

*RESPONSE-REINFORCER DEPENDENCY LOCATION IN
INTERVAL SCHEDULES OF REINFORCEMENT*KENNON A. LATTAL, TIMOTHY J. FREEMAN, AND
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In five experiments we studied the effects on pigeons' key pecking of the location of four or more successive response-dependent reinforcers imbedded in a schedule arranging otherwise response-independent reinforcers. In Experiment 1, high local response rates early in the session were extended farther into the session as the number of response-dependent reinforcers at the beginning of the session increased. A block of four successive response-dependent reinforcers then was scheduled at the beginning, middle, or end of the session (Experiment 2) resulting in higher local response rates at those times in the session when the response-dependent reinforcers were arranged. When placed in random locations in successive sessions (Experiment 3), uniform local rates occurred throughout the session. In Experiments 1, 2, and 3, delivery of the remaining response-independent reinforcers was precluded until the response-dependent reinforcers were collected. Experiment 4 was similar to Experiments 1 and 2, except that all response-independent reinforcers occurred irrespective of whether the response-dependent reinforcers had been collected. This yielded results similar to those obtained in the first two experiments. In Experiment 5, responding early in the session had no consequence other than allowing access to the schedule of response-independent food delivery. As in the first experiment, local rates generally were higher early in the session. The results indicate that the location of response-reinforcer dependencies precisely control behavior and that such effects often are not captured by descriptions of behavior in terms of overall response rates.

Key words: variable-interval schedule, variable-time schedule, response-reinforcer dependency, response-independent food delivery, response-reinforcer dependency location, key peck, pigeons

The response-reinforcer dependency has been described by some behavior theorists as primary in the control of behavior and by others as secondary—the “glue” that holds responses in close temporal contiguity to the reinforcer (e.g., Baum, 1973; Skinner, 1948). Despite differences in emphasis over function, the centrality of dependency in most accounts of behavior is well established. The focus of an experimental analysis of the response-reinforcer dependency has been on procedures in which the dependency is either always or never present (e.g., Herrnstein, 1966; Zeiler, 1968). Combinations of reinforcers occurring independently of responding and those that are response dependent have been valuable in establishing the limits under which the response-reinforcer dependency is effective and

in establishing how dependency and temporal contiguity interact with and separate from one another. The study of such combinations also has suggested relations between response-reinforcer dependency and other behavioral processes (e.g., Rachlin & Baum, 1972; Zeiler, 1976, 1977). Despite the potential value of such combinations, relatively little is known of their behavioral effects.

In schedules that combine response-dependent and response-independent food presentations, response rates vary with the relative frequency of food presentations requiring a response (Lattal, 1973, Experiment 1, 1974; Lattal & Bryan, 1976; Rachlin & Baum, 1972). Lattal (1974) scheduled every third, 10th, or all reinforcers dependent on a response while the remainder of the reinforcers occurred independently of responding. Response rates increased systematically as the percentage of response-dependent reinforcers increased. Rachlin and Baum (1972) studied schedules in which the proportion of response-dependent reinforcers was changed by varying the average interreinforcement intervals in concurrently available variable-interval (VI) and

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Table 1

Sequence of conditions and number of sessions at each for each subject in the first experiment. The conditions are identified by the reinforcer numbers (1 is the first food presentation in a session) that were response dependent. "All" indicates a VI 60-s schedule, and "0" indicates a VT 60-s schedule.

Pigeon 1546		Pigeon 2185	
Condition	Number of sessions	Condition	Number of sessions
All	40	All	47
0	18	0	29
1-4	29	1-4	41
1-8	53	1-8	17
1-12	25	1-12	27
1-8	18	1-8	23
1-4	24	1-4	28
0	75	0	65

variable-time (VT) schedules. Their results were similar to those obtained by Lattal.

In each of these experiments, response-dependent and response-independent reinforcers were distributed relatively evenly throughout experimental sessions. Where local rates have been reported, responding also was evenly distributed within the session (Lattal, 1974; Lattal & Bryan, 1976). The effects on responding of other configurations of response-dependent and response-independent reinforcers have not been investigated. In the present series of experiments we examined the effects on responding of response-reinforcer dependency location within a larger context of reinforcers delivered independently of responding.

EXPERIMENT 1

The effects of requiring a response for the first n reinforcers of a session in which reinforcers otherwise were response independent were examined.

METHOD

Subjects

Two male White Carneau pigeons with histories of key pecking on various schedules of positive reinforcement were maintained at approximately 80% of their free-feeding weights.

Apparatus

An operant conditioning chamber (Gerbrands Model G7311) was housed in a sound-

and light-attenuating enclosure (Gerbrands Model G7210). The chamber contained a single response key, operated by a force of 0.14 N, centered on the work panel 25.5 cm from the floor. The key was transilluminated red except during reinforcement. During all conditions, reinforcement was 4-s access to mixed grain in a hopper located behind a 5-cm square aperture centered on the work panel 8.5 cm from the floor. The aperture was illuminated by two #1819 28-V lights during reinforcement. Two other such lights, located adjacent to each other in the center of the ceiling, were illuminated continuously except during reinforcement. A ventilating fan masked extraneous sounds. Electromechanical programming and recording equipment was located in an adjacent room.

Procedure

The sequence of conditions and number of sessions in each are shown in Table 1. In all conditions, food presentations were arranged according to a single distribution of interfood intervals. The mean interfood interval was 60 s and the range of intervals was 12 to 229 s. Conditions differed only according to the number of food presentations that required responses.

Subjects received preliminary training on a variable-interval 60-s (VI 60-s) schedule of reinforcement to establish key pecking (identified in the tables hereafter as requiring a response prior to "all" reinforcer deliveries). Each subject then was exposed to a variable-time 60-s (VT 60-s) schedule (identified in the tables and figures hereafter as requiring a response before "0" of the reinforcer deliveries). Thereafter, the first n reinforcers scheduled during the session were made response dependent. In these latter conditions, each of n response-dependent reinforcers, arranged according to the variable schedule, had to be collected before the next interfood interval was initiated. That is, the schedule was VI for the first n reinforcers and VT for the remainder of the session. After the last response-dependent reinforcer was collected, the remainder of the reinforcers in a session occurred independently of responding. For each subject, the number of response-dependent reinforcers was increased from four to eight to 12 and then decreased to eight and to four in successive conditions.

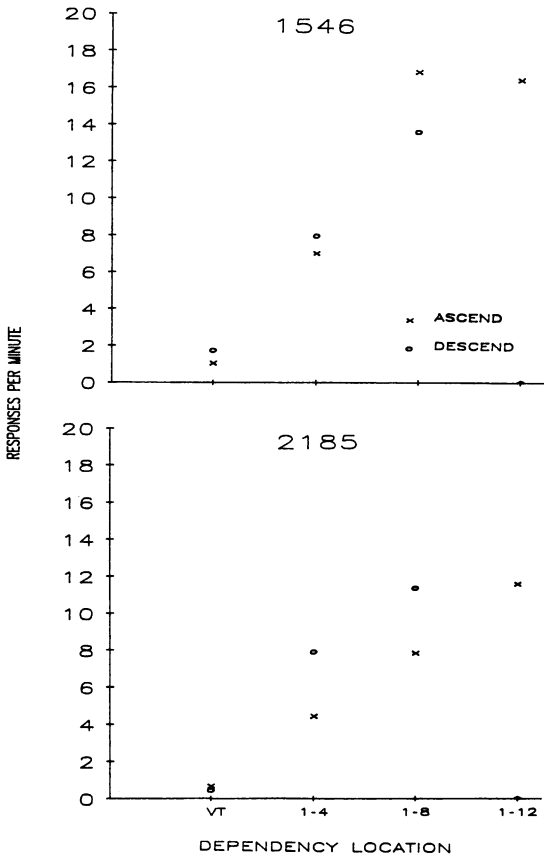


Fig. 1. Responses per minute during each condition for each subject in Experiment 1. Each data point is the mean of the last six sessions of each condition. In the ascending sequence, the order of conditions was 1-4, 1-8, and 1-12, followed by 1-8 and 1-4 conditions in the descending sequence.

