

*RESPONSE-REINFORCER INDEPENDENCE AND  
CONVENTIONAL EXTINCTION AFTER FIXED-  
INTERVAL AND VARIABLE-INTERVAL SCHEDULES<sup>1</sup>*

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After training three albino rats to bar press during a multiple fixed-interval variable-interval schedule, the response-reinforcer dependency was simultaneously removed from both components, converting the schedule to multiple fixed-time variable-time. Response rates were reduced in both components under these conditions but the fixed-time schedule maintained relatively higher response rates with each rat. After reinstating the response-reinforcer dependency in both components, responding was conventionally extinguished by rendering the pellet dispenser inoperative. Responding rapidly decreased to near-zero levels. Differences in fixed and variable-time schedules in sustaining behavior are discussed in terms of differences in response rates at the time of reinforcer delivery. Similarities and differences between conventional extinction and schedules delivering response-independent reinforcers are also discussed.

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Rate of responding of rats or pigeons is reduced, but not necessarily eliminated, when the response-reinforcer dependency is removed after training on a schedule delivering response-dependent reinforcers (Edwards, Peek, and Wolfe, 1970; Herrnstein, 1966; Lattal and Maxey, 1971; Skinner, 1938; Zeiler, 1968). Any schedule of reinforcement (Ferster and Skinner, 1957) can be used to condition the response, but response-independent reinforcers can be delivered only after fixed or variable time periods. Such schedules are designated fixed-time (FT) and variable-time (VT) to distinguish them from analogous interval schedules employing response-dependent reinforcers. In a study of transitions from fixed-interval to variable-time and variable-interval to fixed-time schedules, Zeiler (1968) found that temporal distributions of key-peck responses during time schedules were controlled

by the temporal distribution of reinforcers. The development of these response distributions was independent of both the distribution of reinforcers during the preceding interval schedule and of the ongoing response rate reductions across successive sessions of the time schedules.

An alternative procedure used frequently in the study of response-independent reinforcer effects is to remove the response-reinforcer dependency from an interval schedule (Appel and Hiss, 1962; Herrnstein, 1966; Lattal and Maxey, 1971; Rescorla and Skucy, 1969; Skinner, 1938). Possible confounding effects of simultaneous changes in both the response-reinforcer dependency and in the temporal distribution of reinforcers during time schedules are thereby eliminated. Direct comparisons of reductions in responding after removing the response reinforcer dependency from fixed-interval (FI) or variable-interval (VI) schedules have not been made.

Several hypotheses have been made concerning the relative ability of the two schedules to sustain responding after removal of the response-reinforcer dependency. Edwards, *et al.*, (1970) made the general observation that the role of a time schedule in decreasing response rates is a function of "the baseline level of responding determined by the particular dependency used to build those baseline rates" (1970, p. 306). Reiterating a point made by Skinner (1938, p. 161), Rescorla and Skucy

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(1969) suggested that relatively high response rates could be expected during FT following FI training because of the positively accelerated temporal distribution of responses during FI. Such a distribution of responses would tend to maintain a close temporal relationship between responding and response-independent reinforcer delivery. They stated: "It was in an attempt to prevent such a correlation between food delivery and responding that a VI schedule was used . . ." (Rescorla and Skucy, 1969, p. 383) during training, rather than a FI schedule in the study of the effects of removing the response-reinforcer dependency. The suggestion that removal of this dependency after FI is more resistant to response rate reductions than removal after VI was not tested.

The present experiment examined response rate changes of rats when the response-reinforcer dependency was simultaneously removed from FI and VI components of a multiple schedule to assess the relative efficacy of the resulting time schedules in maintaining behavior. Since previous investigators (*e.g.*, Rescorla and Skucy, 1969) have interpreted the removal of the response-reinforcer dependency as a form of extinction, it was also of interest to compare responding during time schedules and conventional extinction (deactivation of the pellet dispenser) after FI and VI training.

## METHOD

### Subjects

Three experimentally naive male albino rats, approximately 120 days old at the beginning of the experiment, were maintained at 80% ( $\pm 15$  g) of their free-feeding weights.

