INTERMITTENT REINFORCEMENT OF DISCRIMINATIVELY CONTROLLED RESPONSES AND RUNS OF RESPONSES[1]

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When a response is controlled by a discrete external discriminative stimulus, it is possible to introduce a type of intermittent reinforcement different from that involved in an interval or ratio schedule in a free-operant situation. The discriminative stimulus can be made to "set up" reinforcement only on a certain proportion of the occasions when it is presented, even though it leads to the occurrence of the response on all occasions. For example, a bar press might be reinforced only after the onset of a light (which then goes off with the first response), but not after all presentations of the light. Here, the intermittency obtains with respect to the connection between the S^D and reinforcement, rather than with respect to the connection between response and reinforcement.

Used in a Skinner box situation, this kind of intermittency would be analogous to the procedure commonly called partial reinforcement in runways and T-mazes. Partial reinforcement in a runway is not directly comparable with an intermittent schedule of reinforcement in a free-operant situation, because the running response is controlled discriminatively by the opening of the starting-box door, and is not free to occur at other times. The above schedule provides the link between intermittent reinforcement in the free-operant situation and partial reinforcement in the runway.

Once such a schedule is established, further elaborations may be introduced. For example, runs of responses, instead of single responses, may be required to produce reinforcement following the onset of the S^D. If a fairly high ratio of nonreinforced to reinforced S^D presentations is used, very precise and clear-cut control of behavior with infrequent reinforcement becomes possible. Presentation of the S^D leads to a rapid run of responses, but these runs are not often reinforced.

METHOD

Subjects

The *S*s were 14 male albino rats of the Sprague-Dawley strain, ranging from 90 to 250 days old. They were maintained on a 23-hour, water-deprivation schedule throughout the experiment. Dry food was available in the home cages at all times.

Apparatus

The apparatus was a 9- by 9- by 9-inch Skinner box, modified by the addition of a special reinforcement compartment. The reinforcement compartment was 2.75 inches wide, 12 inches long, and 6 inches high; and a motor-driven water-delivery mechanism was located at the far end. It was connected to the main compartment by an opening 2.75 inches wide and 4 inches high. The top of the reinforcement compartment was covered by plexiglas, and a 7.5-watt frosted lamp was mounted above to illuminate the compartment at the time of reinforcement. Reinforcement was also signalled by a 2-second buzzer, which occurred as the immediate feedback from bar pressing.

Additional stimuli, used in establishing discriminations, consisted of two unfrosted

[1]The research here reported was done while the author was a Public Health Service Postdoctoral Research Fellow of the National Institute of Mental Health at the University of Washington.

7.5-watt lamps mounted on the side walls of the main compartment and a tone delivered through a loud-speaker on one side wall. The bar was mounted on the rear wall, 4 inches above the floor. It was made of heavy wire and protruded 1.25 inches into the compartment. The front of the main compartment was covered by plexiglas.

Control and recording apparatus consisted of relays, timers, stepping switches, an Esterline-Angus operations recorder, and a cumulative recorder.

Procedure

Pretraining. All animals were first trained to approach the water dipper at the far end of the reinforcement compartment at the sound of a buzzer and the onset of the light in the reinforcement compartment. Reinforcement was given only if the animal was first located in the main compartment. When the approach response had become stable, bar pressing was established with continuous reinforcement. Animals were given from 20 to 70 reinforcements for bar pressing.

Initial Discrimination Training. All animals were also given the same initial discrimination training, to bring bar pressing under the control of external stimulation (a complex stimulus consisting of the onset of lights in the main compartment together with a tone). The first response to the bar following the onset of this stimulus was reinforced, and the stimulus was then terminated. Two minutes elapsed before the next presentation. If the animal pressed the bar during the intervening period, the timer which determined the interval was reset, so that the stimulus always came on 2 minutes following the last bar response. This procedure was continued until the discrimination was very well established (from four to nine daily 1.5-hour training sessions). The animal's performance was recorded on a cumulative recorder.

Experimental Sessions. Animals were run in the apparatus for a daily 1.5-hour period, on consecutive days. One hour of drinking was allowed immediately after the session.

Schedules. After the discrimination had been established, intermittency was introduced. Two schedules were used: (a) intermittent reinforcement of single responses, and (b) intermittent reinforcement of runs of responses. Random-reinforcement/nonreinforcement ratios were always used. Decrease in frequency of reinforcement was gradual. (See results section.)