Each condition was in effect until response rates were stable, defined as six consecutive sessions in which the mean response rates of the first and last 3 days did not differ by more than 3% from the 6 day mean. There were two modifications to this stability criterion. When response rates were extremely low (less than two or three responses per minute), it was difficult to achieve mathematically stable performance. Under this circumstance, a sufficient number of sessions was studied to ensure that the response rates were not changing systematically and that the patterns appeared stable on visual inspection. The other exception was that conditions sometimes were extended beyond those required to attain mathematically stable performance to examine the durability of a particular local pattern of re-

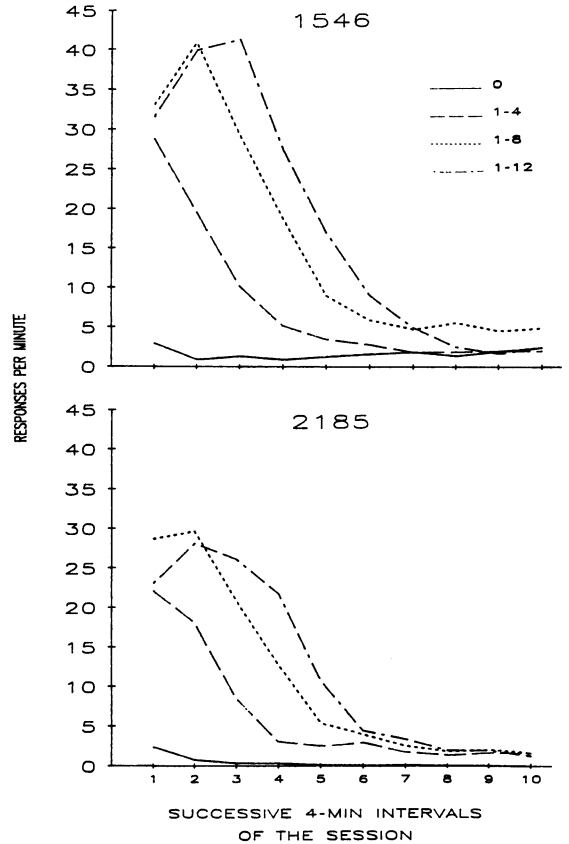


Fig. 2. Responses per minute during successive 4-min intervals of the session for each subject in Experiment 1. Data for replications of conditions have been averaged to yield a single set of points for each of those conditions. Each data point was obtained from the last six sessions of each condition.

sponding. Sessions were terminated after the 40th food presentation and were conducted 6 days per week.

RESULTS AND DISCUSSION

Average response rates were 37.7 and 56.1 for Pigeons 1546 and 2185 during the last six sessions under the VI 60-s schedule. The rates fell to near zero during the first VT 60-s condition. Figure 1 shows that, as the number of response-dependent reinforcers at the beginning of the session was increased, overall response rates (total responses/total session time) increased. Conversely, as the number of response-dependent reinforcers decreased from 12 at the beginning of the session, response rates also decreased.

Figures 2 and 3 show the distribution of

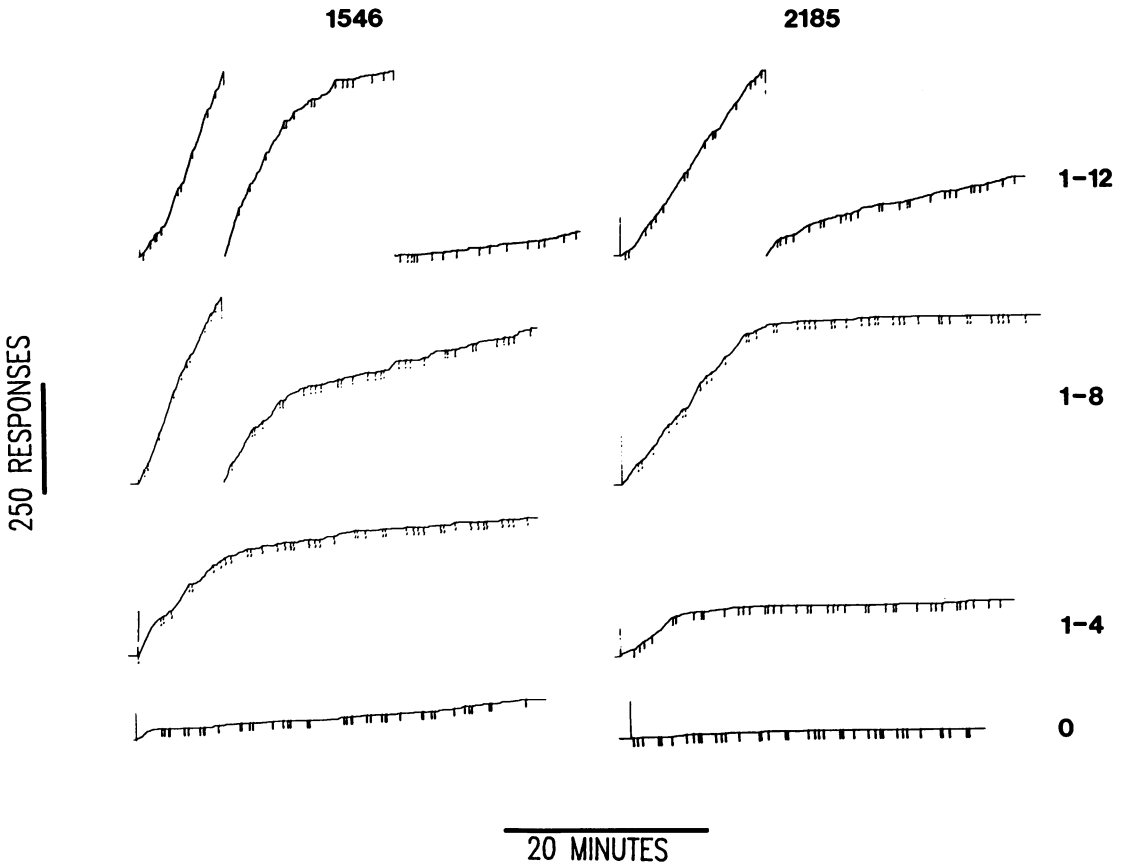


Fig. 3. Illustrative cumulative records showing stable performance from each condition for each subject in Experiment 1.

responses across individual sessions for each subject. Figure 2 shows responses per minute across successive 4-min intervals of the session and Figure 3 illustrates these effects with cumulative records for each subject. In this and all subsequent graphs depicting data in 4-min intervals, the final interval was slightly more or less than 4 min long depending on when reinforcement occurred. That is, because the schedule was variable interval/time, the 4-min interval beginning with Minute 36 might contain more or fewer than four reinforcers and thus be more or less than 4 min in duration. Because the effects were similar for both of the 1-4 and 1-8 conditions, data from each were averaged in Figure 2. For each subject, two effects are depicted in Figure 2. First, response-dependent reinforcers at the beginning of the session initially elevated response rates relative to those engendered by the re-

sponse-independent food delivery (VT) schedule; those rates then decreased as the session progressed. Second, as the number of response-dependent reinforcers increased, response rates remained higher for proportionately longer periods of time into the session. These effects on local response rates are corroborated for individual sessions by the cumulative records in Figure 3.

