*EFFECTS OF DIFFERENT DELAY OF
REINFORCEMENT PROCEDURES ON
VARIABLE-INTERVAL RESPONDING^{1,2}*

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Two experiments studied responding in the rat when the first bar press after a variable period of time produced a cue light that remained on for either 10, 30, or 100 sec and terminated with the delivery of food. In Experiment I, response rate decreased and time to the first response after reinforcement increased as the delay of reinforcement increased. Similar results were obtained whether the delay consisted of retracting the lever during the delay, a fixed delay with no scheduled consequence for responding, or every response during the delay restarted the delay interval. In Experiment II, fixed-delay and fixed-interval schedules of the same duration during the delay period had no differential effect on either response rate or time to the first response after reinforcement, but differentially controlled responding during the delay periods.

The typical finding in delay of reinforcement studies has been that response rate is a negatively accelerated decreasing function of the delay duration (*cf.*, review by Renner, 1964). Exceptions to this finding suggest that the procedure for delaying delivery of the reinforcer can influence the effect of the delay duration on performance. Watson (1917), Ferster (1953), and Logan (1960), for example, found little or no effect on performance of a delay duration which, in other studies, was sufficient to markedly reduce responding. The lack of an effect has been attributed to procedural differences in delaying reinforcer delivery. Conversely, large decrements in responding have also been attributed to the

effects of a delay procedure rather than to the delay duration. The large response decrements obtained by Skinner (1938, p. 139) were attributed by Chung and Herrnstein (1967) to the differential reinforcement of other behavior in which each response during the delay restarted the delay interval. The different effects reported by different persons using different delay procedures suggest the need for a comparison of delay procedures in a single experiment.

EXPERIMENT I

Experiment I compared the effects of three delay procedures on performance under a variable-interval schedule and investigated whether these delay procedures would produce different functions across several delay durations.

METHOD

Subjects

Four naive male albino rats of the Wistar strain were obtained from Harlan Industries of Cumberland, Indiana. At the beginning of the experiment they were approximately 100 days old. After receiving food and water freely for two weeks, they were gradually reduced to 80% of their free-feeding weights and were maintained at those weights throughout the experiment. Water was available at all times in their home cages.

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Apparatus

A Gerbrands operant conditioning chamber, Model B, was equipped with a Lehigh Valley Retractable Lever, Model 1405R. Retraction time and extension time for the bar were 2 sec each. A houselight, mounted on the top center of the box, was on throughout the experimental session. A Gerbrands pellet dispenser, Model D, delivered one Noyes 0.45-g pellet as the reinforcer. The offset of a cue light mounted 3 in. (7.6 cm) above the magazine accompanied the sound of the dispenser. The chamber was placed in a refrigerator shell equipped with a masking noise and a blower. Scheduling and recording apparatus were located in an adjacent room.

Procedure

Lever presses initially produced the cue light on the average of once per minute (a 1-min variable-interval schedule of stimulus presentation) and the reinforcer was delivered 0.5-sec after onset of the cue light. Responding under this condition of 0.5-sec delay permitted comparisons with subsequent performance when the delay durations were increased to 10, 30, and 100 sec. Throughout all conditions the variable-interval schedule was followed by a delay period that terminated with reinforcer delivery. The cue light was on throughout the delay duration and was off at all other times.

Three procedures for delaying reinforcer delivery were compared at each of the delay durations: a retracted lever procedure in which the lever was absent during the delay (Tombaugh, 1966); a fixed-delay procedure in which responses during the delay had no scheduled effect on delay duration (Dews, 1960; Silver and Pierce, 1969); and a DRO procedure in which each response during the delay restarted the delay (Skinner, 1938; Dews, 1960; Azzi, Fix, Keller, and Rocha e Silva, 1964).

The retracted lever procedure was unique in that the lever required 2 sec to retract. The potential effect of bar pressing during the retraction time was assessed by first studying a fixed delay of 2.0 sec without retracting the lever. After all rats had been exposed to the 0.5- and 2.0-sec fixed-delay procedures, the order of presenting the different delay procedures and delay durations was systematic-

cally varied. Rats 1 and 3 were exposed to a given delay procedure through all three delay durations before they were exposed to a second delay procedure. Rats 2 and 4 were exposed to each of the delay procedures at a given delay duration before changing to the next duration.

