THE EFFECTS OF TOTAL DARKNESS ON SCHEDULE CONTROL¹

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The study investigated the effect of total darkness on the key pecking of pigeons under fixed-ratio, variable-ratio, fixed-interval, and variable-interval schedules of food reinforcement. Eight pigeons were divided into groups of two, with each group conditioned to peck under one of the four schedules of reinforcement. Under an ABAB procedure, all pigeons experienced alternating light and dark conditions. The house- and keylights were (a) maintained at full intensity for the first 30 one-hour sessions, (b) faded out and disconnected over Sessions 31 through 50, (c) totally illuminated for Sessions 51 to 60, and (d) disconnected again for the final 10 sessions. Responding under the ratio schedules increased from 20% to 108% in the dark and responding under the interval schedules in the dark decreased by 37% to 93%.

Total darkness or blackout is not an unusual experimental situation for pigeons. A period of darkness has been used to punish a response to an incorrect stimulus, a totally dark chamber condition has been employed as a component of intertrial intervals, and periods of total darkness have been employed to analyze the stimulus functions of response sequence schedules (Ferster and Skinner, 1957, pp. 213, 638-39). Though such dark conditions have often been employed, their effects on the behavior of pigeons have not been directly investigated. The published studies most relevant to darkness effects on pigeons have been psychophysical investigations to determine visual thresholds (Blough, 1956) and to demonstrate sensory scaling (Herrnstein and Van Sommers, 1962).

Darkness has been shown to be an influential variable on the behavior of rodents. Varying luminosity levels and introducing totally dark conditions influenced responding (De Coursey, 1960; Lockard, 1963; Robinson, 1959; Sackett and Wilsoncraft, 1964). The present study determined whether a pigeon's maintained behavior would be differentially affected by light and dark conditions where reinforcement contingencies remained constant. Four basic schedules of reinforcement were employed.

METHOD

Subjects

Eight adult experimentally naive male homing pigeons were maintained at 80% of their free-feeding weights and individually housed in a colony room containing many large windows. No special lighting conditions were employed in the colony room.

Apparatus

The test chambers (35 by 30 by 35 cm) were Lehigh Valley Electronics pigeons test chambers Model 1519 with a 1348 QL stimulus light mounted behind each of the three stimulus response keys, requiring a minimum operating force of 15 g (0.15N). Black electrician's tape was placed over the two outer keys during the experiment. Mallory P11 variable resistors, with approximately 500 ohms maximum resistance, were placed in series with the center keylight and with the 28-V houselight 2 in. above (5.8 cm) so their intensities could be varied from off to full intensity. The chambers were located in a totally dark room during all experimental sessions. All scheduling equipment was housed in an adjacent room.

Procedure

All pigeons were initially conditioned to key peck under a continuous reinforcement schedule with the houselight and keylight at full intensity. During the reinforcement

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period, the hopper containing a grain mash came up for 4 sec. The hopper light was illuminated for those 4 sec, while the key- and houselights were simultaneously extinguished. The eight pigeons were then divided into four groups of two. Each group was assigned to one of four food reinforcement schedules: (a) a variable-interval schedule averaging 60 sec (VI 60-sec), with a range of 10 to 180 sec; (b) a fixed-ratio schedule of 100 responses per reinforcement (FR 100); (c) a variable-ratio schedule averaging 200 responses per reinforcement (VR 200) with a range of 20 to 520 responses for P-5, and 100 responses per reinforcement (VR 100) with a range of 10 to 260 responses for P-6; (d) a fixed-interval schedule requiring 60 sec to pass before a response was reinforced (FI 60-sec). Each pigeon was studied under its assigned schedule 1 hr every day for the next 30 days. Of these 30 sessions, the last 10 were defined as baseline sessions (Sessions 21 through 30 on Figures 1 and 2).

During Session 31, the intensity of the house-light was decreased in steps until completely off, by increasing the resistance of the variable resistor approximately 50 ohms during presentation of every fifth reinforcement. Four to nine additional sessions were needed to fade out the keylight because slight variations in light intensity, especially at the lower luminosity levels, affected responding to the key. Generally, the resistance was increased 50 ohms each time the intensity was lowered. If a pigeon stopped responding with this degree of change, the stepping procedure was reversed two to five steps to reinstate responding. As a consequence, the number of sessions required for a subject to reach total darkness (house- and keylights disconnected) varied from four to nine sessions with a mean of six. In Figures 1 and 2, arrows mark the first session in which a pigeon responded through one complete session in total darkness.