Four response-dependent reinforcers at the beginning of the session increased overall response rates relative to those maintained by response-independent food delivery, replicating an effect reported by Lattal (1974). Unlike Lattal's data, the local rates of responding within the session were markedly higher at the beginning of the session and were controlled by the location of the response-dependent reinforcers. Schedules of response-independent food delivery sometimes led to elevated response

rates early in the session, as the VT schedule local rate data in Figure 2 reveal. That the reported effects of added response-reinforcer dependencies early in the session were not simply a continuation of this pattern is suggested by two further observations. First, adding response-dependent reinforcers at this location yielded much higher rates than those obtained with the VT schedule. Second, including additional response-dependent reinforcers extended the period of high-rate responding.

EXPERIMENT 2

Because the response-dependent reinforcers occurred only at the beginning of the session in Experiment 1, it was of interest next to examine the effects of arranging four successive response-dependent reinforcers at different temporal locations within experimental sessions.

METHOD

Subjects and Apparatus

Two male White Carneau pigeons with histories of key pecking on various schedules of positive reinforcement were maintained at approximately 80% of their free-feeding weights. The apparatus was the same as that described for Experiment 1.

Procedure

The sequence of conditions and number of sessions in each are given in Table 2. The procedures, including stability criteria, otherwise were as described for the first experiment.

The birds first were trained on a VI 60-s schedule and subsequently on a VT 60-s schedule as described in Experiment 1. Following this, the procedure was similar to that used in the condition in Experiment 1 in which four response-dependent reinforcers were scheduled. It differed in that the location of these four reinforcers within a session was varied. In different conditions, food-delivery numbers 1-4, 18-21, or 37-40 required responses and all others did not. For example, in the 18-21 condition, the first 17 food deliveries occurred independently of responding and were arranged according to an interfood interval distribution with a mean of 60 s. The next four scheduled reinforcers were delivered when available only following a response. After this,

Table 2

Sequence of conditions, number of sessions, and average response rates (per minute) over the last six sessions of each condition for each subject in the second experiment. The conditions are identified by the reinforcer numbers (1 is the first food presentation in a session) that were response dependent. "All" indicates a VI 60-s schedule, and "0" indicates a VT 60-s schedule.

Pigeon 5233			Pigeon 5554		
Condition	Number of sessions	Response rate	Condition	Number of sessions	Response rate
All	40	61.80	All	3	44.14
0	49	0.03	0	25	2.79
1-4	19	3.75	1-4	11	4.31
18-21	40	30.36	18-21	48	4.54
1-4	57	4.33	1-4	36	2.82
37-40	75	18.05	37-40	38	5.74 ^a
0	53	0.41			

^a Bird died prior to achieving stable performance on this condition.

the 22nd and all remaining food deliveries occurred independently of responding. As in Experiment 1, the same interfood interval distribution was used throughout the different dependency locations.

RESULTS AND DISCUSSION

Table 2 provides overall response rates for each condition. The location of the four response-dependent reinforcers did not systematically affect overall response rates similarly in the 2 subjects. Figures 4 and 5 show, however, that the location of these four reinforcers systematically altered the pattern of responding across the session. Figure 4 provides response rates in successive 4-min intervals of the session and Figure 5 illustrates these effects with cumulative records of each subject from each condition. Because the effects were similar under the two 1-4 conditions for each subject, the data presented in Figure 4 for these conditions are means of the two replications. Locating the four response-dependent reinforcers at the beginning of the session replicated the local response rate patterns shown in Figure 2. When the response-dependent reinforcers were scheduled as the last four in the session, response rates gradually increased across the session. Pigeon 5554 also had an elevated local rate early in the session that declined to near zero before increasing again

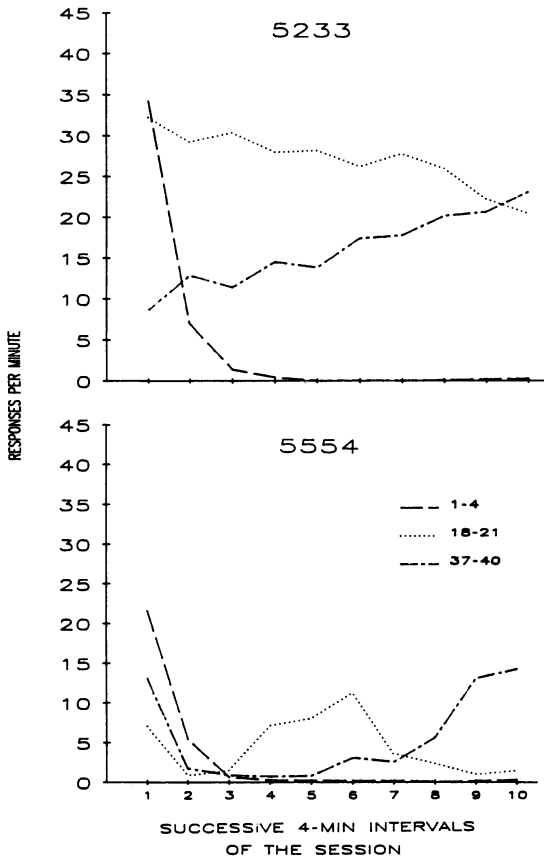


Fig. 4. Mean responses per minute during successive 4-min intervals of the session for each subject in Experiment 2. Data for replications of conditions have been averaged to yield a single set of points for each of those conditions. Each data point was obtained from the last six sessions of each condition.

across the remainder of the session. Locating these reinforcers in the middle of the session resulted in relatively high, consistent responding across the session for Pigeon 5233. This pattern for Pigeon 5233 developed after about 15 sessions of the condition. Under this condition, the responding of Pigeon 5554 increased gradually until midsession, after which its rates declined gradually. Pigeon 5554 responded some at the beginning of each session during each condition. However, these local rates at the beginning of each session were highest when the first four reinforcers were response dependent. Response rates in successive 4-min intervals of the session during the VT schedules were uniformly low and are not included in Figure 4.

Varying the proportion of response-dependent and -independent reinforcers controls overall response rates (Experiment 1 above; Lattal, 1974; Rachlin & Baum, 1972). In this experiment the number of response-independent reinforcers was constant at four, and overall response rates were not related systematically to dependency location. Overall response rates are an average of local response rates. Although local response rates varied as a function of the dependency location, the considerable variability in local rates resulted in overall rates in different conditions that did not differ systematically across the conditions. Of the different locations, the four response-dependent reinforcers located in midsession might be expected to yield the highest rates, in that responding before and after they occur could be elevated, whereas with the beginning and end locations, responding before and after the dependencies was constrained by the onset and termination of the session.

EXPERIMENT 3

In the first experiment, dependency location was constant (beginning), and the number of reinforcers in the block was varied. In Experiment 2, the number of reinforcers in the block was constant and the location was varied across conditions. That is, within a condition, the response-dependent reinforcers always occurred as the n to the $n + 3$ reinforcers of a session. In Experiment 3, we varied the location of the block of four response-dependent reinforcers randomly across successive sessions of a single condition.

METHOD

Subjects and Apparatus

Three male White Carneau pigeons were used. Each had a history of key pecking on various reinforcement schedules, and one (Pigeon 5233) previously served in Experiment 2. The apparatus was the same as that described for Experiment 1.

