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EFFECTS OF REQUIRED RATES OF RESPONDING UPON CHOICE[1]

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Pigeons' responses in the presence of two concurrently available (initial-link) stimuli produced one of two different (terminal-link) stimuli according to identical but independent variable-interval schedules. Responses in the presence of each terminal-link stimulus produced equal frequencies of food reinforcement, but in the presence of one of the stimuli, food depended upon the emission of a response rate either higher or lower than a specified value (differential reinforcement of rates). The measure of preference, the dependent variable, was the distribution of responses in the presence of the concurrently available stimuli of the initial links. Each pigeon, the responding of which was appropriately controlled by the response-rate requirements in the two terminal-link stimuli, consistently preferred the stimulus not associated with a response-rate requirement.

Several of the variables influencing choice by an organism may be controlled and studied by concurrently presenting two chained schedules of reinforcement (Autor, 1960). In this procedure, the subject responds on two concurrently available keys, each of which is associated with the stimulus of the initial link of one chain. Responses on each key are occasionally reinforced by the appearance of the stimulus from the terminal link of the chain associated with that key. Responses in the presence of either of the terminal-link stimuli produce food. The independent variables that have been studied include the rate or schedule of reinforcement (Autor, 1960; Fantino, 1967) or the frequency of occurrence and intensity of punishment (Reynolds, 1963; Rachlin, 1967) in the terminal links of the two chains. The measurement of choice, the dependent variable, is the distribution of responses in the initial, concurrently presented links of the chains. For example, the rate of reinforcement in the terminal link of the chain associated with the right key may be three times greater than the rate of reinforcement in the terminal link of the chain associated with the left key. In this case, the organism emits three times as many responses on the right key as on the left during the concurrently presented initial links of the two chains (Herrnstein, 1964). In other words, the organism distributes its responses during the initial links in the same proportion as reinforcements are distributed in the terminal links; it matches proportions of responses to proportions of reinforcements.

Herrnstein (1964) also indicated that response distribution in the initial links is not sensitive to response rates in the terminal links, although he did not directly manipulate response rates. It is thus possible that choice in this situation is determined solely by the rates of reinforcement. Premack (1965, pp. 159-161), for example, predicted that if different schedules of reinforcement yield the same probability and duration of primary reinforcement, then the conditioned reinforcing value of the stimuli associated with each schedule will be the same.

The present experiment investigated the effect on choice, the distribution of responding in the concurrently available initial links, of a required rate of responding during the terminal link of one chain. The schedule of reinforcement associated with the terminal link of one chain provided reinforcement only when the organism responded at a high rate or, for some subjects at a low rate. The schedule associated with the other terminal link did not require a particular rate of responding, but was arranged to provide the same proportion and the same rate of reinforcement. There-

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fore, if rate of reinforcement were the sole determiner of choice in this situation, then the distribution of responses in the two initial links should not differ systematically.

METHOD

Subjects

Six adult male White Carneaux pigeons were maintained at approximately 80% of their normal body weights during free access to grain. Pigeons 1 and 14 had prior training with single-key chained schedules, Pigeons 16, 17, 18, and 19 were experimentally naive.

Apparatus

The experimental chamber was a modified picnic icebox (Ferster and Skinner, 1957) containing a solenoid-operated grain hopper, two 6-w lamps for general illumination and two translucent response keys mounted 9 in. above the floor. The right key was transilluminated by either a white or red light, the left key by either a white or green light. Transillumination was accomplished by stimulus lights mounted behind the response keys (Westinghouse D18, C-7 1/2 Christmas bulbs). A minimum force of 10 g was required to operate each response key. Each response produced auditory feedback by operating a 110 v ac relay. Standard programming and recording equipment were located in an adjacent room.

Procedure

In the main part of the experiment, responses were reinforced on two concurrent chains: either a chained variable-interval differential-reinforcement-of-high-rate schedule (chain VI DRH) on one key concurrent with a chained variable-interval fixed-interval schedule (chain VI FI) on the other, or chain VI DRL (differential-reinforcement-of-low-rate) on one key concurrent with chain VI FI on the other. The DRH schedule had the following properties: (1) if the pigeon made at least a specified number of responses within 15 sec of the onset of the green light, its first response after the 15 sec had elapsed was reinforced with 4-sec access to grain. Following reinforcement, the two white stimuli of the initial links reappeared and both VI programmers began operating: (2) if fewer than the specified number of responses were made within the 15 sec, reinforcement was not obtained and the pigeon returned to the initial links when the 15-sec period terminated. The DRL schedule had analogous properties: (1) if the pigeon made fewer than a specified number of responses within 15 sec, its first response after 15 sec was reinforced: (2) if the number of responses equalled or exceeded the specified number, the pigeon returned to the initial links when the 15-sec period terminated.

