FIXED-INTERVAL LIMITED-HOLD AVOIDANCE WITH AND WITHOUT SIGNALLED REINFORCEMENT¹

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Rats trained to lever press on a fixed-interval limited-hold avoidance schedule maintained a pattern of responding similar to that maintained by fixed-interval limited-hold schedules of positive reinforcement. But this positively accelerated pattern of behavior was maintained only when the occurrence of reinforcement was signalled by the presentation of a brief flash of light. This result suggests that the discriminative function of the reinforcer in avoidance is less pronounced than the discriminative function of the reinforcer in escape or positive reinforcement. It also suggests that the distinction between positive reinforcement and avoidance is not superfluous. Although the schedule of reinforcement is an important variable in determining the pattern of behavior, other variables, such as the nature (*i.e.*, stimulus presentation, termination, or omission) of the reinforcer, are also potent determinants of behavior.

Although reinforcers are usually classified as being positive or negative, this distinction has been characterized as lacking empirical significance. Morse and Kelleher (1966) briefly reviewed an impressive array of experiments that indicate that behavior maintained by escape (stimulus termination), which is one kind of negative reinforcement, is comparable to that maintained by positive reinforcement (stimulus presentation). Since the similar scheduling of different kinds of events (stimulus termination or presentation) results in similar performances, they concluded that, as far as the pattern of behavior engendered by a particular schedule of reinforcement is concerned, the distinction between positive and negative reinforcement is superfluous.

The generality of this conclusion is limited by a lack of data concerning avoidance behavior. The possibility that there are two distinct kinds of negative reinforcement, escape and avoidance, has long been recognized (*e.g.*, Hilgard and Marquis, 1940, p. 51). All of the negative reinforcement studies cited by Morse and Kelleher were escape experiments.

Thus, it is as yet unknown whether the behavior pattern maintained by stimulus omission (avoidance) is similar to that maintained by an equivalent schedule of stimulus termination or presentation.

Although all reinforcers are alike in that they increase the rate of a response that they follow, reinforcers are quite different in regard to the nature of the reinforcing stimulus. In both positive reinforcement and escape, the reinforcer consists of a marked change in the environment (*e.g.*, presentation of food or termination of shock). In avoidance, however, the reinforcer is not the presentation or the termination of a salient stimulus, but the postponement or the omission of an event (*e.g.*, shock). Consequently, in avoidance, the occurrence of reinforcement is not signalled by an abrupt change in the environment. It seemed possible that this lack of a salient stimulus change at the moment of reinforcement might cause the behavior pattern engendered by a schedule of stimulus omission to be dissimilar to that maintained by an equivalent schedule of stimulus termination or presentation.

In the present experiment, rats were trained to lever press on a fixed-interval limited-hold avoidance schedule. On a fixed-interval schedule, all responses that occur within the fixed interval have no effect on reinforcement. However, the first response that occurs after the fixed interval has elapsed is reinforced and

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also starts a new fixed interval. On a fixed-interval schedule with a limited-hold contingency (FI LH) reinforcement is available for only a specified period of time after the fixed interval terminates. Consequently, on an FI 24-sec LH 6-sec avoidance schedule, all responses that occur between 0 and 24 sec after the start of the fixed interval have no effect on shock presentation; however, the first response that occurs between 24 and 30 sec avoids the shock that would have occurred at the termination of the limited-hold interval had the animal not responded within the limited hold. In some stages of this experiment, a response within the limited-hold interval, in addition to starting a new fixed interval, also produced a brief illumination of the test chamber (*i.e.*, the occurrence of reinforcement was signalled by a salient stimulus change).

It is known (Hearst, 1958) that fixed-interval limited-hold schedules of positive reinforcement maintain a pattern of behavior that is characterized by positive acceleration (*i.e.*, a low rate of response at the start of each fixed interval followed by a gradual transition to a moderate response rate as the limited-hold interval is approached). Consequently, if it could be shown that the behavior pattern maintained by this avoidance schedule is positively accelerated, regardless of whether the occurrence of reinforcement was signalled or unsignalled, it would provide further evidence that the distinction between positive and negative reinforcement is unwarranted. However, if it turns out that the behavior pattern maintained by this avoidance schedule is positively accelerated only when the occurrence of reinforcement is signalled, it would demonstrate that the similar scheduling of different kinds of events does not always engender similar performances and, therefore, that the distinction between avoidance and positive reinforcement is not superfluous.

