TEMPORALLY SPACED RESPONDING BY PIGEONS: DEVELOPMENT AND EFFECTS OF DEPRIVATION AND EXTINCTION¹

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In the first five or six sessions on a DRL 20-sec schedule of reinforcement there developed a stable performance characterized by a relatively constant conditional probability of occurrence (IRTs/op) of interresponse times (IRTs) of durations greater than 5 or 6 sec. Extinction and the level of deprivation changed both the overall rate of responding and the form of the function relating the duration of an IRT to its value of IRTs/op. The value of IRTs/op decreased more rapidly for short than for longer IRTs, resulting in the emergence of a finer discrimination of IRT duration.

Interest in the pigeon's temporally spaced responding maintained by a DRL schedule of reinforcement is due largely to the apparently poor behavioral control exerted by temporal stimuli in this procedure (Catania and Reynolds, 1961; Holz and Azrin, 1963). In comparison, relatively precise control is exerted by temporal stimuli in other procedures, *e.g.*, generalization to the duration of an exteroceptive stimulus (Reynolds and Catania, 1962) and the fixed-interval schedule of reinforcement (Ferster and Skinner, 1957). Whereas in these procedures the pigeon's rate of responding is quite sensitive to the time elapsed since the start of a stimulus or since the presentation of a reinforcer, in DRL the probability of responding usually turns out to be relatively constant over a wide range of times elapsed since the pigeon's previous response. Additional interest accrues from the fact that the temporal stimuli of a DRL schedule exert much more precise control over the behavior of rats (Anger, 1956; Sidman, 1956) and monkeys (Conrad, Sidman, and Herrnstein, 1958), than over the behavior of pigeons. The present data show the development of the temporal control by DRL 20-sec in pigeons and some of the subsequent effects of extinction and deprivation.

METHOD

Subjects

Three adult male, white Carneaux pigeons were maintained at 80% of their free-feeding weights.

Apparatus

The experimental chamber was enclosed in a picnic icebox and contained a key $\frac{3}{4}$ in. in diameter and 10 in. above the mesh floor, lights for transilluminating the key, a 2-in. square hole beneath the key for access to grain, a white masking noise, and general white illumination. An effective force of about 15 g operated the key. Programming and recording equipment were located two rooms away from the chamber. All pecks on the key were recorded on a cumulative recorder. Also, frequency distributions of interresponse times (IRTs) were obtained in 2-sec class intervals.

Procedure

Each *S* was trained to eat from the feeder through the hole in the chamber wall, and to approach the feeder when it operated. During feeder operation, the general chamber illumination and the lights behind the key were turned off. Key-pecking was not shaped, since each *S* pecked on the illuminated key, during the first $\frac{1}{2}$ hr in the chamber. The first 20 pecks were reinforced. On each of the next two days, the first 60 pecks were each reinforced. The reinforcer was always 4 sec of access to mixed grain in the feeder.

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Pecking was reinforced on DRL 20-sec during the following 119 daily sessions, which were successive except for four periods of one or two days each. Each peck which followed the preceding peck by 20 sec or more was reinforced. A session ended after the fifth reinforcement. The sessions were usually between 3 and 4 hr long.

Several levels of deprivation were arranged by returning each S to its free-feeding weight after session 45 and then greatly reducing the usual ration of grain after sessions 46 to 54 or 55. The Ss continued to receive five presenta-

tions of grain in the chamber in each session and water was always available. Following this procedure, the weights were adjusted to and maintained at 80% of their free-feeding value by appropriate feeding.

Responding was extinguished during sessions 81-85. The feeder did not operate during extinction. These sessions ended after 15 reinforcements would have occurred, *i.e.*, after 15 IRTs of 20 sec or longer. The duration of these sessions were between 120 and 20 min. Between the third and fourth session of extinction, one daily session was omitted. The

Fig. 1. The rate of responding in selected sessions of DRL 20-sec reinforcement as a function of logarithmic scale of session, for birds a, b, and c.

Fig. 2. IRTs/op as a function of IRT duration for birds a, b, and c (columns from left to right) in representative sessions (rows numbered at the right) of DRL 20-sec reinforcement. The abscissa is composed of 2-sec class intervals of IRT duration.

weights of the Ss were maintained at 80% of the free-feeding values during extinction.

RESULTS

Figure 1 shows the development of the overall rate of responding between sessions 2 and

119. The number of responses per minute in selected sessions is plotted against a logarithmic scale of sessions for each S. The rate decreases rapidly in the initial sessions. Between sessions 4 and 119, there is a small net increase in the rates of two Ss (filled and unfilled circles), and no net increase in the rate

Fig. 3. IRTs/op as a function of IRT duration for three birds (rows lettered at the right) during a session of each of three procedures (columns labeled at the top). The rate of responding in each session has been entered on the panels.

of the third *S* (triangles). The rates prevailing in session 119 are between 10 and 12 responses per min. A rate of three responses per minute would result if the 20-sec IRT, required for reinforcement were to occur each time.

The changes in the probability of occurrence of IRTs of various durations are shown in Fig. 2. The number of interresponse times per opportunity (IRTs/op) has been plotted against the duration of the IRT in 2-sec class intervals for each *S* (columns of panels) for six of the sessions (rows of panels) whose overall rates appear in Fig. 1. The statistic (IRTs/op) is a conditional probability, devised by Anger (1956) to take account of the fact that IRTs of different durations may have

different numbers of opportunities to occur. For example, the bird has an opportunity to emit an IRT of 1 sec whenever it actually emits an IRT of 1 sec or of any longer duration, but it has an opportunity to emit an IRT of 10 sec only when it actually emits an IRT of 10 sec or longer. To compute IRTs/op, the number of IRTs in a given class interval of IRT duration is divided by the total number of IRTs of that duration and longer.