### Apparatus

A Lehigh Valley Electronics (LVE) model 1417 rat chamber and enclosure was used. A single LVE rat lever was located 3.25 in. (8.4 cm) to the left of the food tray and 1.75 in. (4.8 cm) above the grid floor. It was operated by a force of about 0.14 N. A Gerbrands pellet dispenser delivered 45-mg standard Noyes pellets as reinforcers. Bright and dim levels of chamber illumination were provided through the houselight from the 30 v and 10 v outputs of a LVE model 1429 ac transformer panel. An auditory click stimulus (5 clicks

per second approximately 10 dB above the background noise level in the chamber, generated by a Foringer stimulus panel. White masking noise was continuously present in the experimental room. Control and recording equipment were located in an adjacent room.

### Procedure

After shaping the bar-press response, the animals were placed on a multiple fixed-interval 1-min variable-interval 1-min (*mult* FI 1-min VI 1-min) schedule. A brightly illuminated houselight was on during component A and a dimly illuminated houselight and auditory click stimulus were present in component B. A 15-sec period, during which the auditory stimulus, houselight, and pellet dispenser were inoperative (timeout), occurred between successive components. The sequence of components during each daily session (Monday to Friday) was A-B-B-A-B-A-A-B-A-B. Reinforcers scheduled during one component but not collected were automatically cancelled at the end of that component.

Table 1  
Sequence of Multiple Schedules for Each Animal

Condition	Number of sessions		
	Rat 1	Rat 8	Rat 9
<i>mult</i> FI 1-min VI 1-min	37	35	40
<i>mult</i> FT 1-min VT 1-min	50	25	25
<i>mult</i> FI 1-min VI 1-min	15	15	15
<i>mult</i> EXT EXT	10	9	10
<i>mult</i> FT 1-min VT 1-min	14	—	11
<i>mult</i> FI 1-min VI 1-min	11	—	11

Each rat was exposed to the multiple schedules shown in Table 1. In each, the fixed-interval or time schedule was in effect in component B and the variable-interval or time schedule was in effect in component A. The parameters of *mult* FT VT were identical to those of *mult* FI VI except that the response-reinforcer dependency was eliminated in the former. The pellet dispenser was inoperative during conventional extinction (EXT).

## RESULTS

Absolute response rates in the different multiple schedules are shown in Table 2. Overall absolute response rates (total responses/total time) were higher in FI with Rat 8 and in VI with Rats 1 and 9 (Table 2).

Table 2

Absolute response rates for each animal during the last six sessions of each of the first three conditions and during each session of the last three conditions (responses per minute).