METHOD

Subjects

Seven experimentally naive female hooded rats, approximately 100 days old at the start of the experiment, were housed in individual cages and maintained on free feeding and water throughout the experiment. They were purchased from Blue Spruce Farms, Altamont, New York.

Apparatus

The experimental chamber, which was housed in a sound-attenuated chest, was 8 in. long by 10 in. wide by 9 in. high (20 by 26 by 22 cm). The walls of the chamber were metal and the ceiling was made of transparent Plexiglas. The floor was a grid composed of 6.35-mm stainless steel rods 0.75 in. (2 cm) apart, measured from center to center, a sufficient distance to prevent fecal boli from shorting out the shock. A rat lever (Lehigh Valley Model 1352), was located 1.25 in. (3 cm) above the grid floor. The lever protruded 0.5 in. (1.25 cm) into the box. A response, which was defined as a depression of the lever, required a force of 15 g (0.15N) to activate the micro-switch. Shock was delivered to the walls, grid floor, and to the lever from a Grason-Stadler shock generator and scrambler (Model E1065GS). An exhaust fan masked extraneous sounds.

Procedure

The rats were initially trained in complete darkness on a fixed-cycle schedule of reinforcement (Sidman 1962, 1966). The experimental session was divided into successive cycles of *t* sec in duration. Shocks were scheduled to be delivered at the end of each cycle (*e.g.*, 7.5 sec). The rat had only to depress the lever once during any part of the cycle to prevent shock at the end of that cycle; additional responses during that particular cycle had no scheduled consequence. The response that avoided the shock at the end of a cycle is here referred to as an avoidance response. Each avoidance response produced a 1.25-sec illumination of the chamber (a 6-w bulb at 117 v ac). A response during this brief stimulus did not extend the duration of illumination. One modification was made to Sidman's fixed-cycle schedule of reinforcement: whenever a shock occurred it remained on until terminated by an escape response. A new cycle always began at the point in time where the animal either terminated the shock or where it would have been shocked if it had not successfully avoided.

The duration of the fixed cycle was initially 7.5 sec (see Table 1 for a summary of the procedures). Cycle length was gradually increased to 10 and then to 15 sec. Shock intensity was 0.6 mA for the first 20 min on the first day of training. For the remainder of the first session

and for the second session, shock intensity was 1.0 mA. From the third session onward, shock intensity was set at 1.6 mA.

After the initial training on the fixed cycle 15-sec schedule, the rats were placed on a fixed-interval schedule with a limited-hold contingency. On a fixed-interval limited-hold avoidance schedule all responses that occur within the fixed interval have no effect upon shock delivery. However, a response that occurs within the limited-hold interval is reinforced by avoiding the shock that would have occurred at the termination of the limited-hold interval had the animal not responded within the limited hold. A response in the limited-hold interval always starts a new fixed interval. Whenever a shock occurs it remains on until terminated by an escape response. An escape response also starts a new fixed interval. During this initial training, each escape and limited-hold response, in addition to starting a new interval, also produced the brief illumination of the chamber. In this manner the beginning of every fixed interval was signalled by the presentation of a salient stimulus.

Table 1
Summary of Procedures

Schedule		Brief Stimulus	No. of Sessions
FC	7.5	Each avoidance response	4 to 9
FC	10	Each avoidance response	3
FC	15	Each avoidance response	5
FI 9	LH 21	Start of every interval	11
FI 15	LH 15	Start of every interval	11
FI 21	LH 9	Start of every interval	11
FI 24	LH 6	Start of every interval	11
FI 24	LH 6	Only escape responses	10
FI 24	LH 6	Start of every interval	11

FC = fixed cycle

The rats were trained 11 sessions on each of the following fixed-interval limited-hold avoidance schedules in the order given: FI 9-sec LH 21-sec, FI 15-sec LH 15-sec, and FI 21-sec LH 9-sec. All animals were then trained for 11 sessions on FI 24-sec LH 6-sec (first determination). As above, the start of every interval was signalled by the brief stimulus.