The DRL and DRH schedules used in the present experiment differed from those generally used by other investigators (*e.g.*, Wilson and Keller, 1953; Staddon, 1965) in that they did not explicitly reinforce selected interresponse times. A schedule which reinforces selected interresponse times may be viewed as the limiting case of the class of schedules used in the present study. The present DRL schedules, for example, reinforced a response after the emission of no more than n responses in t secs; in the more commonly used DRL schedules, $n = 0$.

At the start of a session on these concurrent chains, each key was transilluminated by a white light. Identical, but independently operated, VI schedules were correlated with each key. Each VI schedule had a mean interreinforcement interval of 1 min. When reinforcement was scheduled by either VI programmer, it stopped operating, but the other VI programmer continued to operate. The next response on the appropriate key produced the terminal stimulus associated with that key and two additional events: (1) the VI programmer associated with the other key stopped operating, (2) illumination was removed from the other key, which became inoperative. For the left key, the terminal stimulus was transillumination with green light, the right key with red light. Pecks in the presence of the green light were reinforced on the DRH schedule (Pigeons 14, 16, 19) or the DRL schedule (Pigeons 1, 17, 18). Pecks in the presence of the terminal stimulus on the right key were reinforced on a modified fixed-interval (FI) schedule of 15 sec. This schedule programmed reinforcements in the same proportion as the terminal link of the other chain. For each subject, the number of reinforcements programmed on the FI key in a particular session was equal to the number obtained on the DRH or DRL key in the previous session. In practice, for each subject in each part of the experiment, the number of reinforced trials on the FI key was equal to that on the DRH or DRL key. The sequence of reinforcement intervals was irregular. When an interval was to contain reinforcement, the first response after 15 sec produced reinforcement and the pigeon then returned to the initial links. When the interval did not end in reinforcement, the initial links were reinstated when the 15-sec period terminated. The general procedure is schematized in Fig. 1.

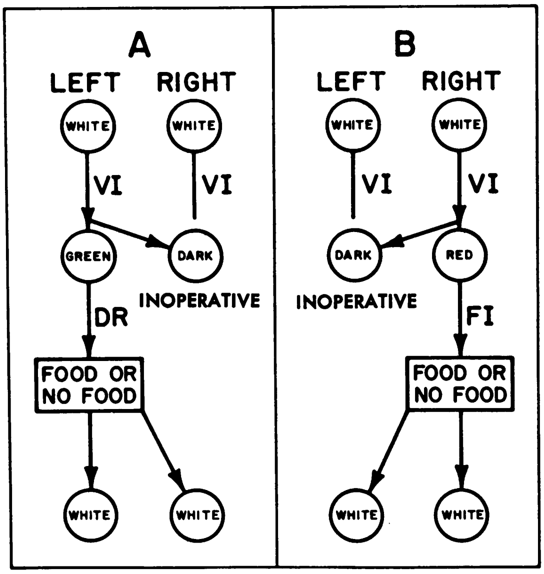

Fig. 1. Pictorial representation of the concurrent-chains procedure. Figure IA indicates the sequence of events when responses on the left key were reinforced. Figure IB represents the analogous sequence on the right key. "DR" stands for "differential reinforcement" schedule which for some pigeons was a DRH and for others a DRL.

After magazine training, each pigeon's pecks were shaped in the presence of the red and green lights. The concurrent chains procedure was then instituted with white lights and VI 1-min in the initial links and FI 15-sec in each (both red and green) terminal link. Each pigeon learned to respond in the initial links without further shaping. After seven daily "pretraining" sessions, in which there was no systematic preference for either key, the DRH and DRL requirements were introduced in the terminal links of the left key. The first DRH or DRL value studied was the multiple of five closest to the average number of responses made during FI 15-sec on the left key in the final pretraining session. These values and the ones studied subsequently, and the number of sessions observed at each value, are shown in Table 1. A value remained in effect until response rates appeared stable for at least 12 consecutive sessions out of a minimum of 28 observed. Four values were studied for each subject. Following these determinations, each subject was studied with equal-valued DRH or DRL schedules in the terminal links of each key. No systematic preference for either key was evident for either the DRH or DRL groups.