RESULTS

Intermittent Reinforcement of Single Responses

Figure 1 shows cumulative records of the performances of two animals. These animals had already undergone prolonged discrimination training, in which the first response following the onset of the stimulus was reinforced. Stimulus onset is indicated by the short vertical lines below the record. Intermittency is introduced at the arrow. The filled circles indicate reinforced responses, and the open circles indicated nonreinforced responses. The interval between stimulus presentations is 2 minutes, and a premature response always postpones the next stimulus presentation for an additional 2 minutes. Continuation of the curves is from top to bottom of the figure.

The effect of intermittency is shown on a closer scale in Fig. 2, which plots (for three individual animals) the latency (in seconds) of the first response following stimulus onset over a series of stimulus presentations just before and just after intermittent reinforcement begins. The transition occurs at the broken vertical line in the figure. Each section of the figure shows the performance of a different animal.

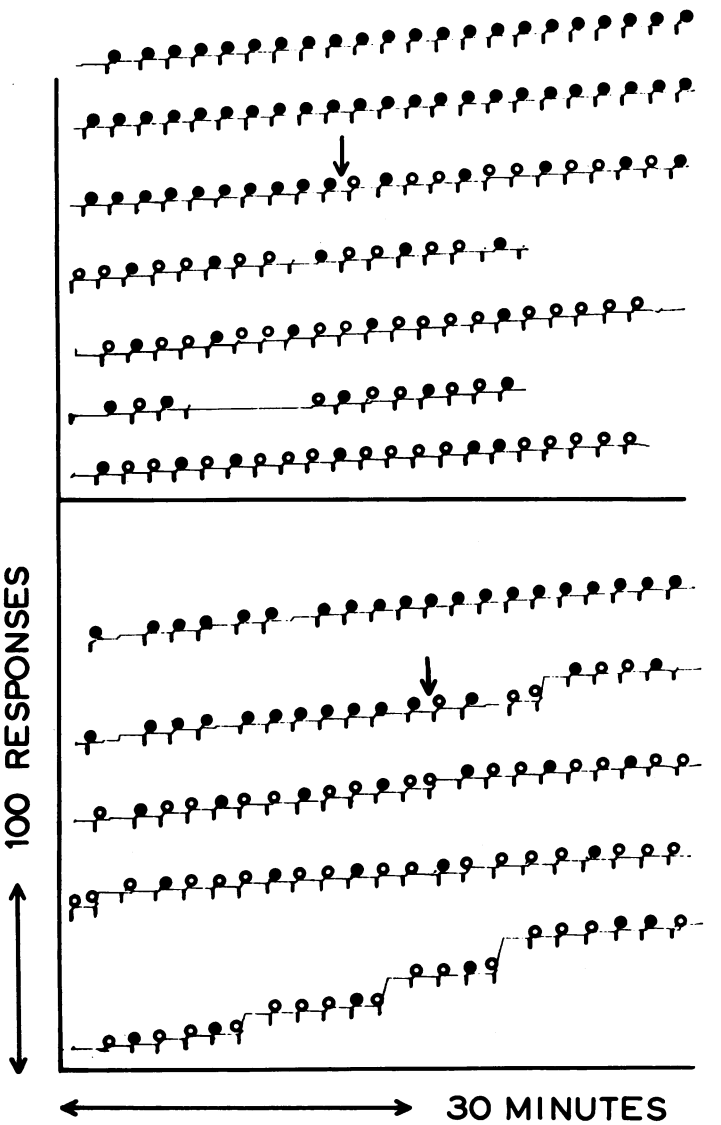

Figure 1. Intermittent reinforcement of responses controlled by a discrete disciminative stimulus.

Intermittency produces some over-all increase in latency and an increase in variability. On numerous occasions, however, the latencies are as low as those which occurred before the beginning of intermittency: The discrimination itself is retained, as can be seen in Fig. 1.

Figure 3 shows the reverse transition, from intermittent reinforcement back again to 100% reinforcement, for the same three animals. An additional session of intermittent reinforcement (not shown) intervened between the periods covered by the two figures.