Condition	Rat 1			Rat 8			Rat 9			
	Fixed	Fixed Terminal	Variable	Fixed	Fixed Terminal	Variable	Fixed	Fixed Terminal	Variable	
mult FI VI	68.8	111.5	69.1	65.4	96.8	59.3	66.1	120.0	73.2	
	77.0	124.0	103.4	73.4	100.3	59.5	80.0	132.6	85.4	
	69.6	100.8	83.2	76.3	106.6	69.0	93.1	151.7	92.6	
	61.8	99.0	75.9	79.1	107.4	75.2	80.1	143.8	94.0	
	62.0	114.6	80.5	72.3	103.2	58.8	76.9	137.6	84.1	
	83.4	121.9	90.4	68.2	93.4	55.8	78.6	151.0	82.7	
mult FT VT	43.3	54.7	22.2	66.0	79.8	15.9	41.0	104.6	15.0	
	45.1	63.2	25.0	55.0	72.6	19.2	36.9	104.5	10.5	
	41.6	63.2	14.8	58.5	81.0	22.3	35.2	89.1	5.8	
	42.8	55.4	21.9	55.4	69.0	26.2	41.4	100.2	19.8	
	41.8	67.0	23.8	39.2	54.6	10.4	36.6	96.6	8.4	
	44.1	54.9	26.6	47.0	55.8	15.2	32.8	86.6	13.8	
mult FI VI	41.4	71.8	61.2	59.1	100.6	43.4	49.5	117.0	37.9	
	52.2	84.6	79.1	53.9	93.4	41.9	43.8	103.2	34.1	
	50.4	73.9	76.5	61.5	115.2	55.8	50.7	121.0	42.2	
	51.4	88.6	73.2	68.4	128.6	50.8	45.8	113.1	44.6	
	59.0	97.8	88.1	49.3	84.8	44.3	50.8	124.8	43.0	
	56.5	94.7	90.2	65.5	113.0	55.9	47.6	119.7	41.4	
mult EXT EXT	27.8	32.4	30.2	8.6	10.1	9.1	17.0	22.4	15.1	
	9.6	9.9	8.9	4.4	6.6	7.0	5.0	4.0	6.8	
	1.2	1.8	16.4	1.7	0.8	3.7	12.4	12.5	8.4	
	23.3	30.2	24.9	3.0	2.2	2.4	3.0	1.9	3.6	
	7.8	10.6	19.4	11.6	12.8	14.8	2.0	1.6	1.8	
	0.0	0.0	0.7	1.6	2.8	3.2	1.7	1.3	2.0	
	0.7	0.1	0.4	0.3	0.8	5.8	0.2	0.0	1.6	
	0.0	0.0	2.6	0.0	0.0	0.4	2.4	2.1	1.0	
	0.0	0.0	0.4	0.0	0.0	1.9	0.8	0.5	1.4	
	0.0	0.0	1.4				0.4	0.0	0.8	
	mult FT VT	5.7	9.3	8.4				17.3	42.2	14.7
		11.2	19.0	7.7				6.5	19.5	2.1
8.9		15.4	5.3				13.9	48.3	0.8	
10.3		18.1	9.3				24.6	34.6	2.0	
23.9		37.7	13.7				18.1	52.0	1.8	
33.5		70.2	33.0				13.9	41.4	1.6	
37.4		70.4	23.7				11.8	36.3	1.2	
46.9		80.1	29.9				18.5	56.3	5.9	
36.2		76.5	23.3				9.4	27.0	0.6	
32.5		60.1	23.4				8.7	27.0	1.8	
33.9		66.6	13.8				16.5	47.0	2.7	
47.2		78.1	30.4							
45.0		84.0	28.1							
59.7		105.6	25.2							
mult FI VI	40.9	85.4	46.2				22.2	62.7	12.7	
	48.1	92.3	60.9				30.0	76.9	13.6	
	45.6	82.7	54.3				28.8	83.2	23.5	
	48.4	92.1	62.7				27.4	78.7	15.2	
	49.8	88.6	53.7				27.2	78.2	19.3	
	43.8	88.3	64.6				32.0	93.1	32.2	
	48.8	94.6	73.9				26.4	68.8	17.7	
	53.7	85.6	67.7				41.8	102.6	26.4	
	55.2	102.7	84.6				35.3	89.3	25.0	
	49.4	83.8	79.4				33.4	91.5	23.9	
	52.4	88.8	85.9				31.3	82.9	27.7	

Progressive reductions in responding occurred during successive sessions of response-independent reinforcer delivery following *mult* FI VI. Since absolute rates in the two components were not equal during *mult* FI VI, overall rates during FT and VT and rates during the last 15-sec of each FT period (terminal rates) were normalized with respect to the analogous mean rates during the last six *mult* FI VI sessions (*cf.* Keller and Schoenfeld, 1950, p. 76). Figure 1 shows that, with Rats 8 and 9, normalized VT rates were reduced to relatively lower levels than FT rates within one to four sessions after the response-reinforcer dependency was removed. Such differences occurred

with Rat 1 after approximately 28 sessions. Absolute terminal response rates in FT were consistently higher than the overall rates during either VT or FT (Table 2). Normalized terminal FT rates did not differ systematically from overall FT rates.