Table 1

Order of Conditions and Number of Sessions

Bird Number	*DRH Requirement*	*Number of Sessions*
16	25	43
	20	65
	15	32
	5	39
19	25	38
	20	64
	30	29
	35	38
14	40	38
	45-50	•(1)
	35	43
	30	38
	DRL Requirement	
17	15	42
	5	62
	2	31
	1	39
1	15	43
	20	51
	5	48
	10	39
18	15	42
	20	50
	5	45
	2	39

(1) *Failed to sustain responding*

Each daily session terminated after 40 presentations of the terminal-link stimuli. For each pigeon, at every value studied, each terminal stimulus was presented an average of 20 times per session, because the concurrent VI schedules kept the number of reinforcements on each key fairly constant over a wide range of preference (*e.g.*, Fantino, 1967, p. 36). The number of primary reinforcements was, of course,, determined by the pigeon's performance and could vary from 0 to 40 per session.

RESULTS

The absolute rates of responding in the initial links are plotted against the absolute rates of responding in the terminal links in Fig. 2 for each of the DRH subjects. These rates are the arithmetic means of data for the last four sessions of each procedure listed in Table 1. If the logic of the experiment were satisfied, response rates in the DRH schedule should have exceeded those in the interval schedule. Figure 2 indicates that this was so; for each pigeon, the response rate in each DRH schedule was always higher than the response rate generated in each FI schedule. Thus, all DRH data points in Fig. 2 are to the right of each FI point. Was the dependent variable affected? Figure 2 indicates that each pigeon responded at a higher rate on the FI schedule key than on the DRH schedule key. Hence, for each pigeon, all DRH data points fall below the lowest interval point.

A different picture is obtained in Fig. 3, which plots the corresponding data for the DRL subjects. Only Pigeon 17 satisfied the logic of the experiment; it always responded at a lower rate in the presence of the DRL schedule than in the FI schedule. Hence, the DRL data points fall well to the left of the FI points. This did not occur for either of the other subjects. They gave no evidence of discriminating between the DRL and FI requirements in the sense that their rate and pattern of responding in the terminal links of each key did not differ systematically. Pigeon 17, like its DRH counterparts, responded at a consistently higher rate in the initial link producing the FI schedule. Of the subjects which failed to discriminate between the two conditions one, Pigeon 18, responded at a systematically higher rate in the initial link producing the DRL schedule, while the other, Pigeon 1, displayed no systematic difference.

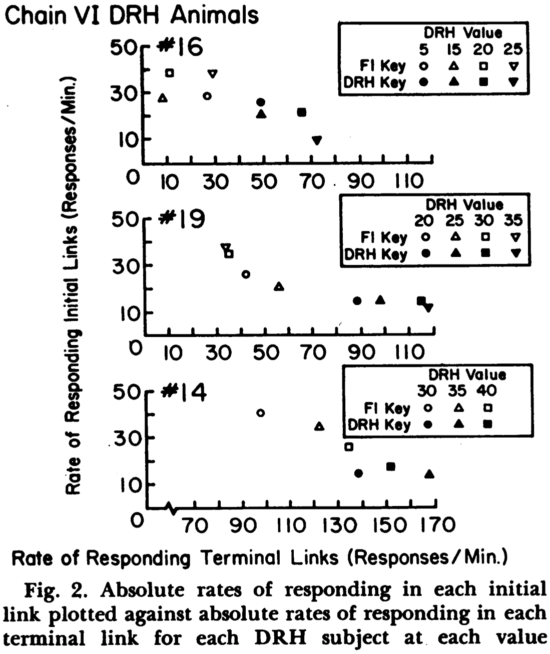

Fig. 2. Absolute rates of responding in each initial link plotted against absolute rates of responding in each terminal link for each DRH subject at each value studied.