Figure 4 shows extinction and spontaneous recovery following intermittent reinforcement. Prior to the periods shown in the figure, these three animals had undergone three

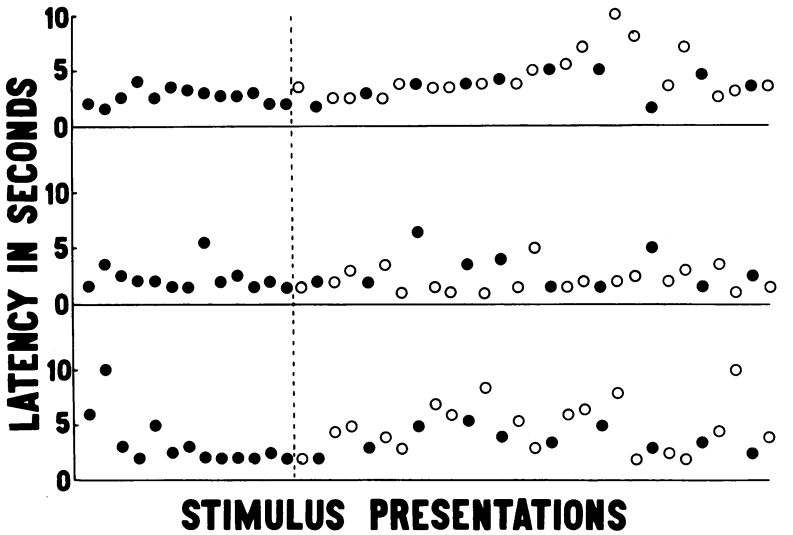

Figure 2. Transition from 100% reinforcement to intermittent reinforcement.

1.5-hour sessions of intermittent reinforcement with a random schedule, using an average of three nonreinforced responses to one reinforced response. Extinction begins at the first vertical line. At the second vertical line a new daily session begins, and the same at the third and fourth lines. Latencies of 20 seconds or longer are recorded as 20. Although long latencies occur early in the extinction period, a large number of short latencies continue to appear for a long time, and there is considerable spontaneous recovery at the beginning of each new daily session.

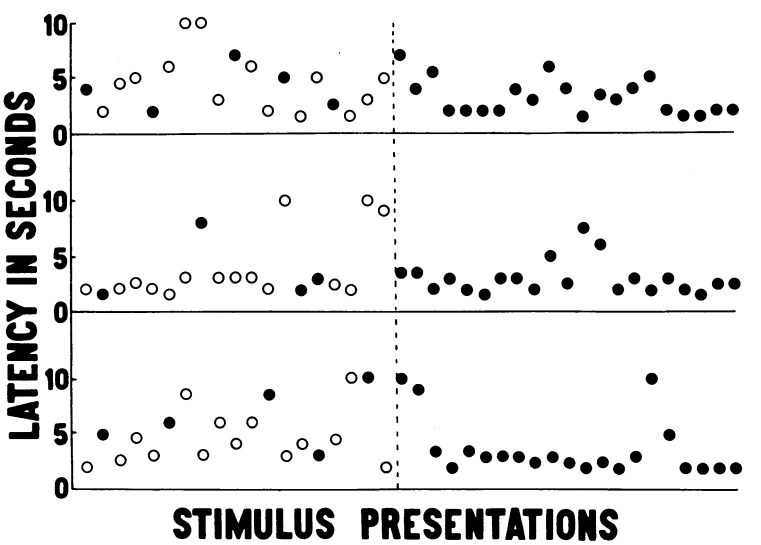

Figure 3. Transition from intermittent reinforcement to 100% reinforcement.

Intermittent Reinforcement of Runs of Responses.

Figure 5 shows the result of increasing the number of responses required to produce reinforcement following the onset of the stimulus. Continuation of the curves is from top to bottom. The transition to runs of 10 responses, in the upper two curves in the figure, is made easily. The animal shown in this record is different from the ones shown in previous records, and the run is extended to 10 for this animal before intermittency is introduced.

Stimulus onset occurs at the short vertical lines below the record before each run. The discrimination is retained, as is shown by the regular, "staircase" appearance of the curves.

In the third record, intermittency begins. The solid circles above the curves indicate reinforced *runs*; the open circles, nonreinforced *runs*. As in the case of single responses, intermittency produces a slight increase in the latency of the first response of the run following stimulus onset, although the over-all form of the performance is not disrupted. Once begun, the run of ten responses occurs at a uniform high rate.