Procedure

The sequence of conditions and number of sessions in each are provided in Table 3. Pigeons 3482 and 9521 first were trained on a VI 60-s schedule and then exposed to a VT 60-s schedule. Because Pigeon 5233 had been exposed to the conditions in Experiment 2, it

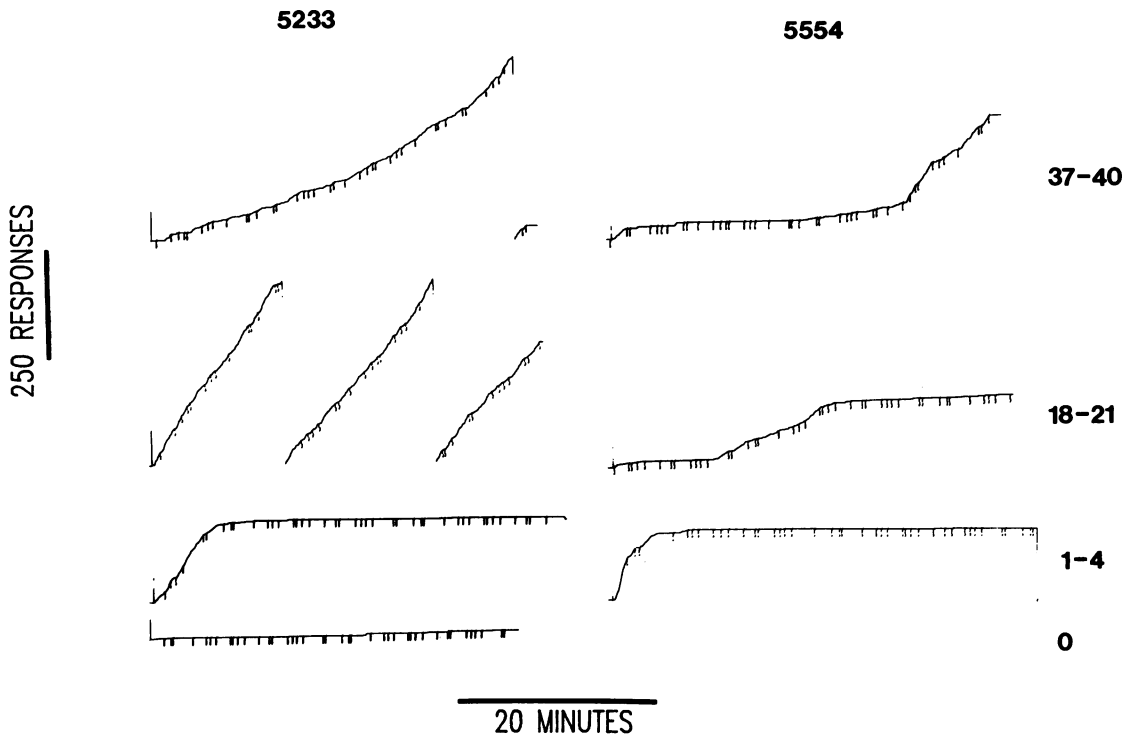


Fig. 5. Illustrative cumulative records showing stable performance from each condition for each subject in Experiment 2. Cumulative records for the VT condition (0) were not obtained for Pigeon 5554.

was assigned directly to the VT 60-s schedule. During the random condition, four successive response-dependent reinforcers were scheduled according to the distribution of variable interreinforcement intervals with a mean of 60 s. Prior to each day's session, the location of the first of these reinforcers was assigned randomly to occur between the first and 37th reinforcer of a session in which a total of 40 reinforcers were delivered. The remaining 36 reinforcers, before and after the block of four response-dependent reinforcers, were delivered independently of responding. For example, if the first response-dependent reinforcer was assigned to be the fifth reinforcer delivered during the session, the fifth, sixth, seventh, and eighth reinforcers required a response for their delivery. Reinforcers 1-4 and 9-40 occurred independently of responding. Reinforcers 9-40 were made available only after Reinforcers 5-8 were collected. In the next session, the block of response-dependent reinforcers might be assigned to Reinforcers 27-30 of the session, and so on. The random condition was compared to a condition in which

the 37th to the 40th reinforcers in a session always were response dependent. This latter condition was as described in Experiment 2. The procedures, including stability criteria, were otherwise as described for the first experiment.

RESULTS AND DISCUSSION

As the data in Table 3 show, locating the block of four response-dependent reinforcers randomly or at the end of the session (Numbers 37-40) yielded intermediate overall response rates between those obtained during the VI 60-s and VT 60-s schedules, but these intermediate rates did not differ systematically from one another.

Figure 6 shows the response rates for successive 4-min intervals of the session during the VT, random, and 37-40 conditions. Because the patterns were similar in successive replications of the conditions, data were averaged across these replications for each subject. The VT condition yielded low, rather evenly distributed responding across the session. The random dependency location con-

Table 3

Sequence of conditions, number of sessions, and average response rates (per minute) over the last six sessions of each condition for each subject in the third experiment. The conditions are identified by the reinforcer numbers (1 is the first food presentation in a session) that were response dependent. "All" indicates a VI 60-s schedule and "0" indicates a VT 60-s schedule.

Pigeon 3482			Pigeon 5233			Pigeon 9521		
Condition	Number of sessions	Response rate	Condition	Number of sessions	Response rate	Condition	Number of sessions	Response rate
All	62	34.63	0	53	0.34	All	72	63.35
0	18	0.78	37-40	29	14.50	0	43	0.45
Random	43	8.77	Random	42	20.09	Random	53	17.46
0	30	1.33	37-40	99	7.74	0	28	0.34
Random	20	10.05				Random	41	9.49
37-40	28	10.55				37-40	12	11.55
Random	14	15.74				Random	19	10.81

dition also yielded local response rates that were distributed evenly across the session and local rates that were higher than during the VT conditions. The 37-40 condition yielded patterns like those reported for an identical condition in Experiment 2, that is, gradually increasing response rates across the session. The effects of random dependency location were distinct from those of other birds in the 1-4 condition in Experiments 1 and 2, from those of other birds in the 37-40 condition in Experiments 1 and 2, and from the 37-40 condition of Pigeons 5233 and 3482 in the present experiment. The effects of the random and 37-40 conditions with Pigeon 9521 were similar except that rates in the 37-40 condition were slightly lower than in the random condition in the first 4 min of the session and higher in the last 4 min of the 37-40 condition than in the same period of the random condition. Inspection of the cumulative records from these subjects suggested that, in general, response rates following response-dependent and response-independent reinforcers did not differ.

Lattal (1974) found that six single response-dependent reinforcers distributed evenly among 54 response-independent reinforcers yielded equal local response rates across the session. One question raised by the present findings is how the effects of four single response-dependent reinforcers distributed randomly across the session would compare to the present procedure in which a block of four response-dependent reinforcers was located randomly across successive sessions. Comparing the present random condition results to those of Lattal

(1974) suggests that the effects would be similar.

EXPERIMENT 4

In each of the first three experiments, it was necessary that the four response-dependent reinforcers be obtained before further response-independent reinforcers were delivered. (The only exception, of course, was in the 37-40 condition in which the session terminated with the last response-dependent reinforcer.) As a result, the obtained patterns could have developed in part because of the remote contingency between responding and subsequent delivery of response-independent reinforcers remaining beyond the block of the four that were response dependent (see Hammond, 1980). To examine this possibility, the dependency location manipulations of Experiments 1 and 2 were replicated. However, instead of requiring that the response-dependent reinforcers be collected before further response-independent reinforcers were delivered, the response-dependent and the response-independent reinforcers were arranged concurrently according to two independent schedules. As a result, the delivery of reinforcers from the two sources was independent of one another.