In the next stage of the experiment (10 sessions), a response in the limited hold no longer produced the brief stimulus. The schedule of reinforcement remained FI 24-sec LH 6-sec but now only those fixed intervals started

by an escape response continued to be signalled by the brief illumination of the chamber. Consequently, since five of the seven rats continued to avoid over 87% of the potential shocks, fewer than 13% of the fixed intervals were now signalled by the brief illumination. This stage of the experiment allowed us to determine whether this avoidance schedule would maintain a pattern of responding similar to that maintained by fixed-interval limited-hold schedules of positive reinforcement when the beginning of every interval was not signalled by the presentation of a salient stimulus. Finally, in the last stage of the experiment (11 sessions) limited-hold responses again produced the brief stimulus on FI 24-sec LH 6-sec (redetermination).

The data of primary interest were responses cumulated over the fixed intervals in 3-sec bins; that is, all responses occurring in the first 3-sec after the start of every fixed interval were recorded on one counter, then all occurring in the second 3-sec on a second counter, and so on through the 10 bins comprising the 30-sec period ($FI + LH = 30$ sec). Throughout the experiment, the schedule of reinforcement was not changed until the rats' behavior had stabilized. Stabilization was judged by visual inspection of the cumulative records. Sessions were 180 min in length and occurred six days a week.

RESULTS

Figure 1 shows that when the start of every interval was signalled by the production of the brief stimulus (first determination) a behavior pattern resulted that was similar to behavior maintained by fixed-interval limited-hold schedules of positive reinforcement. There was a low response rate, excepting bin 1, after the start of the interval followed by a higher response rate as the limited hold was approached. It should be emphasized that the lower number of responses in bins 9 and 10 (24 to 30 sec) in Figure 1 as compared to bins 1 through 8 does not necessarily mean that there was a lower response rate in the limited hold (*i.e.*, bins 9 and 10). Bins 1 through 8 were always 3 sec in length, since the duration of these bins could not be affected by the rat's behavior. However, a response in bin 9 or 10 immediately started a new interval. Thus, when a rat responded in bin 9 or 10 it termi-

Fig. 1. Total number of responses cumulated over the fixed intervals in successive 3-sec bins on an FI 24-sec LH 6-sec avoidance schedule. Each graph represents the characteristic performances of one rat. Each curve in each graph is one session's performance taken from the last two or three sessions under each procedure. The first eight bins (0 to 24 sec) represent responses in the fixed interval. Solid circles: brief stimulus presented at the start of every interval; triangles: only those intervals started by an escape response produced the brief stimulus; open circles: redetermination of the effects of presenting the brief stimulus at the start of every interval. Note that the scale on the ordinate is different for each row of graphs. Note also that the scale on the abscissa is compressed for the bottom row of graphs.

nated the bin without allowing it to last the full 3 sec. Therefore, the amount of time spent in bin 9 or 10 was far less than in any one of the first eight bins. Consequently, in

interpreting Figure 1, closest attention should be paid to the amount of responding in bins 1 through 8, for an equal amount of time was spent in each of these eight bins. Clearly,

though, if an animal had a higher total number of responses in bin 9 or 10 than in each of the first eight bins it was showing a precise discrimination (see, for example, Rat A 7 and Rat A 21).

During those sessions in which the start of every interval was no longer signalled by the brief stimulus, responding occurred at a fairly steady rate throughout the fixed interval. Thus, the omission of the brief stimulus for responses in the limited hold, eliminated the differential responding in different parts of the fixed interval and increased the overall rate of responding. When the brief stimulus again signalled the start of every interval, the differential responding returned, and the overall rate of responding decreased.

Figure 2 shows some typical cumulative records for four rats on FI 24-sec LH 6-sec with signalled reinforcement. These records show that the positively accelerated pattern of responding shown in Figure 1 is quite representative of the response patterning in individual

intervals. Figure 2 also shows that the high proportion of responses in bin 1 is not attributable to a high response rate after shock termination (*i.e.*, post-shock bursts). As seen in this figure, shocks were quite infrequent and when they did occur, there was not a high response rate after they terminated.