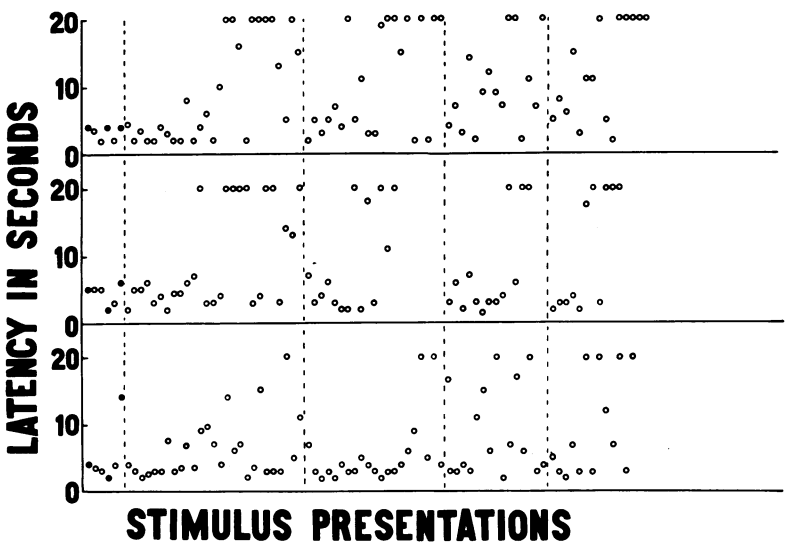

Figure 4. Extinction and spontaneous recovery following intermittent reinforcement.

Figure 6 is a continuation of the performance of the same animal. Although latencies become somewhat longer as time passes, the form of the performance is maintained.

Figure 7 shows the performance of another animal under the same type of schedule. The evolution of the performance here is the same.

DISCUSSION

The schedule shown in Fig. 5, 6, and 7 might be considered a fixed-ratio schedule in which all the pauses become equal in length because of the added discriminative stimulus. The performance is developed, however, by beginning with discriminative control of single responses and then increasing the response requirement in the presence of S^D. Efforts to develop similar performance by first establishing a ratio performance and then adding an S^D have proven unsuccessful.

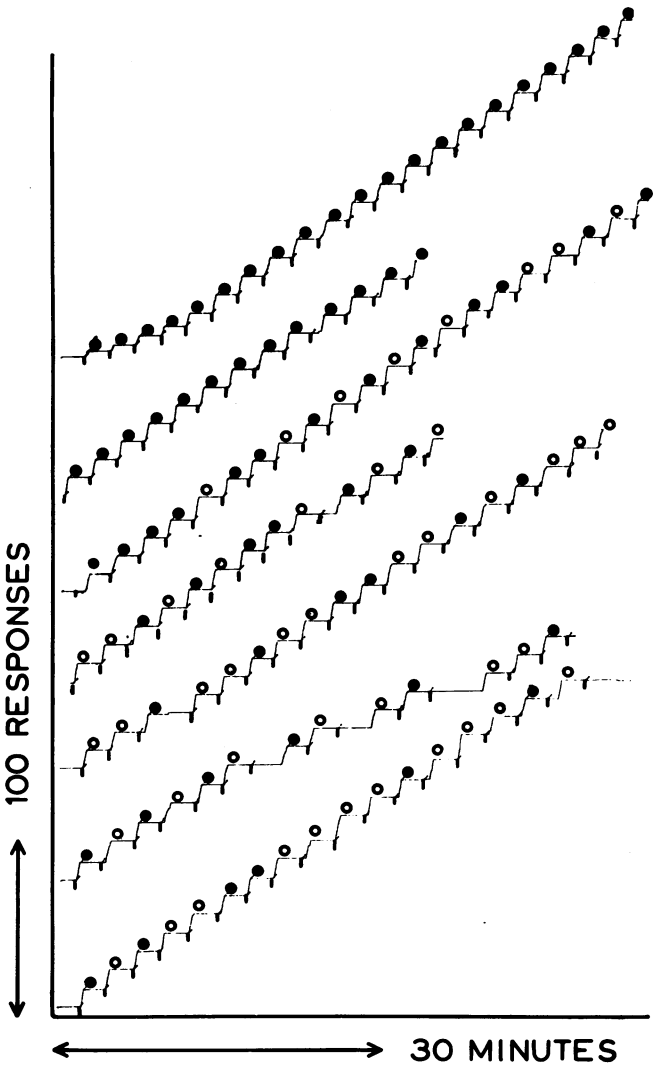

Figure 5. Intermittent reinforcement of discriminatively controlled runs of responses.

The schedule is similar to the multiple-schedule technique used by Ferster and Skinner (1957). It could be considered mult FR 10 ext. One external stimulus, light, controls a ratio performance, while another external stimulus condition, absence of light, is associated with extinction. However, it differs from the multiple schedule in that not every run of responses in the presence of S^D leads to reinforcement, and in that the transition from one stimulus condition to the other always occurs after each run.