Quarter life (Q) measures of responding in FI and VI were calculated to provide an index of the temporal distributions of responses in each component. Q is defined as the portion of the interval required for the emission of one quarter of the total responses in that interval. Responses in successive quarters of FI were recorded separately and cumulated over each session. These cumulated responses

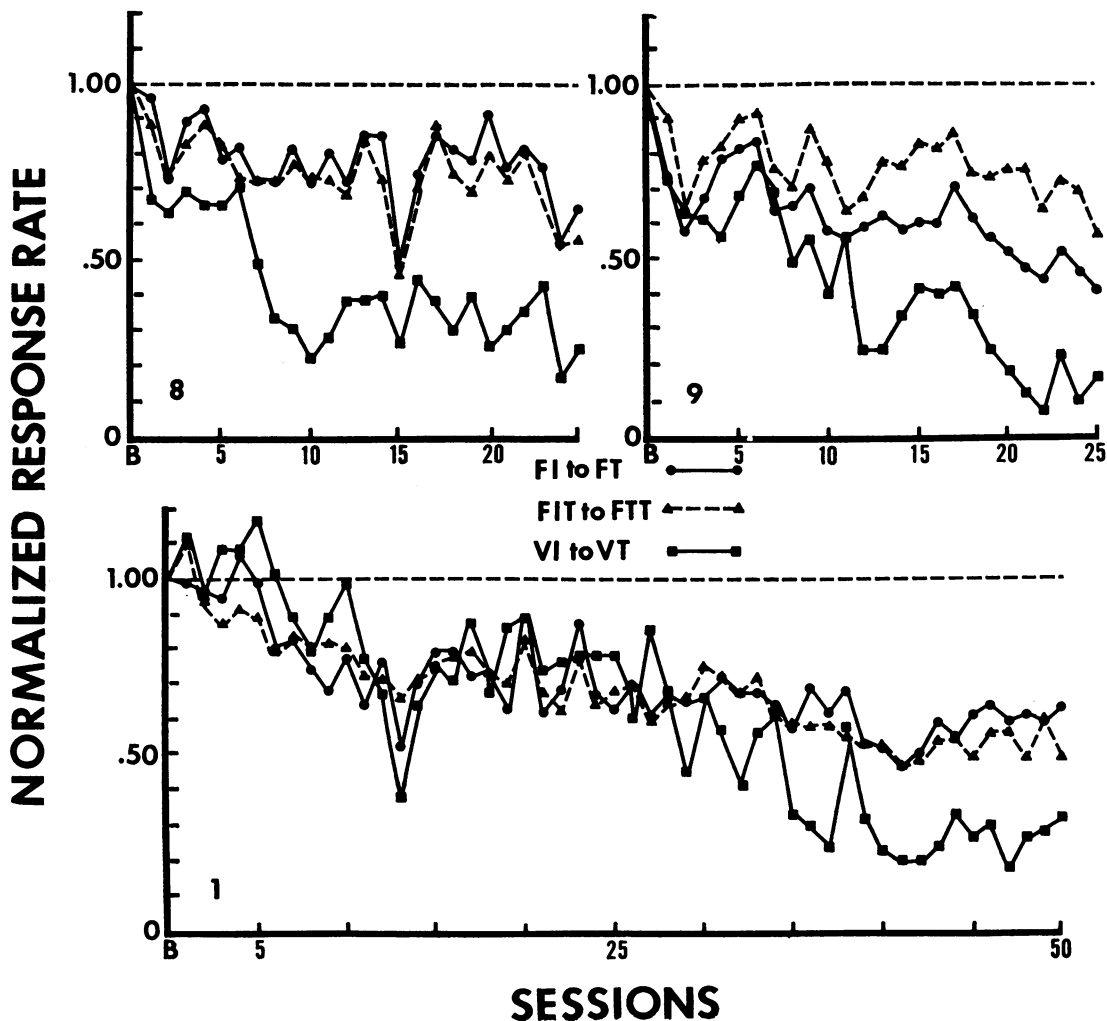


Fig. 1. Normalized response rates during the fixed- and variable-time components during successive sessions. The first schedule in each legend was in effect during "B" (baseline) on the abscissa. The second schedule in each legend was in effect during all subsequent sessions. FIT and FTT refer to terminal rates in the fixed-interval and fixed-time components and is explained further in the text.