METHOD

Subjects and Apparatus

Five White Carneau pigeons as described in Experiment 1 served as subjects. Pigeons 1546 and 2185 previously served in Experiment 1. The others had a history of key pecking

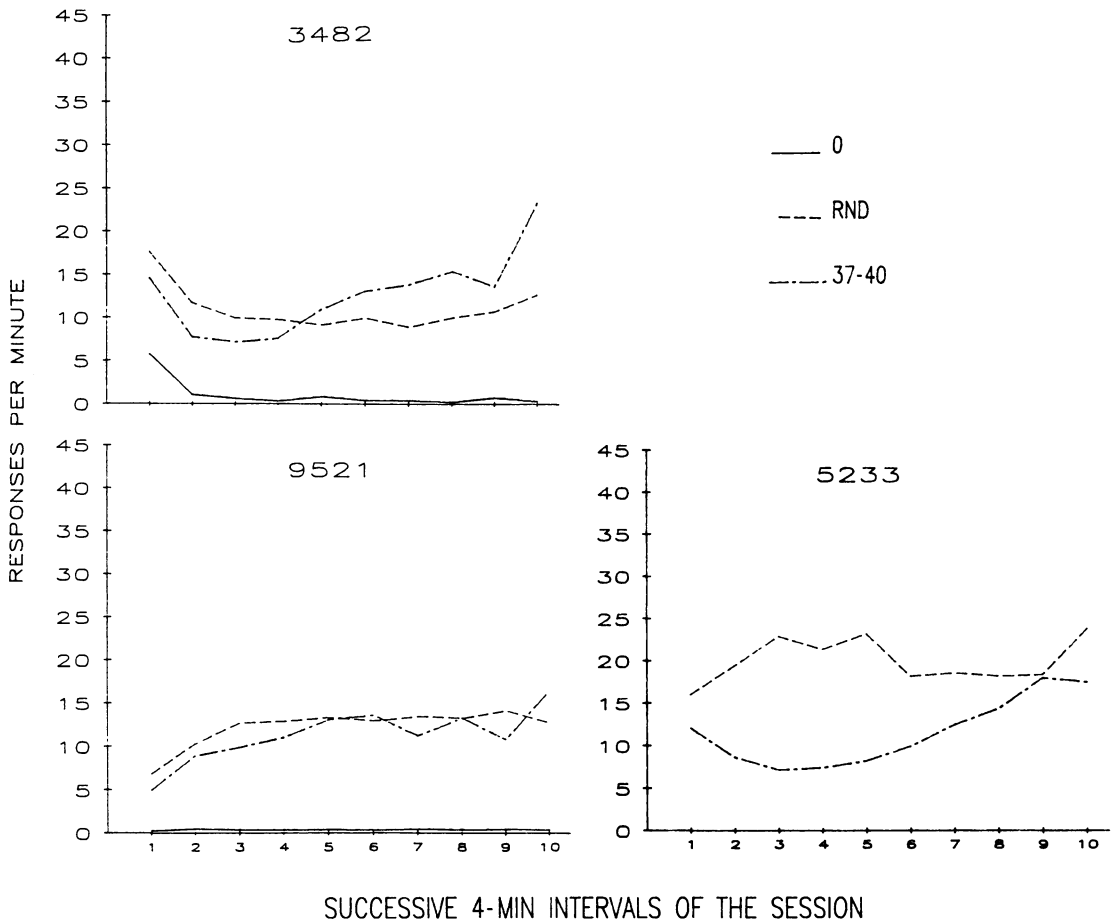


Fig. 6. Mean responses per minute during successive 4-min intervals of the session for each subject in Experiment 3. Data for replications of conditions have been averaged to yield a single set of points for each of those conditions. Each data point was obtained from the last six sessions of the condition. Data for the VT condition (0) were not obtained for Pigeon 5233.

on different schedules of reinforcement. The apparatus was as described in Experiment 1.

Procedure

The sequence of conditions and number of sessions in each for each subject are provided in Table 4. Pigeons 344, 2543, and 7335 first were trained on a VI 60-s schedule and then on a VT 60-s schedule. Then, a concurrent schedule in the presence of a single key was implemented. One component was a VT 60-s schedule, and the other component arranged n successive key-peck-dependent reinforcers according to a variable-interval 60-s schedule (range, 12 to 229 s) at different locations within the sessions. There was no changeover delay between the components. Pigeons 1546 and

2185 were exposed to concurrent schedules in which the response-dependent reinforcers were scheduled concurrently starting with session onset and continuing until n were collected as indicated in the sequence of conditions. The value of n was four, eight, or 12 in the different conditions. For the remaining subjects, the VI schedule arranging response-dependent reinforcers was effected either at the beginning of the session (concurrent, conc, 1-4), after the 17th response-independent reinforcer of the session was delivered (conc 18-21), or after the 36th such reinforcer was delivered (conc 37-40). For these 3 subjects, the VI 60-s schedule continued to operate concurrently with the VT 60-s schedule until four reinforcers were obtained by key pecking. Between the conc 1-

Table 4

Sequence of conditions, number of sessions, and average response rates (per minute) over the last six sessions of each condition for each subject in the fourth experiment. The conditions are identified by the reinforcer numbers (1 is the first food presentation in a session) that were response dependent. "All" indicates a VI 60-s schedule, and "0" indicates a VT 60-s schedule.

Pigeon 344			Pigeon 1546			Pigeon 2185			Pigeon 2543			Pigeon 7335		
Condition	Number of sessions	Response rate	Condition	Number of sessions	Response rate	Condition	Number of sessions	Response rate	Condition	Number of sessions	Response rate	Condition	Number of sessions	Response rate
All	23	72.86	0	75	1.74	0	65	0.45	All	26	37.98	All	34	48.54
0	56	0.39	conc			conc			0	22	2.46	0	35	0.55
conc			1-4	17	11.33	1-4	33	3.69	conc			conc		
18-21	61	21.90	conc			conc			1-4	29	26.46	1-4	30	5.43
			1-8	18	11.96	1-8	22	8.89	0	33	1.08	conc		
			conc			conc			conc			37-40	45	5.13
			1-12	12	17.57	1-12	109	12.99	18-21	63	17.28			
			conc			0	42	4.05	0	98	3.62			
			1-8	7	14.88				conc					
									37-40	47	14.48			

4 and conc 37-40 conditions, Pigeon 7335 was exposed to contingencies not relevant to the present comparisons (indicated by dashed lines in the table). Because response-dependent and response-independent reinforcers were available concurrently, local reinforcement rate and response-reinforcer dependency increased together as the number of response-dependent reinforcers was increased across conditions. As a partial check on these effects, following the last conc 1-12 condition Pigeon 2185 was exposed to a VT schedule arranging an identical number of reinforcers to that in the conc 1-12 condition.

Sessions ended after the 40th response-independent reinforcer was collected. Thus, the total number of reinforcers per session for Pigeons 1546 and 2185 varied between 44 and 52 in the different conditions, and for the others it was 44. Conditions were changed according to the stability criterion described in Experiment 1. Other procedural features were as described in the first experiment.

RESULTS AND DISCUSSION

Each subject always collected all of the concurrently scheduled response-dependent reinforcers in a session, typically within a few seconds of their availability. Figure 7 shows that, as in the first experiment, overall rates under the concurrent schedules increased as the number of concurrently available VI reinforcers at

the beginning of the session increased (Pigeons 1546 and 2185, cf. Figure 1). As in Experiment 2, there was no systematic relation between overall response rates and the location of the concurrently available response-dependent reinforcers at the beginning (conc 1-4), middle (conc 18-21), or end (conc 37-40) of the session (see Table 4).