At first, in session 2, IRTs/op is a decreasing function of the duration of the IRT. During session 3, the IRTs/op of the shortest IRTs begin to decrease, and the IRTs/op of the longest IRTs increase relatively, so that

the value of IRTs/op is approximately the same for each duration of IRT. By the end of session 6, the function has almost reached its final form: the IRTs/op of IRTs of 0.2 sec and 2.4 sec are relatively low, and the IRTs/op of longer IRTs are higher and approximately constant. After session 6, the changes in the performance are not great.

A somewhat finer temporal discrimination sometimes occurs in a session, but it is not stable. The IRTs/op continue to increase slightly with increasing IRT duration greater than 4 sec in sessions 6 and 64 for pigeon b, but there is no systematic increase in session 119. Pigeon c shows a finer discrimination in session 119, but not in earlier sessions. For this *S* only, the value of IRTs/op for IRTs of 0.2 sec is greater than the value of IRTs/op for IRTs of 2.4 sec.

Increases in the weight of the *S* and extinction both produced decreases in the rate of responding. Decreases in *S*'s weight generally produced increases in the rate of responding. The magnitudes of these changes in rate correspond with those reported by Holz and Azrin (1963) who used a similar procedure.

The present data also accord with theirs in showing a change in the shape of the frequency distribution of IRTs toward a more pronounced temporal discrimination if the rate of responding decreases. Figure 3 shows the distribution of IRTs/op over IRT duration for the last session of reinforcement (left column of panels) and for the last session of extinction (middle column of panels). The numbers in each panel give the overall rate of responding in the session. During extinction, the IRTs/op decreased to a lower value for some short than for some long IRTs. This produced a more persistent increase in IRTs/op with increasing durations of IRTs than generally occurred when responding was reinforced. The IRTs/op distribution from a session with increased body weight appears in the right column of Fig. 3. The effect of satiation is similar to that of extinction for pigeons b and c, but not for pigeon a, which differs from b and c in that satiation did not decrease its rate of responding near to or below the rate that prevailed in extinction.

The finer temporal discrimination emerges because, as the rate of responding decreases, the value of IRTs/op decreases more rapidly for short than for longer IRTs. From the top

Fig. 4. The relationship between IRTs/op and the rate of responding in every second class interval of IRT duration (separate panels), for bird a. The various rates were produced by varying the weight of the bird (filled circles) and during extinction (unfilled circles) or by reinforcement on DRL 20-sec (triangles). The line is a least-squares fit to the data. The shorter lines were fitted to the data of birds b (dashed) and c (dotted), which are not shown.

Fig. 5. A summary of the parameters of the straight lines fitted to the relation between IRTs/op and rate of responding shown in Fig. 4. The slope (top panel) and the intercept (bottom panel) appear as functions of the IRT duration in 2-sec class intervals, for the three birds.

to bottom, the panels of Fig. 4 show IRTs/op as a function of the rate of responding for every other class interval of IRT duration. Unfilled circles are data from extinction; filled circles, data for various levels of deprivation; unfilled triangles, data from session in which responding was reinforced. The data are from pigeon a, and are representative of the performances of all three pigeons. In order to summarize the relations depicted here, straight lines of minimum squared deviations from the data were computed. These appear as the solid lines in Fig. 4. Straight lines were also computed for the data of pigeons b and c. They appear in Fig. 4 as the short dashed (pigeon b) and dotted (pigeon c) lines in each panel.

The dependence of the relation between IRTs/op and the rate of responding on IRT duration is further summarized in Fig. 5. The top panel shows the slope of the lines in Fig. 4 and the bottom panel shows the intercepts, both as a function of the duration of the IRT. The slope indicates the rate of decline of IRTs/op for a given class interval of IRT duration as the rate of responding declines. The rate of decline is low for 0.2 sec IRTs, perhaps because they begin as so low a value (Fig. 4, top panel). From IRTs of 4-6 sec to IRTs of 18-20 sec, the rate of decline decreases. The longer the IRT, the less rapidly does its conditional probability of occurrence decrease as the rate of responding decreases. This results in the appearance of a more pronounced temporal discrimination.

DISCUSSION

In DRL, a peck is reinforced in the presence of a temporal stimulus, 20 sec or more since the previous peck, and not reinforced in the presence of temporal stimuli of shorter duration. This should tend to bring pecking under the discriminative control of IRTs greater than 20 sec. However, the discrimination does not appear during the maintained performance. As the rate decreases, however, the differential control of IRTs/op by longer IRTs appears. Since this comes about, for one way, during extinction, it does not seem appropriate to speak of the development of a finer temporal discrimination in the usual sense, but rather of its appearance or emergence.

Perhaps two of the functions of reinforcement are separable here: the one to maintain responding at an appropriate rate, the other to bring responding under the discriminative control of additional stimuli in whose presence it is reinforced. In the maintained DRL, the effects of the first hide the effects of the second. When the effects of the first decrease, as in extinction (and with decreases in deprivation), the effects of the second appear. There seems to be some justification for tentatively separating these two functions of reinforcement: in the bird adequately trained to the magazine, key pecking is acquired after one reinforced response, but discriminative control by the color of the key may take time.

In its maintained performance, the pigeon seems consistently to fail to discriminate among the durations of its IRTs from 4 to 20 sec; in each 2-sec class interval, the probability that it will peck now rather than wait to peck later is approximately the same. It is interesting to note that the IRTs of the pigeon in this procedure follow a statistical rule similar to that which describes the duration of intracity telephone calls and the time taken to repair automatic machinery (Feller, 1957). The implications of this fact for the variables controlling the behavior are not clear.

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