were assumed to be a continuous variable and values of Q were interpolated from these distributions (Gollub, 1964). Q-scores for VI were computed from the cumulative response records by using the last interval in each VI component. A Q-score of 0.25 represents responding that is precisely linearly distributed in the interval. Values greater than 0.25 indicate increasingly positively accelerated response distributions. Figure 2 shows that Q-scores in VI were 0.36 to 0.38 for each rat. Since timeouts did not occur after reinforcer delivery, consumption of the food pellet occurred during the next interval. This resulted in short post-reinforcement pauses after most reinforcers, which caused the VI Q-scores to deviate from 0.25. However, VI response distributions were considerably more linear than those in FI, where Q varied between 0.59 and 0.65 for the different rats. These Q-scores support the data in Table 2, showing that the response rates in FI immediately preceding reinforcement were considerably different from overall FI response rates. Overall rates in VI, however, reflect more precisely the response rates in that component at the time of

reinforcer delivery, as indicated by Q-scores showing near-linear response distributions. Figure 3 illustrates these patterns of responding during interval and subsequent time components. Even after 25 sessions (50 for Rat 1) of time schedule training, responding at rates greater than 10 responses per minute occurred in both components with responses distributed throughout the session.

During conventional extinction, after the return to *mult* FI VI, responding in both components was reduced to near-zero rates in nine or 10 sessions (Figure 4 and Table 2). In contrast to the reductions upon removal of the response-reinforcer dependency, Rats 8 and 9 showed more rapid proportional response rate reductions during the component previously associated with FI. However, a similar effect was not systematically observed with Rat 1. Again, in contrast to the occurrence of responding throughout the session

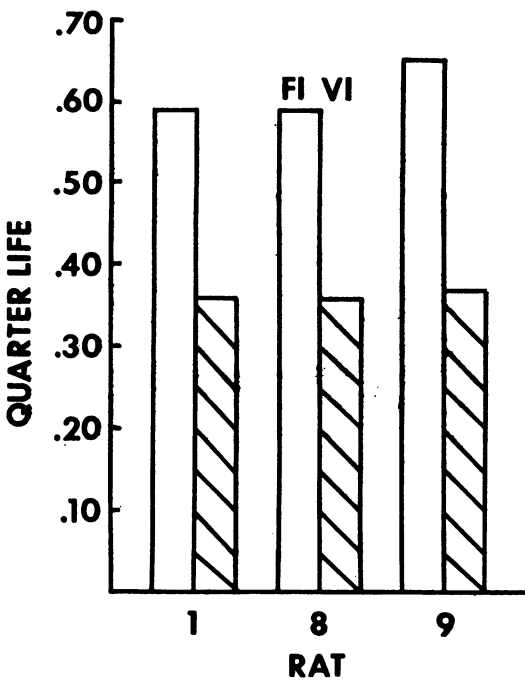


Fig. 2. Quarter-life scores (Q) in FI (solid bars) and VI (slashed bars) for each rat. Each bar is the mean Q of the last three sessions of the first *mult* FI VI condition.