All sessions were 2 hr long and were conducted daily. All rats were studied under a given condition and delay length until there was no apparent upward or downward trend in response rates for five consecutive days. Each data point presented in the figures is based on the mean of the last five days of each condition. Table 1 lists the order of presentation of conditions and the number of sessions for each subject.

Table 1

The various delay procedures and sessions studied in four rats. FD represents the fixed-delay procedure, RL the retracted lever procedure, DRO the differential-reinforcement-of-other-behavior procedure. Numbers in parentheses show chronological order of procedures for each rat. The numbers beside each delay procedure indicate the delay duration in seconds.

Procedure	Number of Sessions			
	R1	R3	R2	R4
FD 0.5 sec	12(1)	13(1)	12(1)	26(1)
FD 2.0 sec	13(2)	20(2)	25(2)	14(2)
FD 10 sec	13(3)	11(3)	10(11)	10(11)
FD 30 sec	10(4)	10(4)	10(6)	10(6)
FD 100 sec	11(5)	10(5)	13(5)	13(5)
RL 100 sec	12(6)	11(6)	10(4)	11(4)
RL 30 sec	13(7)	10(7)	10(7)	10(7)
RL 10 sec	12(8)	13(8)	11(10)	10(10)
DRO 10 sec	12(8)	13(8)	13(9)	11(9)
DRO 30 sec	10(10)	10(10)	10(8)	10(8)
DRO 100 sec	11(11)	12(11)	11(3)	11(3)

RESULTS

For all subjects, response rates under the variable-interval (VI) schedule declined as the delay duration increased (Figure 1). Figure 1 indicates that the three delay procedures had similar effects on performance under the VI schedule and that the delay procedures produced similar effects across delay durations. There were no systematic differences in responding as a result of the fixed-delay, retracted lever, and DRO procedures of delaying reinforcer delivery. Response rate under the variable-interval schedule of stimulus presentation was a function of the delay dura-

Fig. 1. Rate of responding during a VI 1-min schedule for each delay procedure as a function of delay duration. Each data point represents the mean response rate for the last five sessions preceding each condition change. The letters FD refer to the fixed-delay procedure in which responses during the delay had no scheduled effect on delay duration, RL refers to the retracted lever procedure in which the lever was absent during the delay, and DRO refers to the procedure in which each response during the delay restarted the delay.

tion. Decreases in response rate as the delay duration increased were consistently obtained. Different orders of presentation of delay procedures and delay durations had no effect upon this consistent relation between response rate and delay duration.

Time to first response (post-reinforcement pause) increased for all rats as the delay duration increased. Figure 2 shows that similar functions were also generated by the three delay procedures. The importance of delay duration to VI performance is further substantiated by the fact that different delay procedures produced no consistent differences in either post-reinforcement pause time or in response rate, although both measures were systematically affected by delay duration.

Fig. 2. Post-reinforcement pause duration during a VI 1-min schedule for each delay procedure as a function of length of delay. Each data point represents the mean pause length for the last five sessions preceding each condition change. The procedures are described in Figure 1.

EXPERIMENT II

Fixed-Delay and Fixed-Interval Schedules During the Delay Period

Experiment II directly compared the effects of requiring a response to terminate the delay with termination independent of responding. A fixed-interval schedule that required a response after a period of time to terminate the delay period was compared with the fixed-delay procedure used in Experiment I. Equal durations of fixed-delay and fixed-interval schedules were compared. When the rat completed the fixed-interval schedule as soon as possible, the only difference between the fixed-delay and fixed-interval schedules was the response required under the fixed-interval schedule.

Subjects and Apparatus

The subjects and apparatus were the same as in Experiment I.

Procedure

At the completion of Experiment I, all rats were exposed to the initial procedure under which the 0.5-sec cue light was response-produced according to a VI 1-min schedule.

At the end of the 0.5 sec (and the offset of the cue light), a reinforcer was delivered. As in Experiment I, a VI 1-min schedule was used throughout all conditions and was always followed by a delay period. After response rate under the VI schedule with 0.5-sec delay stabilized, the following procedures were instituted. Fixed-delay (FD) and fixed-interval (FI) schedules of 10-sec duration now followed the VI 1-min schedule and were compared in the order FD, FI, FD, FI. The rats were then exposed to the 0.5-sec delay condition and then the same procedures were repeated in the same sequence, except the delay period was increased to 30-sec duration. Shortly after beginning the 30-sec series, R1 and R2 died. Therefore, complete data are reported for R3 and R4 only. Table 2 summarizes the procedures and gives the number of sessions per condition. The session length and stability criterion remained the same as in Experiment I.