Figure 8 shows response rates during successive 4-min intervals of the session for each subject. As in the previous figures, data for each subject during each dependency location were averaged across replications because the patterns were similar. The response patterns during the session under the different concurrent schedules were similar to those obtained in Experiments 1 and 2 where collection of the response-dependent reinforcers was required before further response-independent reinforcers occurred. This comparison can be made directly for Pigeons 1546 and 2185 by comparing these data to those presented in Figure 2. Pattern data for Pigeons 344, 2543, and 7335 also were similar to those for the subjects in Experiment 2 (cf. Figure 4). The effects of changes in local reinforcement rate appeared to be small relative to that of the changes in the response-reinforcer dependency. For Pigeon 2185, the local response rates under the VT schedule arranging an identical reinforcement frequency to that in the conc 1-12 condition were approximately one

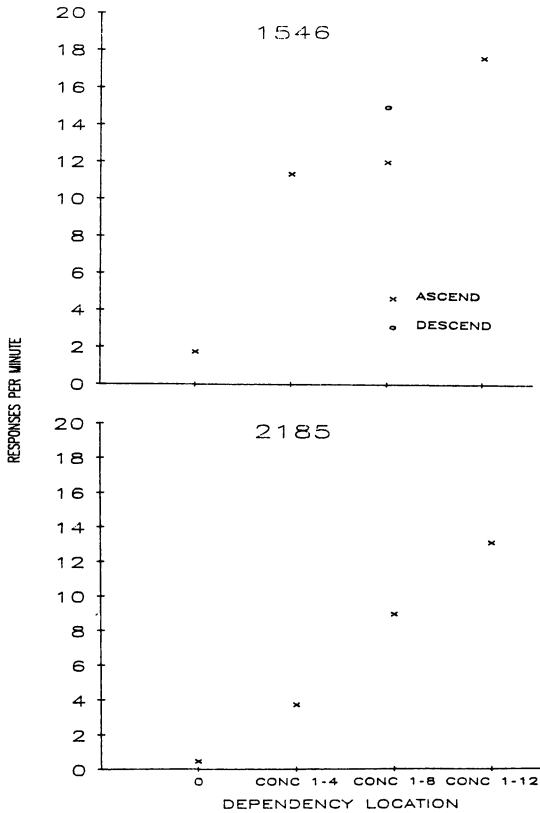


Fig. 7. Responses per minute during each condition for Pigeons 1546 and 2185 in Experiment 4. Each data point is the mean of the last six sessions at each condition. In the ascending sequence, the order was 1-4, 1-8, and 1-12. In the descending order, for Pigeon 1546 the manipulation was a return to the 1-8 condition.

half to one third what they were when the reinforcers were response dependent in the first six successive 4-min intervals of the session.

Hammond (1980) suggested that the contingency between collection of response-dependent reinforcers and subsequent delivery of response-independent reinforcers may be a factor in the maintenance of responding in schedules combining response-dependent and response-independent reinforcement. Comparison of the results of Experiment 4 to those of Experiments 1 and 2 suggests that the contingency described by Hammond had no systematic effect on the response patterns controlled by the response-reinforcer dependency location. That is, similar behavioral patterns were obtained regardless of whether the delivery of response-independent reinforcers required prior completion of the requirements

for response-dependent reinforcers. Similarly, within-subject comparisons (Pigeons 1546 and 2185) reveal no consistent effect of this contingency on overall (session) response rates.

EXPERIMENT 5

Neuringer (1973) found that operant responding could be maintained when such responding produced or sustained periods of response-independent food delivery at times temporally remote from the operant response. Despite the results of Experiment 4, it seems plausible that the contingency between responding and subsequent response-independent reinforcer delivery might be sufficient to maintain at least some responding. The delivery of food following responding in the dependency location manipulations described in Experiments 1, 2, and 3 may obscure any effects of the contingency alone. To examine possible contingency effects more directly and independently of the response-strengthening effects of the response-dependent reinforcers, the final experiment was conducted. The effects of the contingency between responding and subsequent delivery of response-independent reinforcers were isolated from food delivery by retaining the contingency but omitting the food presentation following completion of the response requirement.

METHOD

Subjects and Apparatus

Three White Carneau pigeons as described in Experiment 1 served as subjects. Pigeons 344 and 7335 were used previously in Experiment 4. The apparatus was as described in Experiment 1.

Procedure

The sequence of conditions and number of sessions in each are provided in Table 5. Pigeon 474 had been trained previously on a VT 60-s schedule and was placed directly in the first condition. The other 2 subjects first were exposed to a VT 60-s schedule. Pigeon 474 was exposed to the conc 1-4 condition as described in Experiment 4. Each pigeon was exposed to a condition, described hereafter as pseudo 1-4, in which a VI 60-s schedule was effected with the session onset. When the first interreinforcement interval lapsed, the VI tape programmer ceased operation. A key peck

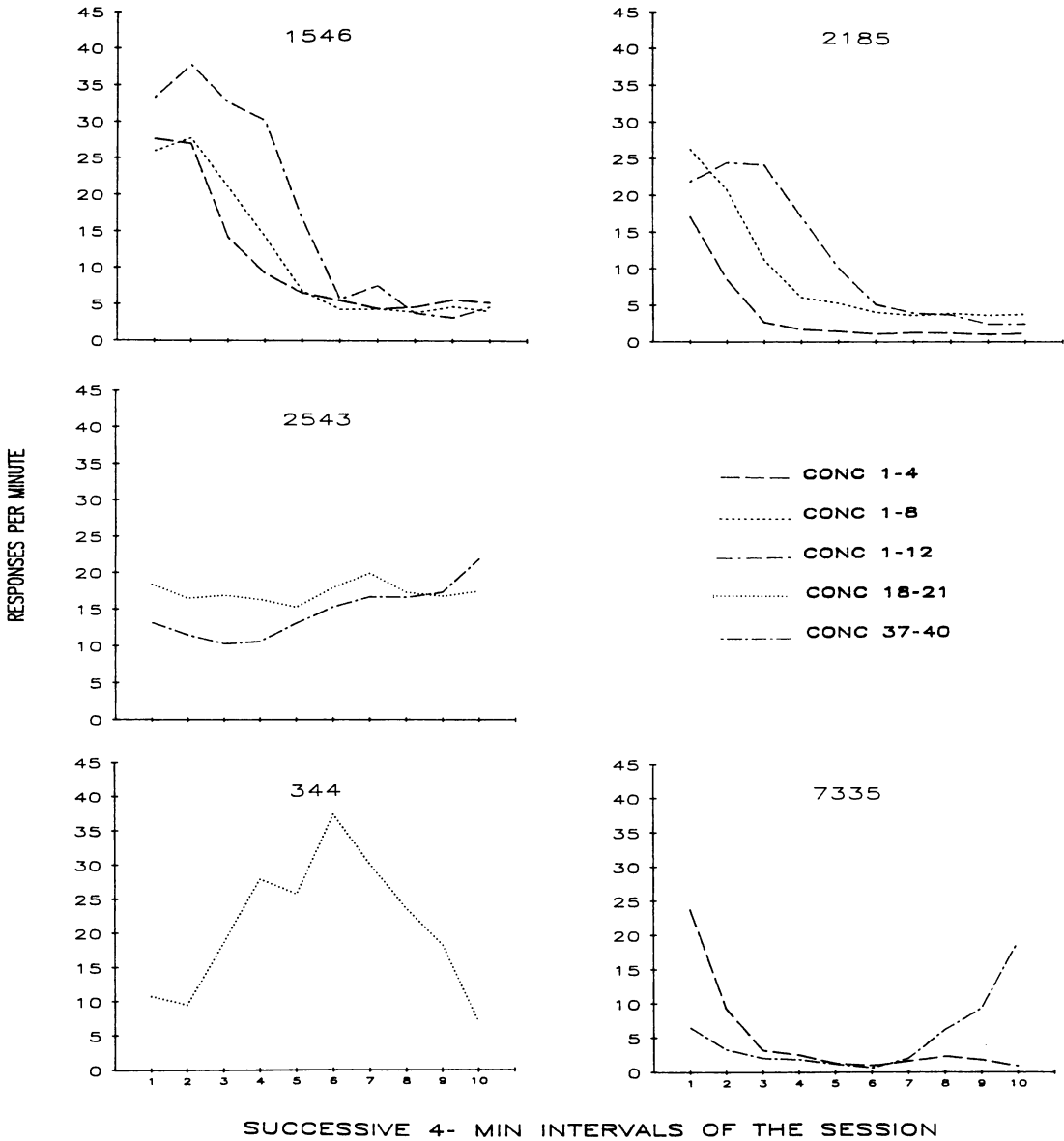


Fig. 8. Mean responses per minute during successive 4-min intervals of the session for each subject in Experiment 4. Data for replications of conditions have been averaged to yield a single set of points for each of those conditions. Each data point was obtained from the last six sessions of the condition. These data for the 1-4 condition for Pigeon 2543 were not collected.

reactivated the VI tape programmer but had no scheduled consequence in the chamber. This procedure was repeated three more times, after which the VI schedule was discontinued and reinforcers were delivered according to a VT 60-s schedule. Thus, the contingency was as in the 1-4 conditions of Experiments 1 and 2, except that food delivery was omitted following

key pecks. The procedures otherwise were identical to those described in Experiment 1.