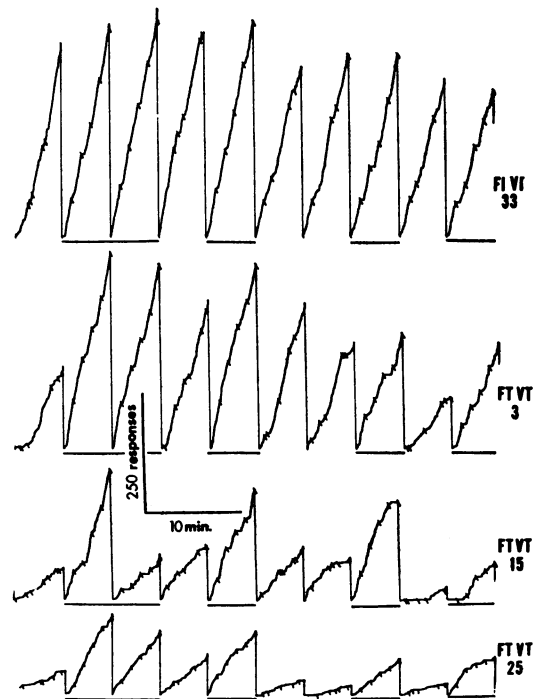


Fig. 3. Illustrative cumulative records for full sessions of Rat 8's performance during fixed (indicated by a line below the component) and variable (no line below the component) schedules. The top record is *mult* FI VI and subsequent records are *mult* FT VT. Session numbers of each record are given at the right. The response pen reset at the end of each component. Reinforcer delivery is indicated by a deflection of the response pen.

during *mult* FT VT, responding during extinction generally occurred only in the early part of each session. After the first half of the first session of *mult* EXT EXT, responding in either component occurred infrequently and then only in bursts of a few responses, separated by long pauses in responding.

Reinstatement of *mult* FT VT after extinction increased responding in both components, with higher absolute response rates in FT (Table 2). (Rat 8 was terminated after *mult* EXT EXT). As during the previous *mult* FT VT, responses occurred throughout the session in both FT and VT with Rat 1 and in FT with Rat 9. Further increases in response rates occurred when reinforcers were again made dependent upon bar pressing (*mult* FI VI). The single exception was the FI response rates of Rat 1.

#### DISCUSSION

Removal of the response-reinforcer dependency following FI training results in the maintenance of relatively higher response rates than does a similar operation after VI training. The response rate reductions and temporal distributions of responding of rats during response-independent reinforcer schedules are similar to those obtained by Zeiler (1968) with pigeons. The results also support the sugges-

tion of Edwards *et al.*, (1970) that the baseline schedule of response-dependent reinforcer delivery determines the degree to which responding is maintained when the response-reinforcer dependency is eliminated.

A consideration of the temporal distributions of responding and resulting terminal rates of response appears to account satisfactorily for these findings (*cf.* Skinner, 1938; Rescorla and Skucy, 1969). Terminal rates in FI were considerably higher than the more linearly distributed VI rates (Table 2 and Figure 2). Thus, the likelihood of a reinforcer being delivered after a higher rate of bar pressing was greater in the previously FI component when the response-reinforcer dependency was removed. The cumulative effects of successive response-independent reinforcers in reducing rates of bar pressing were greater in the previously VI component, where there was a greater relative frequency of behaviors other than bar pressing at the time of response-independent reinforcer delivery which could be adventitiously reinforced. Overall response rates in the two interval components were not systematically related to relative response rate changes after removal of the response-reinforcer dependency. They were important here in determining response rate reductions only insofar as they reflected behavior in close temporal proximity to reinforcer delivery.