Table 2

The delay procedures and sessions studied in four rats. The letters refer to fixed-delay (FD) and fixed-interval (FI) schedules during the delay period with the subsequent numbers referring to the delay duration in seconds.

Procedure	Number of Sessions			
	R1	R2	R3	R4
FD 0.5 sec	33	18	19	18
FD 10 sec	14	10	10	10
FI 10 sec	10	13	13	14
FD 10 sec	10	15	15	13
FI 10 sec	15	20	21	16
FD 0.5 sec	19	13	13	18
FD 30 sec	14	18	17	15
FI 30 sec	18	16	10	23
FD 30 sec			20	39
FI 30 sec			29	22

RESULTS

Marked and consistent differences between fixed-delay and fixed-interval schedules were evident in the delay period. Figure 3 shows that response rate was always higher when a response was required to terminate the delay period than when no response was required.

An analysis of the distribution of responses during the delay period indicated that when a response was required, responding increased sharply over the duration of the interval (a

Fig. 3. Rate of responding during the delay period for both fixed-delay and fixed-interval schedules at different delay durations. Each data point represents the mean response rate for the last five sessions preceding each condition change.

scalloped curve), while responding showed no change over the interval when food was presented independently of responding at termination of the delay period. Figure 4 presents the response distribution for the last session of each condition of the fixed-delay and fixed-interval schedules of 10-sec duration. The abscissa is divided into five consecutive 2-sec intervals. The response distribution for the 30-sec conditions was similar to that of the 10-sec conditions and, therefore, those data are not presented.

Responding during the VI schedule hardly changed when the delay period was of the same duration but different schedules comprised the delay period (Figure 5). Response rates for R1, R2, and R3 decreased when the delay duration was increased from 10 to 30 sec, but rates were not affected by changing the delay from fixed-delay to fixed-interval.

Fig. 4. Response distribution in the 10-sec delay period during the last session of each condition. Each data point represents the response rate during 2-sec consecutive intervals.

There were no systematic differences in the post-reinforcement pause time between fixed-delay and fixed-interval schedules and, therefore, those data are not presented.

DISCUSSION

The similarity of effects obtained in Experiment I with post-reinforcement pause and response rate under the variable-interval schedule supports and extends the findings of Azzi *et al.* (1964), who reported that both variables were sensitive measures of delay of reinforcement effects when the initial schedule was continuous reinforcement.

The results of Experiment II indicate that the fixed-delay and the fixed-interval schedule each maintained control over the rate and pattern of responding in the delay period but did not differentially affect responding in the VI schedule. These data support the hypothesis that delay of reinforcement may be functionally similar to a chained schedule when the delay interval is accompanied by an exteroceptive stimulus (Ferster, 1953; Ferster and Hammer, 1965).

Results very similar to those of Experiment II have also been obtained in two-key situations. Neuringer (1969) demonstrated that

Fig. 5. Rate of responding under the VI schedule as a function of schedule and duration of the delay period. Each data point represents the mean response rate for the last five sessions preceding each condition change.

there are relatively slight differences in preference between a blackout procedure for delaying reinforcer delivery and a fixed-interval schedule of the same duration. Experiment II differed from Neuringer's in several important aspects: responding was permitted during the delay period with the delay always made discriminable by a cue light; absolute measures of performance were used as the dependent variables; that is, response rate and post-reinforcement pause in contrast to the choice procedure of Neuringer; and rats rather than pigeons were the subjects. Despite these differences, the present results, which indicate that fixed-delay and fixed-interval schedules have similar effects on response rate and on post-reinforcement pause (Experiment II), confirm the results of Neuringer (1969). The present results further confirm Neuringer's conclusion that delay duration is an important variable affecting both response rate and post-reinforcement pause (Experiment I). The present results also indicate that similar effects can be obtained under the variable-interval schedule when responding during the delay is prevented (the retracted lever condition), is permitted (the fixed-delay conditions), results in restarting the delay interval (the DRO condition), or is reinforced (the fixed-interval condition). These results further support the conclusion of Neuringer (1969, p. 382) that "the time between a response and reinforcement

controls the probability of that response, whether other responses intervene or not”.

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