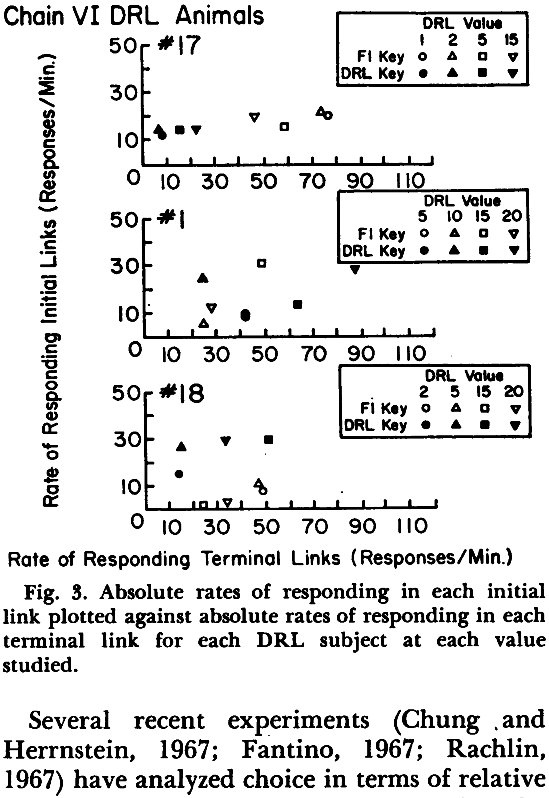

Fig. 3. Absolute rates of responding in each initial link plotted against absolute rates of responding in each terminal link for each DRL subject at each value studied.

Several recent experiments (Chung and Herrnstein, 1967; Fantino, 1967; Rachlin, 1967) have analyzed choice in terms of relative rates of responding. Table 2 presents the relative rates of responding in each link for each condition. These rates were obtained as follows: (1) for each of the last four sessions of each procedure, the number of responses in the initial link on the FI key was divided by the total initial link responses; (2) the arithmetic mean of the four quotients for each procedure was then computed. The same procedure was followed for the terminal links. These data present a similar picture to the analogous data, in terms of absolute response rates, presented in Fig. 2 and 3. Column (iv)

Table 2

Relative Rates of Responding (Interval Key) and Percent Success on each Key

Bird Number	*(i)* *DRH Requirement*	*(ii)* *Relative Rate of Responding (Interval Key)* *Initial Links*	*(iii)* *Terminal Links*	*(iv)* *% Reinforcement*
16	5	.53	.33	98
	15	.58	.15	63
	20	.63	.14	27
	25	.78	.30	42
19	20	.65	.32	76
	25	.59	.36	71
	30	.70	.23	62
	35	.76	.23	65
14	30	.74	.42	87
	35	.72	.42	90
	40	.60	.47	90
	DRL Requirement			
17	15	.57	.67	100
	5	.53	.79	62
	2	.59	.92	54
	1	.63	.91	17
1	20	.30	.24	46
	15	.71	.44	23
	10	.19	.51	84
	5	.55	.50	3
18	20	.08	.49	93
	15	.07	.31	52
	5	.28	.77	70
	2	.34	.77	5

in Table 2 presents the percentage of trials in which reinforcement was obtained. This percentage was a function of performance on the differential-reinforcement schedules and was equal for the two keys. It can be seen that the relative rates of responding in the initial links did not vary monotonically with the degree of the pigeon's success in obtaining reinforcements.

Figure 4A presents a sample cumulative record for Pigeon 16. While Pigeon 16 responded at a higher rate during the DRH stimulus than during the FI schedule, it responded at a higher rate in the initial link producing the FI schedule; this is reflected by the steeper slope for the FI key. The cumulative records for Pigeons 14 and 19 present the same picture. Table 1 indicates that Pigeon 14 failed to sustain responding when the DRH requirement was raised from DRH 40 to either DRH 50 or DRH 45. Figure 4B illustrates the breakdown of this behavior. In segment (a) the pigeon generally satisfied the DRH 45 requirement. In segment (b), however, it missed several reinforcements in succession and performance disintegrated. Although Pigeon 14 was easily retrained to recover its DRH behavior on DRH 40, several attempts to impose a higher DRH requirement led to extinction. Thus, it was not possible to obtain stable behavior from Pigeon 14 except on DRH schedules in which it generally achieved reinforcement. Figure 4C illustrates the performance of Pigeon 17. It responded throughout at a higher rate on the FI key. Figure 4D presents a sample record of Pigeon 18 showing that it failed to discriminate the DRL requirement adequately. This is evidenced by higher response rates during the DRL schedule than during the FI. Pigeon 18 responded throughout at a higher rate on the DRL key.