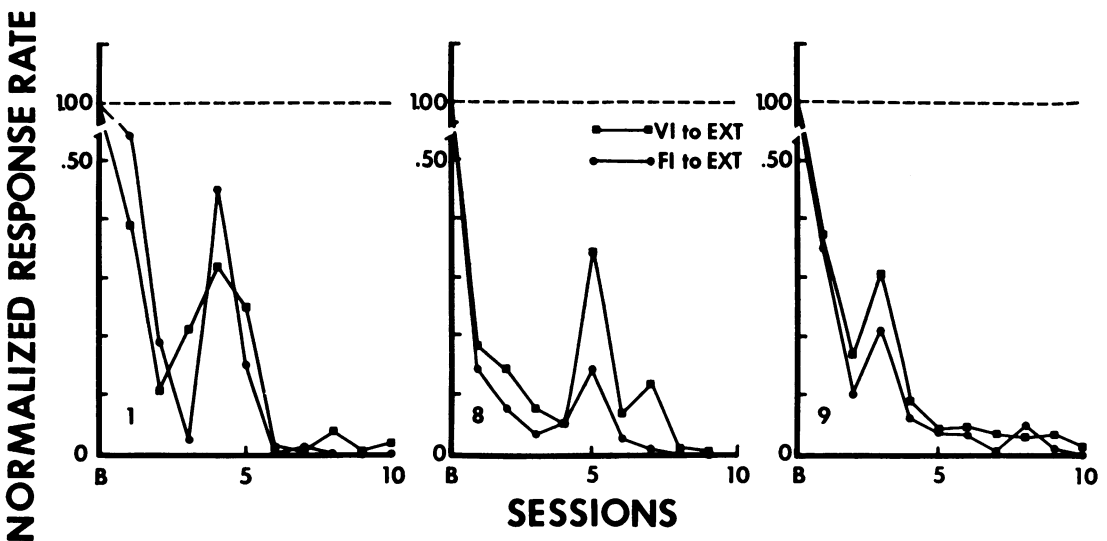


Fig. 4. Normalized response rates during successive extinction sessions. The first schedule in the legend was in effect during "B" (baseline) on the abscissa. The second schedule in the legend was in effect during all subsequent sessions. Response rates were normalized with respect to the analogous rates in the last six *mult* FI VI sessions before extinction.

Variables other than response rate differences at the time of reinforcer delivery may also be important in the present results. For example, this experiment did not attempt to differentiate rate of response and schedule of reinforcement. Experiments in which reinforcement schedules are held constant while rates of response are varied (*e.g.*, Hearst, 1960) are needed to extricate further the effects of response rates in the control of behavior during schedules delivering response-independent reinforcers. Rescorla and Skucy (1969) approximated this procedure and concluded that the rate of response at the time of transition from interval to time schedule was not systematically related to subsequent response rate reductions. To obtain different response rates, groups of rats were given VI 2-min training for 1, 2, 4, or 8 days before 13 sessions of VT 2-min. This procedure generated response rates that varied between approximately 0.50 and 8.75 responses per minute (estimated from Figure 2, p. 285) at the point of transition from VI to VT. With such low response rates it is not surprising that the independence of responding and reinforcer delivery was equally well established, in approximately the same number of sessions, with rats in the different response rate groups. In contrast, the present experiment studied such transitions when differences in VI rates and FI rates in the vicinity of the reinforcer were as great as 68 responses per minute at the time the response-reinforcer dependency was removed.

Both time schedules and conventional extinction resulted in response rate reductions, but to differing degrees (*cf.* Herrnstein, 1966; Edwards, *et al.*, 1970) and with different temporal response distributions. Kelleher (1961) showed that when conventional extinction is made more similar to previous schedules of positive reinforcement by continuing presentation of response-dependent flashes of the feeder light, temporal response distributions occur that are quite different from those found in conventional extinction when neither conditioned or primary reinforcers occur.

It is not surprising that response distributions more typical of response-dependent reinforcer schedules than of conventional extinction were obtained in the present experiment when the only difference between the positive reinforcement schedule and "extinction" was the removal of the response-reinforcer dependency

(Figure 3). Rescorla and Skucy (1969, Experiment I) found that after five sessions of VI 2-min training, rats' responding in both VT and conventional extinction reached near-zero asymptotic response rates after about 10 sessions. Responding during conventional extinction also approached a zero rate after about 10 sessions in the present experiment (even though the rats had a longer history of training with both response-dependent and response-independent reinforcers than those in the Rescorla and Skucy experiment), but responding during the time schedules was still greater than 10 responses per minute even after as many as 50 sessions. Such a difference in the number of sessions required to reduce responding during time schedules is probably related to the differences in training with interval schedules in the two experiments. This could also account for the sustained responding throughout the session in VT not found by Rescorla and Skucy (1969).

Variable-time probe sessions during conventional extinction temporarily reinstates responding, although the effect dissipates across several such probes interspersed within a conventional extinction procedure (Lattal and Maxey, 1971). The present data show that persistent reinstatement of responding can occur when time schedules are permanently reinstated, rather than used as probes, after conventional extinction. Further experimentation is needed, however, to define precisely the conditions under which this effect occurs, since it was not observed with Rat 9 during the VT component.

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