produce equal absolute or relative frequencies. This was found in the present and previous (Zeiler, 1976) studies with conjoint schedules, and by Davis and Bitterman (1971) with DRO and yoked response-independent schedules in effect alone.

The rate-reducing effects of DRO schedules are comparable to those of punishment. The punishment study most closely paralleling the present experiment was one by Azrin, Holz, and Hake (1963). They maintained responding with a VI schedule of food presentation and superimposed a fixed-ratio schedule of electric-shock delivery. Maximal response suppression occurred with FR 1, and responding increased with successively higher ratios. These were

similar to the present effects of ratio size with DRO units. In addition, both the present study and that of Azrin *et al.* found that the pattern of responding was not determined by the fixed-ratio schedule. Also, variations in a basic parameter, in one case shock intensity and in the other DRO time, were important. The higher the intensity or the shorter the DRO time, the lower the response rate. Another similarity was that performance was recoverable with each exposure to a given condition. This meant that removal of either punishment or DRO resulted in the recovery of responding, *i.e.*, the effects did not transfer to baseline responding. Finally, presentation of food dependent on not-responding is likely to reduce rate more than does response-independent presentation, just as response-dependent shock has larger suppressive effects than does response-independent shock (Azrin, 1956).

Differences were apparent as well. With the initial introduction of punishment, Azrin *et al.* found marked suppression followed by some degree of recovery, except with the most intense shocks. Transient effects also appeared when shock was removed, in that rate was temporarily inflated. With DRO, however, there was neither undershooting with initial onset nor temporary acceleration with removal.

To date, therefore, the response-reducing properties of DRO have compared favorably with those of punishment when both are imposed in the context of maintained reinforcement for response occurrence. Response-independent schedules sometimes act similarly, but more often do not. The primary advantage of response-independent schedules would seem to lie in the ability to operate at parameter values too large for DRO to exert significant rate-reducing effects.

A general theory capable of integrating the various aspects of these data would be most attractive. Rachlin and Baum (1972) found that a modified version of the matching law previously applied to concurrent and simple schedules (Herrnstein, 1970) could describe responding in a conjoint schedule involving VI and DRO components. Conjoint and concurrent schedules are two ways of employing two or more schedules simultaneously. The formal difference is that the same response enters into all components of conjoint schedules, whereas different responses (either in topography or in the prevailing discriminative stim-

ulus) are involved in concurrent schedules. Figure 3 shows the present data in a form suitable for application of Rachlin and Baum's equation. Although constants in the equation could be described for best-fitting curves, a nontrivial number of obtained points would deviate from the curves in several cases. However, several of the curves are reasonably smooth, and perhaps deviations can be attributed to experimental error. In general, with the exception of the FT conditions for P-140, the increased response rate with increased relative frequency of food via VR or VI corresponds with predictions from the model.

Unfortunately, the attractiveness of this account diminishes with further consideration. The model assumes that relative reinforcement frequency determines response rate (in conjunction with whatever factors control the constants in the equation). In the present case, where the two sources of food presentation were responding and not-responding, as one increased the other had to decrease. Furthermore, it does not seem surprising that as response rate decreased the relative frequency of food presentation correlated with not-responding increased. To assert a causal relation between the two dependent variables of response rate and reinforcer frequency attributes causality to correlation. Such assertions are hazardous at best, and they would seem to be particularly dangerous in the present situation, where the two variables are totally interdependent. The case might be strengthened had two different operations, DRO and FT, not shown quantitatively different effects of reinforcer frequency. Although the shapes of the curves were often similar, a given relative frequency derived from DRO reduced rate more than the same derived from FT. Whether differences stemming from different schedules are simply observed or are described quantitatively (*cf.* Baum, 1974), the same conclusion follows. Explanations based on reinforcer frequency must be qualified by consideration of how the frequency is achieved. In short, an essential aspect of DRO schedules is that they deliver a reinforcer dependent on a pause of a specified duration. If relative or absolute frequency indeed determines how reinforcers for responding and not responding are integrated, at least part of the theoretical task is to predict the obtained frequency generated by differential reinforcement of particular pause durations. No model to date is designed to predict reinforcer frequency via DRO schedules or, for that matter, with any other schedule in which frequency is uncontrolled or departs from the nominal level. Pending such theoretical development, we cannot know whether even the strongest correlations explain, sidestep, or obscure the problem.

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