DISCUSSION

The most important result of the present experiment was that a FI 24-sec LH 6-sec avoidance schedule maintained a pattern of responding similar to that engendered by fixed-interval limited-hold schedules of positive reinforcement only when the occurrence of reinforcement was signalled by the presentation of a salient stimulus. Therefore, when the beginning of every interval was no longer signalled by the brief illumination, the positively accelerated pattern of responding disappeared, even though the schedule of reinforcement remained a fixed-interval limited-hold.

Fig. 2. Representative cumulative records of four individual rats on FI 24-sec LH 6-sec with signalled reinforcement. Shock presentation is indicated by a downward pen deflection. The dots indicate the occurrence of a brief illumination for an escape or a limited-hold response.

The only marked dissimilarity between the behavior maintained by fixed-interval limited-hold schedules of positive reinforcement and avoidance (when the start of every interval was signalled) was the high response rate on this avoidance schedule immediately after reinforcement (*i.e.*, bin 1). This high rate resulted from responding during and immediately after the brief stimulus. These responses cannot be attributed to a high response rate after shock-termination because the rats rarely emitted more than two or three responses after shock. A convincing explanation of this high response count is lacking.

The failure of this avoidance schedule to maintain the "characteristic" fixed-interval pattern of behavior when the occurrence of reinforcement was not signalled becomes understandable when one considers that the occurrence of reinforcement in avoidance is not marked by an abrupt change in the environment. On a fixed-interval schedule, the occurrence of reinforcement is always followed by a fixed period of time in which reinforcement is unavailable. Therefore, when the reinforcer on a fixed-interval schedule consists of a salient stimulus change, animals learn that responding immediately after reinforcement is never reinforced. Thus, a low rate of response after reinforcement characterizes the pattern of behavior on fixed-interval limited-hold schedules of escape or positive reinforcement. On a fixed-interval limited-hold avoidance schedule, however, the occurrence of reinforcement is not, of course, signalled by an abrupt change in the environment. Accordingly, since the occurrence of reinforcement is not signalled, animals are unable to discriminate the moment of the occurrence of reinforcement. Consequently, responding immediately after reinforcement does not extinguish and a constant response rate throughout the fixed interval prevails.

It should be emphasized that fixed-interval schedules of positive reinforcement (*e.g.*, second-order schedules) also do not produce positively accelerated behavior in each component unless the termination of every interval is marked by a salient stimulus (Kelleher, 1966; Marr, 1969). Thus, it appears that all fixed-interval schedules of reinforcement are alike in that a salient stimulus change must occur at the completion of every interval for positively accelerated responding to occur.

One broad implication arising from the results of the present experiment is that a distinction should probably be made between reinforcers; but this distinction is not the traditional one that differentiates between those reinforcers that are presented (positive) as against those that are terminated or omitted (negative). An important distinction among reinforcers is between those that consist of the presentation or termination of a salient stimulus as against those that do not consist of an abrupt change in the environment. Reinforcers that do not consist of a salient stimulus change appear to have a less pronounced discriminative (*i.e.*, signalling) function. Because of this disparity in their discriminative function, this type of reinforcement often maintains a pattern of behavior that is dissimilar to that maintained by an equivalent schedule of stimulus presentation or termination (Dunn, Foster, and Hurwitz, 1971; Hurwitz and Millenson, 1961; Sidman, 1962; Verhave, 1959). Thus, in the present experiment, the similar scheduling (fixed-interval limited-hold) of a different kind of event (stimulus omission) did not always maintain similar performances (a positively accelerated pattern of behavior). In other words, the results of this experiment demonstrate that a fixed-interval limited-hold schedule is not a sufficient condition for the maintenance of a positively accelerated pattern of behavior. Although the schedule of reinforcement is an important variable in determining the pattern of behavior, other variables, such as the nature (*i.e.*, presentation, termination, or omission) of the reinforcer, are also potent determinants of behavior.

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