DISCUSSION AND CONCLUSIONS

Each of the four pigeons which discriminated between the differential rate and the interval schedules consistently responded at a higher rate when responses produced the interval schedule. This suggests that a conditioned reinforcer associated with a response

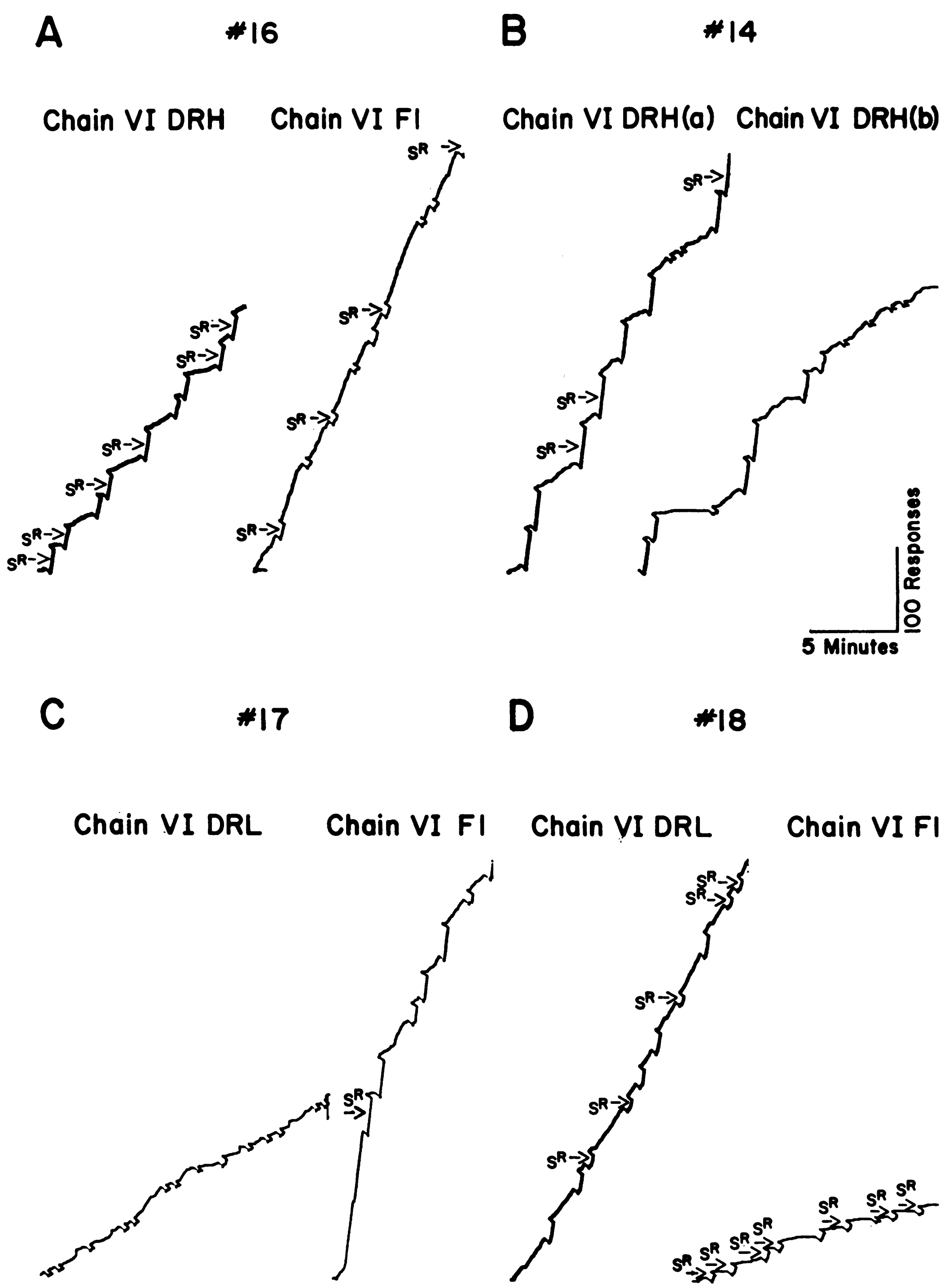

Fig. 4. (A) Sample cumulative record for Pigeon 16. In this session the DRH requirement was 20. Displacement of the recording pen indicates that the terminal-link stimulus was in effect. Displacements marked by arrows indicate which terminal links terminated with reinforcement (S^R). (B) Sample records for Pigeon 14 on DRH 45. Segment (a) is from a session in which reinforcements were being obtained. Segment (b) from the next session, shows a disintegration of this performance. (C) Sample records for Pigeon 17 with a DRL requirement of 1. (D) Sample records for Pigeon 18 with a DRL requirement of 15.

rate which is required for reinforcement is weaker than one which is not. For the DRL schedule, this conclusion is based on the data of only one pigeon, however.