In summary, the experiment was divided into four main conditions. Condition I consisted of the first 30 sessions, of which the last 10 were defined as the baseline. The house- and keylights were faded out in Condition II, Sessions 31 through 50. Condition III consisted of Sessions 51 through 60 in which the house- and keylights were held at full intensity. In Condition IV, the house- and keylights were again turned off for Sessions 61 through 70, with the light intensity being alternately

turned on and off from one session to another for Sessions 71 through 74. In the data analysis, all means are based on the total number of responses for the last three sessions under each condition.

RESULTS

The dark condition had a marked effect on the response rate of all pigeons. The direction of the rate change depended on the type of reinforcement schedule, an increase occurring under ratio schedules and a decrease under interval schedules. Responses per session for each pigeon are presented in Figures 1 and 2.

Variable-interval (VI) schedule. The number of responses was lower during dark conditions (II, IV) than during light conditions (I and III) (Figure 1). For P-1, the average number of responses during each dark condition (II and IV) was respectively 37% and 38% less than in the preceding light condition; for P-2, 60% and 64% less, respectively. The average number of responses per session during Conditions I through IV for P-1 was 2830, 1775, 2940, 1820 respectively; for P-2, 3190, 1265, 3220, and 1150. The number of reinforcements per session remained relatively constant in the light and dark conditions, averaging for the four consecutive conditions, 47, 48, 47, 49 for P-1 and 49, 45, 48, 47 for P-2. Cumulative records showing typical performances under the light and the dark conditions are shown in Figure 3. Both pigeons were given three extra sessions, to see if the differential effect of light and dark conditions could be obtained when the conditions were reversed from session to session, rather than every 10 sessions. The house- and keylights were at full intensity in Sessions 71 and 73, and were disconnected during Session 72.

Fixed-interval (FI) schedule. The response rates for P-7 and P-8 also were lower in total darkness (Figure 2). The reduction in the number of responses per session was greater than for pigeons on VI schedules. For each change from light to dark conditions, the average number of responses for P-7 decreased by 93% (I to II) and 88% (III to IV); the average number of responses for P-8 decreased by 89% (I to II, and III to IV). For Conditions I through IV, P-7 averaged 2922, 205, 2327, and 285 responses. P-8 averaged 2919, 310, 3107, and 338. The mean number of reinforcements

Fig. 1. Total number of responses emitted per session for pigeons on a variable-interval (P-1, P-2) and a variable-ratio (P-5, P-6) schedule of reinforcement. House- and keylights were at full intensity during Conditions I and III. During part of Condition II and all of Condition IV, the birds were in total darkness. Arrows indicate first complete session in total darkness. Sessions 71 and 73 were carried out with the house- and keylights at full intensity, and 72 and 74 in total darkness.

Fig. 2. Total number of responses emitted per session for pigeons under the fixed-interval schedule of reinforcement (P-7, P-8) and under a fixed-ratio schedule (P-3, P-4). House- and keylights were at full intensity during light conditions (I, III). During part of Condition II and all of IV, the birds were in total darkness. Arrows indicate first complete session in total darkness.

for Conditions I through IV for P-7 was 56, 52, 58, and 55 and for P-8, 51, 49, 54, 53, respectively. Figure 4 shows typical cumulative records under light and the totally dark conditions.

Fixed-ratio (FR) schedule. The pigeons on the FR schedule had higher response rates under dark conditions than were obtained in the light conditions (Figure 2). The per cent increase in mean number of responses from light to dark conditions was 29% (I to II) and 19% (III to IV) for P-3, and 59% (I to II) and 35% (III to IV) for P-4. The mean number of responses for the four conditions for P-3 were 5050, 6506, 5530, and 6560; for P-4: 4740, 7510, 5850, and 8030. The number of reinforcements increased during dark conditions by 10 to 15 for P-3 and by 22 to 27 for P-4. Figure 5 shows cumulative records for P-3 under the FR

schedule of reinforcement in light and in total darkness.

Variable-ratio (VR) schedule. Pigeons on the VR schedule showed a higher response rate in dark, similar to those pigeons under the FR schedules (Figure 1). The average number of responses for P-5 was 42% (I to II) and 33% (III to IV) higher in dark conditions than in light; for P-6, 108% and 76% higher. P-5 averaged 9896, 14,024, 10,265, 13,680 responses per session and P-6 averaged 4308, 8987, 4560, and 8039 responses for each of the four conditions. Two cumulative records in Figure 6 show typical performances in light and totally dark conditions. Five extra sessions were conducted with P-5 to determine whether the effect of light intensity would still hold if conditions were changed from session to session. Sessions 71 and 73 were scheduled with

Fig. 3. Cumulative record of the twenty-fifth session (light) and the sixty-eighth session (dark) for P-2 under the VI 60-sec schedule of reinforcement.

the house- and keylight at full intensity; Sessions 72 and 74 in total darkness. The data from those four sessions paralleled those obtained by alternating conditions after 10 sessions.