RESULTS AND DISCUSSION

Overall response rates, shown in Table 5, were lowest when the VT schedule was in effect and only slightly higher when the pseudo 1-4 condition was in effect. The conc 1-4 con-

Table 5

Sequence of conditions, number of sessions, and average response rates (per minute) over the last six sessions of each condition for each subject in the fifth experiment. The conditions are identified by the reinforcer numbers (1 is the first food presentation in a session) that were response dependent. "All" indicates a VI 60-s schedule and "0" indicates a VT 60-s schedule. "Pseudo" refers to the condition in which four key-peck response requirements had to be met prior to the initiation of the VT 60-s schedule.

Pigeon 344			Pigeon 474			Pigeon 7335		
Condition	Number of sessions	Response rate	Condition	Number of sessions	Response rate	Condition	Number of sessions	Response rate
0	19	0.23	conc			0	55	0.38
pseudo			1-4	47	16.44	pseudo		
1-4	30	0.66	pseudo			1-4	60	2.86
0	56	0.39	1-4	104	0.50	0	25	0.55

dition yielded higher overall rates than the pseudo for the 1 pigeon (474) exposed to this condition.

Figure 9 shows the distribution of responses across successive 4-min intervals of the session. The pseudo 1-4 condition resulted in relatively high response rates in the early minutes of the session, but these rates were lower than those obtained when reinforcers followed key pecks in the analogous conc 1-4 condition (Pigeon 474). In the early part of the session, the differences between VT and pseudo 1-4 conditions were slight for Pigeon 344 but marked for Pigeon 7335. The pseudo 1-4 data for Pigeon 7335 can be compared to the conc 1-4 data for this subject in Figure 8. In the first 4 min of the session under the 1-4 condition, response rates were about 24 responses per minute, whereas in the pseudo 1-4 condition they were about 17 responses per minute.

These results suggest that, in the absence of response-dependent reinforcement, a contingency between responding and subsequent response-independent reinforcer delivery maintains higher local responding relative to that maintained in the absence of such a contingency (cf. Neuringer, 1973). The effect was small for 1 subject (344) and larger for the other (7335). Such remote contingencies do not appear to provide a general account of the magnitude of the local rate effects obtained when reinforcers immediately follow responses as in the first four experiments.

GENERAL DISCUSSION

Both the relative number and the temporal location of response-dependent reinforcers

within a context of otherwise response-independent reinforcers exerted strong control over behavior. The results show the effects of repeated transitions between response-dependent and response-independent food delivery. The effects obtained in each experiment were replicated both within and between subjects and procedural variations (compare, for example, the results of Experiments 1 and 2 with those of Experiment 4). Increasing the number of response-dependent reinforcers while holding the location of these reinforcers constant within a session increased overall response rates (e.g., Pigeons 1546 and 2185 in Experiments 1 and 4). When the number of response-dependent reinforcers was held constant and their location varied, overall response rates were not related systematically to dependency location. Varying the temporal location of a constant number of response-dependent reinforcers controlled the patterns of responding within individual sessions. Specifically, local response rates were higher in the vicinity of the dependency and lower in its absence in Experiments 2 and 4. The only systematic exception to these location-specific effects of dependency occurred in Experiment 3, when a block of four response-dependent reinforcers was scheduled randomly across successive sessions. This may represent a failure of detection or bias (Lattal, 1979), in that response rates were sufficiently high and even throughout the session (Figure 6) to preclude discriminable differences in response-reinforcer temporal contiguity.

The relation between number of response-dependent reinforcers and response rates extends previous experimental work in which nonlocalized distributions of response-depen-

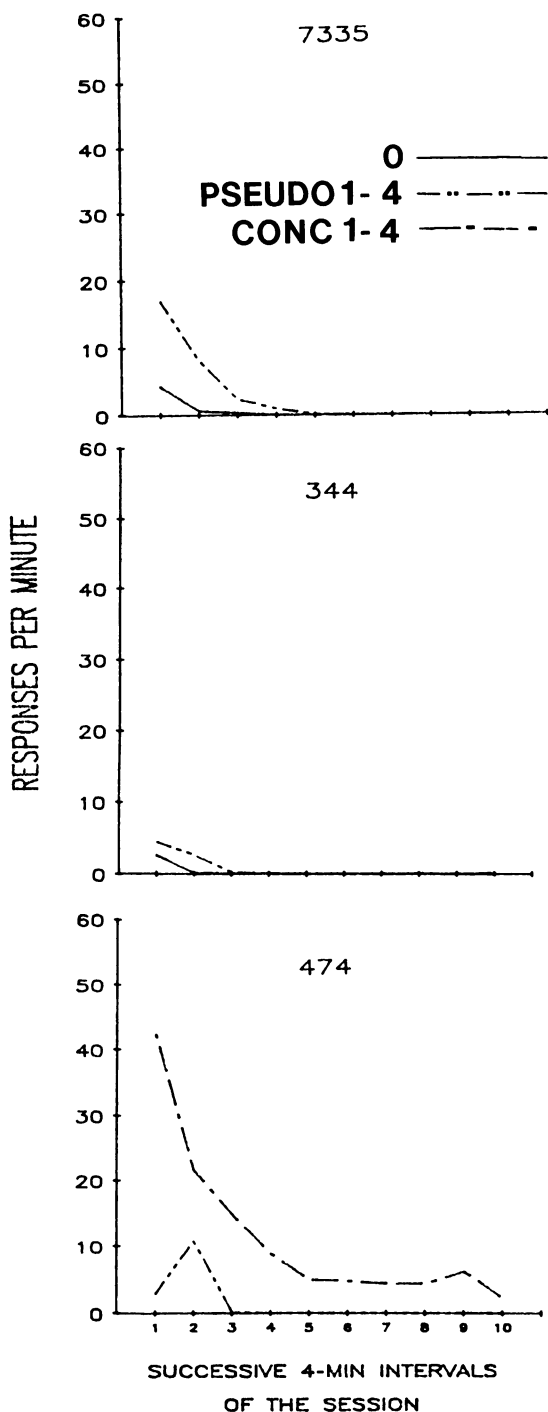


Fig. 9. Mean responses per minute during successive 4-min intervals of the session for each subject in Experiment 5. Data for replications of conditions have been averaged to yield a single set of points for each of those conditions. Each data point was obtained from the last six sessions of the condition.

dent and response-independent reinforcers were arranged (e.g., Lattal, 1974). The relation between dependency location and local patterns was not predictable from previous studies that used evenly distributed mixes of response-dependent and response-independent reinforcers. Lattal (1973), however, noted changes in local response rates as a function of component duration in mixed VI VT schedules. With longer component durations, responding during VI and VT components increased and decreased, respectively, as the time in a given component increased. Keenan and Leslie (1984) reported patterns in individual interreinforcement intervals during conjunctive fixed-ratio 1 fixed-time (FR 1 FT) schedules that were similar to the patterns obtained across sessions in the present experiments. Variations in the location of the FR 1 requirement yielded higher local response rates in the portion of the interval containing the FR 1 requirement.