This result refutes the prediction, derived from Premack (1965), that the pigeon would not systematically choose between these schedules of reinforcement since they yield the same probability and duration of primary reinforcement. Instead, the results suggest that the manner in which a particular rate of reinforcement is obtained affects choice. These results do not contradict Herrnstein's (1964) previous finding, however, since he did not directly manipulate the rate of responding required for reinforcement. He found a matching function between the distribution of responses in the initial links and the distribution of reinforcements in the terminal links. The present results indicate that when response rates are directly manipulated the matching function may be disrupted.

These DRH results also bear upon the possibility, raised most recently by Logan and Wagner (1965) and by Wike (1966), that the effects of primary and conditioned reinforcement are confounded in chained schedules. Logan and Wagner, in discussing Herrnstein's experiment, caution that "the rate of pecking the keys during Phase I might be affected in anticipatory fashion by the rate that would later be appropriate on that key when the schedule changed" (p 58). Previous work with single response keys, however, indicated that responding in the initial links of chained schedules is primarily maintained by conditioned reinforcement (Kelleher and Gollub, 1962). The present study extends this finding to the concurrent choice situation: although pigeons responded at a consistently higher rate in the terminal links (DRH *vs* FI comparison) on the chain VI DRH key, they responded at a consistently higher rate in the initial links (VI *vs* VI comparison) on the chain VI FI key. If the rate of responding in the initial links were in "anticipation" of the rate of responding in the terminal links, the rates on the DRH key would have been higher in both links.

The DRH data also suggest that a schedule which generates a high rate of responding for reinforcement may have aversive components, a fact that has been well documented only for fixed-ratio (FR) schedules (Azrin, 1961; Appel, 1963; Thompson, 1964). Indeed, an FR schedule is aversive even though it does not require a high response rate. These results raise the possibility that manipulations which generate a high rate of responding in the presence of a stimulus will weaken the potency of the stimulus as a conditioned reinforcer. The data for Pigeon 17 suggest that a schedule requiring the subject to respond at a low rate may also weaken the value of the associated conditioned reinforcer.

It should be noted that, although the probability of reinforcement on the interval schedule was successfully kept equal to that on the differential-reinforcement schedules, in one respect the temporal distribution of reinforcements could differ for the DRH, DRL, and interval schedules. Since the pigeon responded at a higher rate on DRH than on the interval schedule, its first response after 15 sec, *i.e.*, the reinforced response, would tend to be emitted sooner. Hence the interval between the onset of the terminal-link stimulus and reinforcement might be shorter for the DRH key. By the same token, for Pigeon 17, the reinforced response on the DRL schedule would tend to be emitted later than on the interval schedule. The data, however, indicate that this tendency was small. On the average, for Pigeon 17, reinforcements on the interval key occurred only 1.5% sooner (about 0.2 sec) than reinforcements on DRL. It seems unlikely, therefore, that this variable was responsible for the interval schedule preference. For the DRH pigeons, reinforcements occurred only 2% sooner (about 0.3 sec) on the DRH schedule. This difference could not account for the obtained preferences which were in the opposite direction.

Although each of the four pigeons clearly preferred the interval schedule, Fig. 2 and 3 fail to indicate an orderly relation between the magnitude of this preference and the size of the differential reinforcement requirement. One factor which might account for this failure is the limited range of values studied. This was most striking for Pigeon 14 whose responses were frequently reinforced (87% to 90%) in the DRH 30 to DRH 40 range, but which extinguished at higher values.

The present experiment demonstrates that, at least for the schedules studied, a conditioned stimulus is stronger when it is not associated with a requirement of a particular rate of responding for reinforcement. The DRH data also indicate that a discriminative stimulus that occasions a high rate of responding need not be a stronger conditioned reinforcer than a discriminative stimulus occasioning a lower response rate. This finding supports previous work indicating that the conditioned reinforcing value of a stimulus need not covary with its value as a discriminative stimulus (Gollub, 1958; Autor, 1960; Fantino, 1965).

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