An additional session, 75, was scheduled for P-5 in which the first half hour was in total darkness, and the house- and keylights at full intensity for the last half hour. The cumulative record for Session 75 is shown in Figure 7 with an arrow indicating where the lights were

turned on. Total responses were 6881 in light and 5003 in dark.

DISCUSSION

Although pigeons generally roost when placed in a dark environment, the results of this study indicate that pigeons can be trained to respond in total darkness and that darkness results in greater schedule control. In terms of ratio schedules, greater schedule control is suggested by an increase in responses

Fig. 4. Cumulative record of the twenty-fifth session (light) and the seventieth session (dark) for P-7 under FI 60-sec.

per unit time, with a correlated increase in number of reinforcements. All four birds on ratio schedules increased their rate of responding in total darkness. Schedule control for interval schedules may be spoken of in terms of responses per reinforcement and the number of reinforcements possible per time. If an organism responds less and gains the same number of reinforcements, it may be considered to be under greater schedule control. All four pigeons under interval schedules decreased their rate of responding without any decrease in the rate of reinforcement. In the

case of the VI pigeons, the response rate in dark was approximately one-half that in the light; the pigeons on an FI schedule responded about one-eighth to one-tenth as much in the dark compared to the light conditions.

One of the most interesting aspects of the results is their relevance to the analysis of stimulus control, under which schedule control is subsumed. The term stimulus control has been defined as "a change in response probability that results from a change in a stimulus value" (Terrace, 1966, p. 271). Stimulus control is most frequently studied along three

Fig. 5. Cumulative record of the twenty-eighth session (light) and the forty-third session (dark) for P-3 on FR 100.

lines: (a) nonresponse pretraining (*e.g.*, Honig, 1970; Jenkins and Harrison, 1960); (b) innate prepotencies (*e.g.*, Baron, 1965; Baron and Vacek, 1967; Biederman, 1967; Guttman, 1963; Sutherland and Andelman, 1967); and (c) differential reinforcement. The third category includes using various schedules of reinforcement (*e.g.*, Hearst, Koresko, and Poppen, 1964), employing different types of reinforcement (Hearst, 1962), varying the complexity of

the reinforced stimulus (Butter, 1963; Fink and Patton, 1953), transfer of reinforced effects (Honig, 1965), and manipulation of deprivation level (Conrad, Sidman, and Herrnstein, 1958). An explanation for the present results does not easily fall into any of these three categories.

Though the present study demonstrates a significant sharpening of stimulus control under the dark condition, it is difficult to explain

Fig. 6. Cumulative record of the fifty-fourth session (light) and the sixty-first session (dark) for P-5 under VR 200.

the results in terms of biological or conditioning variables. First, there is no apparent survival value for pigeons to peck in the dark, and as previously mentioned, they generally roost in the dark unless specifically conditioned to do otherwise. Second, because there was no laboratory pretraining of the pigeons in the dark and because the natural environment induces roosting in the dark, an explanation in terms of pretraining or counter conditioning is unsuitable. Third, the study did not include any direct manipulation of differential reinforce-

ment. No concurrent reinforcement contingencies were directly manipulated.

A possibility exists for indirect differential reinforcement, however. It seems possible to explain the change of response rate in terms of the reduction of competing or concurrent reinforcement contingencies. Actually, the pigeon's behavior in the experimental chamber may be a function of various unspecified concurrent reinforcement contingencies. Some behaviors may be strengthened adventitiously by the temporal contiguity with reinforce-

Fig. 7. Cumulative record of the seventy-fifth session (not shown in Figure 2) for P-5. Chamber was totally dark for the first half of the session. The house- and keylight were at full intensity for the second half of the session. An arrow indicates the point in the session when the lights were switched to full intensity.

ment when the reinforcement is scheduled for a different response. Other behaviors may be strengthened by other independent reinforcers inherent in the experimental situation, such as a pigeon being reinforced by seeing itself in the reflection of the chamber's one-way mirror. The increased schedule control arising in the dark condition may be due to the removal of these competing contingencies and any discriminative stimuli associated with them.

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