The relation between number of response-dependent reinforcers and overall response rates also raises the question of how many dependencies are necessary to yield reliable behavioral effects. Unfortunately, there is no simple answer. A block of four response-dependent reinforcers was selected for analysis here for two reasons. First, this number was 10% of the reinforcers in a session, as in Lattal's (1974) experiment. Second, the selection of a block of four was derived empirically from pilot work in which fewer than 10% of the total reinforcers delivered following responses produced less reliable effects on overall response rates and response patterns across and within subjects at different locations within a session. For example, in contrast to the effects obtained when single response-dependent reinforcers were used, a block of four response-dependent reinforcers produced reliable increases in overall response rates across various locations over those rates maintained after extended exposure to VT schedules. A block of four also yielded consistently different effects when placed in different locations.

Both the reinforcing and discriminative functions of food presentation contribute to the effects of the location of response-reinforcer dependencies. First, elimination of food presentation immediately following responses required to continue delivery of response-independent reinforcers (Experiment 5) resulted

in low local rates in the vicinity of the dependency and in low overall response rates. The local rates, however, were higher than those maintained in the absence of such requirements. This finding suggests that the contingency between responding and access to subsequent response-independent food delivery may contribute to dependency location effects but does not by itself account for such effects. The immediate consequence of food presentation following a response enhanced the behavioral effects of the contingency described in Experiment 5. Relatively higher local response rates in the temporal vicinity of the response-food dependency were obtained regardless of whether or not the contingency had to be met prior to later response-independent food presentation (cf. the results of Experiments 1 and 2 with those of Experiment 4). In Experiment 4, reinforcers that were scheduled according to the VI schedule remained available until collected. As a result, the pigeons could have waited until any point thereafter to peck without affecting the delivery of response-independent reinforcers. In no case, however, was such pausing observed. Rather, pecking occurred reliably at those times when the VI schedule was in effect and such pecking was less likely in the absence of the VI schedule, suggesting that the response-food dependency was a most important determinant of local responding.

The second function of the food presentation, and the related response-food dependency, in dependency location effects is a discriminative one. There are several ways in which the blocks of response-dependent and response-independent reinforcers might exert discriminative stimulus control over the presence and absence of responding. It often was the case, when the block of response-dependent reinforcers were located in the beginning or middle of the session, that responding ceased abruptly following the last reinforcer in the block. Such an effect may be related to one or more stimulus properties of food delivery: number of reinforcers, the response-reinforcer relation (Lattal, 1975, 1979), time since the first response-dependent reinforcer (although this varied somewhat from session to session), or a combination of these. Similarly, response-independent reinforcers might serve a discriminative stimulus function in the control of lower responding in their presence. Franks and Lattal (1976), for example, showed that the same

response-independent reinforcers differentially controlled high- or low-rate responding as a function of their prior correlation with fixed-ratio or differential-reinforcement-of-low-rate reinforcement schedules. When response-independent reinforcers cease to occur as a result of the "setting up" of a response-dependent reinforcer (e.g., a period of n s without a reinforcer), the absence of reinforcers might function as a discriminative stimulus to evoke responding that then is reinforced. These latter discriminative stimulus functions would not operate under the concurrent schedules studied in Experiment 4. However, in this experiment, different frequencies of reinforcement during the period in which the VI schedule does and does not operate might serve this discriminative function in the control of local response rates (cf. Commons, 1979).

The analysis of dependency location effects is relevant to a more general understanding of schedules of reinforcement in at least two ways. First, analyses of operant behavior usually focus on the relation between responding and the ensuing reinforcer, but imbedded in all schedules of response-dependent reinforcement is an additional contingency between current responding and future reinforcers. That is, the next available reinforcer must be obtained before the next interfood interval, and thus before the remainder of the schedule is initiated. In this trivial sense, every schedule of reinforcement potentially involves the control of behavior concurrently by the molecular relation between a particular response and the next reinforcer and by a more molar relation between responding and the occurrence of future reinforcers. Although it is difficult to isolate this latter relation in schedules arranging strictly response-dependent reinforcers, schedule arrangements like those in the present experiments may be useful in assessing the relative contributions of such molar and molecular variables to response maintenance. For example, a direct comparison of the procedures in Experiments 2 and 4 would reveal any contribution of the dependency between present responding and future reinforcers to response maintenance. Comparisons like those in Experiment 5 also permit an analysis of the dependency effects unconfounded by immediate food presentation.

In this latter regard the present findings may be compared with those of Nevin, Smith, and

Roberts (1987), who studied the effects of response-dependent and response-independent transitions between multiple-schedule components arranging relatively infrequent (lean) and relatively frequent (rich) reinforcement. With lean component duration held constant, pigeons responded more in the lean component when a peck was required to produce the rich component than when the rich component occurred independently of responding at the end of a specified interval. That is, the dependency between responding and access to subsequent schedule events apparently contributed to response maintenance. The effect was more consistent than that reported here (although the differences resulting from response-dependent versus response-independent transitions disappeared when Nevin *et al.* tested the effects of resistance to extinction or prefeeding).

Explanations of such outcomes should be drawn cautiously. Higher response rates in the presence versus absence of a dependency between a current response and future scheduled events may be attributed to either molar or molecular mechanisms. A molar account would emphasize the correlation or dependency between responding and future food deliveries. A molecular account could be drawn that parallels Dews' (1966) suggestion that successive responses in a fixed-interval schedule are reinforced after varying delays as a function of their temporal location. Such variable delays may be presumed to operate similarly in other schedules, including unconventional procedures like those in Experiment 5. In that experiment, responses early in the session might be considered to be reinforced after varying delays by one or more of the subsequent food presentations. Similarly, in the Nevin *et al.* (1987) procedure, responses in one multiple-schedule component were followed after varying delays by both a component-stimulus change and the food presentations of the subsequent component. In neither case, however, was the temporal relation between responding and subsequent food presentations assessed empirically.

The second point related to reinforcement schedules is that it is unlikely that dependency location effects are limited to combinations of response-dependent and response-independent reinforcers. For example, placing four response-dependent reinforcers at various locations in a session otherwise devoid of rein-

forcers likely would yield orderly differences in response patterns. Whether these patterns would be similar to those obtained in the present experiment is an open question, as are the effects of other juxtapositions and combinations of response-reinforcer and response-punisher dependence and independence.

The study of behavioral patterns in the context of reinforcement schedules has yielded abundant empirical relations (e.g., Ferster & Skinner, 1957) and theoretical development (e.g., Thompson & Zeiler, 1986). Central to theoretical discussions of the organization of behavior is the issue of appropriate levels of analysis of behavioral effects. Behavioral order has been described at the levels of interresponse times, groups of responses in time (e.g., ratio runs and interval requirements), and in more molar terms. The present experiments suggest that reliable patterns of behavior are established by the temporal locations of different relations between responding and reinforcers. The level of organization here can be viewed in terms of individual response-reinforcer dependencies or in terms of blocks of dependencies. It is significant that the varied response patterns produced by different dependency locations often were lost within the context of overall response rates. On the other hand, an analysis that failed to consider behavior over a more extended time frame, in the present case over an entire session, also would fail to yield interesting behavioral data. Our results not only suggest the role of dependency location in determining behavioral control but also underline the necessity of a careful match between behavioral effects and level of analysis in the study of response structure and behavioral organization.

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