Ferster and Skinner (1957) have called another similar schedule, which also involves intermittency in the S^D-reinforcement connection, percentage reinforcement. In percentage reinforcement, some of the reinforcements in an intermittent schedule are omitted and replaced by another event, which then functions as a conditioned reinforcer. The schedule used in the present experiment would become one of percentage reinforcement if some prior

response were allowed to produce the S^D which controls the fixed-ratio run. If we begin with a response under the control of a discrete S^D, several alternative procedures are possible:

(1) A prior response can be allowed to produce the S^D, the prior response can be placed on an intermittent schedule, and, finally, a percentage of the reinforcements following the S^D can be omitted. This is the procedure used in the Ferster-Skinner experiment, where the S^D was the magazine stimuli and the prior response was key pecking.

(2) Following the S^D, a run of responses, instead of single responses, can be required to produce reinforcement. Then, after the S^D has acquired control over runs, a percentage of

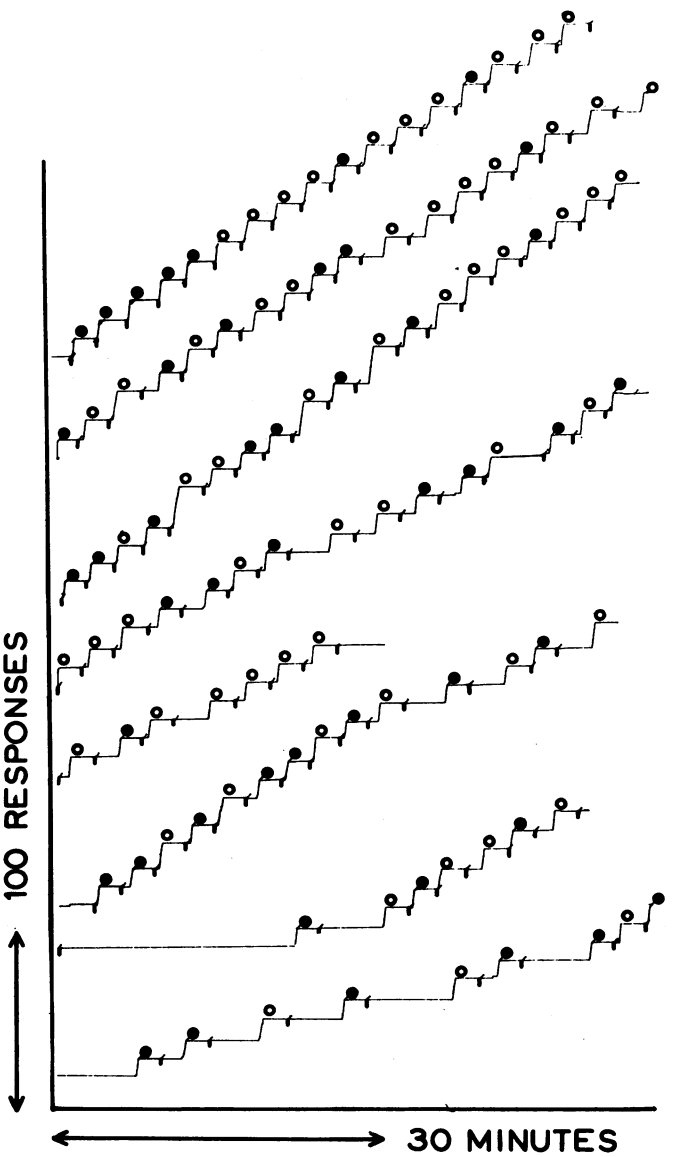

Figure 6. Intermittent reinforcement of discriminatively controlled runs of responses (continuation).

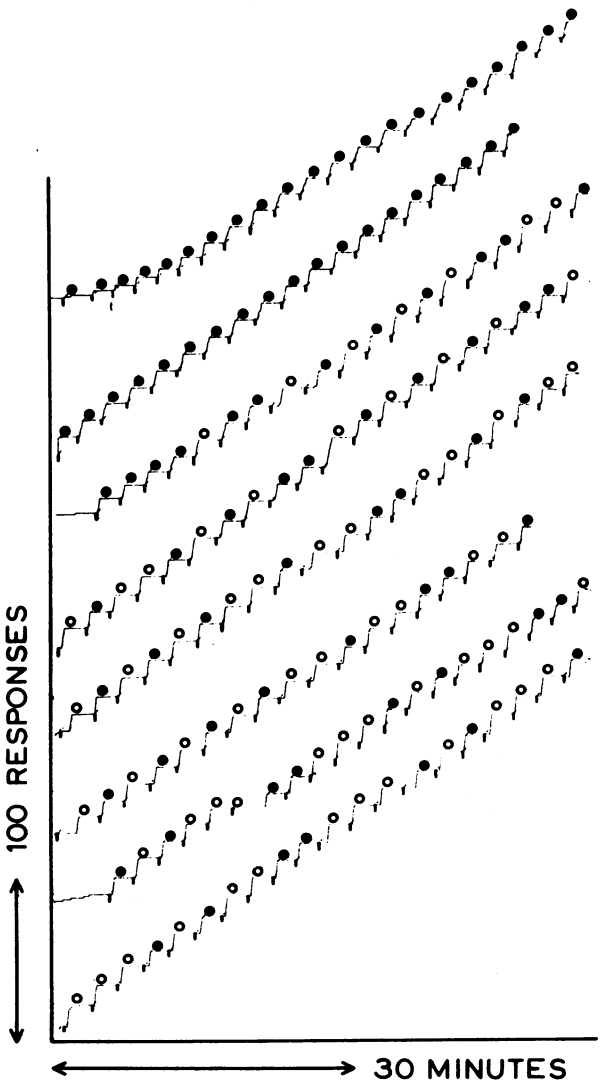

Figure 7. Intermittent reinforcement of discriminatively controlled runs of responses (second animal).

reinforcements can be omitted following the runs. This is the procedure used in the present experiment, the response being bar pressing and the S^D, a light and tone. Magazine stimuli and approach to the magazine remained constant.

(3) A percentage of the reinforcements following the S^D could first be omitted. Then, a run of responses following S^D could be required. No data is available on this procedure.

(4) A percentage of the reinforcements following the S^D could be omitted; a prior response, in turn, could be allowed to produce S^D; and, finally, the prior response would be placed on an intermittent schedule. No data is available on this procedure.

(5) Beginning with the procedure in (2), another prior response could be allowed to produce the S^D which controls runs.

The chain may be represented in this way:

$$R_1 \longrightarrow S_1^{D,r} \ldots\ R_2 \xrightarrow{FR} S_2^{D,r} \ldots\ R_3 \longrightarrow \text{reinf.}$$
$$\qquad\qquad\quad \vdots \qquad\qquad\qquad\quad \vdots$$
$$\qquad\qquad\quad A \qquad\qquad\qquad\quad B$$

Here, R_3 represents the response of approaching the food magazine, and $S_2^{D,r}$ is the sound of the food magazine operating and any other accompanying conditioned-reinforcing stimuli. The FR above the second arrow indicates that a fixed-ratio run is required to produce the next stimulus. In the Ferster-Skinner experiment a percentage of the reinforcements at link B were omitted, and the chain began at R_2. In the present experiment, the omission occurred at A, and the chain began with the onset of $S_1^{D,r}$ which controlled the run of responses, R_2. The question which is raised by considering the chain in this way is: Once intermittently reinforced responding is under the control of a discrete stimulus, how effective is that stimulus as a conditioned reinforcer for new behavior?

Ferster and Skinner found that a fixed-ratio performance could be maintained under percentage reinforcement, but that the pauses became longer. In the Ferster-Skinner experiment the change was gauged by the reinforcing power of the stimulus in maintaining a fixed-ratio schedule. In the present experiment the change is shown by the increase in latency and in variability of latency of the first response following the S^D. Both results are consistent with the finding that partial reinforcement in a runway tends to increase latency.

The foregoing data show that effective discriminative control over behavior can be maintained for long periods of time with only occasional reinforcement. Such methods may prove useful when it is desired to maintain control, but when, because of satiation effects or for other reasons, reinforcements must be given sparingly.

The schedule is suggestive of certain kinds of human behavior. Humans, for example, often "do work" only after the onset of distinct stimulation, and cease work following one reinforcement or with the offset of the stimulation.

SUMMARY

Intermittent reinforcement of the connection between a discrete external discriminative stimulus and reinforcement in a free-operant situation was studied. Two kinds of schedules were used. In one, the first response following the presentation of the S^D was reinforced on some occasions. In the other, a run of responses following S^D was required to produce reinforcement on some occasions.

It was found that intermittency of this type has effects similar to those of partial reinforcement in the runway. Latency of the first response following the S^D tends to increase and become more variable, although the over-all form of the performance is maintained. Precise stimulus control of runs of responses was obtained by increasing the ratio following the S^D.

REFERENCE

Ferster, C. B., and Skinner, B. F. *Schedules of reinforcement.* New York: Appleton-Century-Crofts, 1957.

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