FIXED-RATIO DISCRIMINATION: EFFECTS OF RESPONSE-PRODUCED BLACKOUTS¹

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For three pigeons, reinforcement depended upon a left side-key response after execution of a fixed ratio 10 on the center key, and upon a right side-key response after fixed ratio 20. Each response during the fixed ratios produced a 0.5-sec blackout. The time between the first and last response in fixed ratio 10 was then equated with the time between the first and last response in fixed ratio 20 by increasing the blackout duration. The accuracy of side-key choice was disrupted, thereby suggesting that time, rather than number of responses, controlled choice responding. When the time between the first and last response was equated during both ratios, asymptotic accuracy was approximately equal to (two birds) or somewhat higher than (one bird) that obtained previously. The results of probes with intermediate fixed ratios and blackouts suggested that control of side-key choice had transferred from the time between the first and last response in ratios to blackout duration.

In fixed-ratio (FR) schedules, reinforcement depends upon the emission of a specific number of responses. Skinner (1938) suggested that discriminative stimuli could arise either from the number of responses or the time taken to complete those responses. Mixed schedules, in which there are two or more fixed-ratio schedules with no differentiating exteroceptive stimuli, afford an opportunity to demonstrate control by stimuli arising from performance. For example, Ferster and Skinner (1957) found that pigeons on a mixed FR 190 FR 30 schedule would emit slightly more than 30 responses and then pause when the FR 190 component was in effect. The remainder of the FR 190 would then be completed without further pausing. Because within-ratio pausing does not normally occur during responding under simple FR schedules, this pausing after about 30 responses is evidence that behavior controlled by the FR 30 schedule possessed stimulus properties. Similarly, when two or more components in mixed FR schedules alternate regularly, the preratio pause is proportional to the size of the upcoming FR (*e.g.*, Crossman, 1971; Findley, 1962). Although the variable manipulated in these studies was

response number, time covaried with responses. Thus, elapsed time could be the controlling stimulus.

Recent studies using simple FR schedules have suggested that time controls the duration of preratio pausing (Killeen, 1969; Neuringer and Schneider, 1968). For example, Neuringer and Schneider reinforced the responses of pigeons on an FR 15 schedule in which each response produced a brief blackout. When the blackout duration was lengthened, both the time to complete FR 15 and the preratio pause increased. Since the number of responses remained constant, this suggests that temporal factors controlled FR performance.

The discriminative properties of FR performance have also been examined by the use of conditional discrimination tasks, in which the stimuli associated with completion of either of two FRs instruct the subject as to which of two side keys is correlated with reinforcement (*e.g.*, Pliskoff and Goldiamond, 1966; Rilling, 1967, 1968; Rilling and McDiarmid, 1965). With these procedures, the discrimination index is represented by the accuracy of side-key choice. Rilling (1967, 1968) suggested that responses rather than temporal stimuli are the effective discriminative stimuli.

To summarize, studies that primarily measured preratio pausing implicate time as the controlling stimulus, whereas those measuring choice accuracy implicate response number. Therefore, it seemed desirable further to ex-

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amine performances under these two types of procedures. The present experiment studied the Neuringer and Schneider (1968) technique of using response-produced blackouts to control the real time to complete ratios in an FR discrimination procedure. Changes in choice accuracy were examined when the times to complete the two FRs were equated. Probes with intermediate FRs and blackout durations were used to assess further the possible sources of stimulus control.

METHOD

Subjects

Three experimentally naive White King pigeons (C1, C3, and C4) about 2 yr old and maintained at about 80% of their free-feeding weights, served. A fourth bird (C2) was eliminated from the study because of excessive responding during blackouts.

Apparatus

The sound-attenuating experimental chamber was 45.7 cm long, 61.0 cm wide, and 53.3 cm high and contained a three-key stimulus panel. The keys were 2.5 cm in diameter, 7.6 cm apart, center to center, and 24.1 cm above the floor. Each key required about 0.15 N force for operation. An aperture 6.4 cm wide, 5.1 cm high, and centered 10.2 cm above the floor occasionally permitted access to Purina Pigeon Chow for 3 sec. The aperture was illuminated with white light during hopper operation. General chamber illumination was provided by two 7.5-W bulbs mounted 17.8 cm above the response keys, 10.2 cm apart, and shielded so as to illuminate the ceiling. Continuous white noise and a ventilating fan served to mask extraneous sounds. Chamber events were controlled by a system of electro-mechanical components located in an adjacent room.

Procedure

After being autoshaped to key peck (Brown and Jenkins, 1968), subjects had one session during which each of 50 responses to a white center key was reinforced. Over the next 25 sessions, the schedule was gradually changed to FR 20. Throughout, each response except the last in the ratio produced a brief blackout, during which the keylight and houselights were turned off. The blackout duration

was gradually increased from 0.1 sec to 0.5 sec across sessions. Each response to a lit center key produced an audible feedback click; a response to a dark key neither produced the feedback nor advanced the ratio. Reinforcement was followed by a 10-sec intertrial interval during which the houselights were on, but the keys were dark.

Next, all trials began with the onset of a red center key. After completion of either FR 2 or FR 20 (mixed FR 2 FR 20 schedule) the center key was turned off and the two side keys were transilluminated with white light. If the FR 2 was in effect, a response to the left key produced reinforcement; a response to the right key produced a 3-sec timeout, during which the key lights and houselights were off. If FR 20 was in effect, a response to the right key produced reinforcement; a left-key response produced a 3-sec timeout. Any choice response produced a 10-sec intertrial interval, followed by the next ratio in a randomized sequence. The smaller ratio was gradually increased to FR 10 across sessions. When acquisition training terminated, the mean choice accuracy of each of two consecutive 10-session blocks was within 1% of the combined 20-session mean.

The time between the first and last response in FR 10 components was then increased by lengthening the blackout duration that followed each FR 10 response by 0.1 sec per session, until the total time to complete the FR 10 approximately equalled the total time to complete FR 20. For Birds C1 and C3, the terminal blackout value was 1.4 sec, and for Bird C4 the terminal value was 1.5 sec. After a minimum of 10 sessions, or until visual inspection of data revealed no systematic changes, a series of probes was conducted.

Blackout probes were studied first. On FR 10 probe trials, a training trial was replaced by a trial during which each response was followed by a shorter blackout (0.5, 0.8, or 1.1 sec for Birds C1 and C3, or 0.5, 0.8, or 1.2 sec for Bird C4). On FR 20 probe trials, the normal 0.5-sec blackout was replaced by longer blackout durations of 0.8, 1.1, or 1.4 sec (Birds C1 and C3) or 0.8, 1.2, or 1.5 sec (Bird C4). Each of the six probe durations was presented twice per session, with the order randomized, and with at least three nonprobe trials between probes. These sessions were continued until each probe had been presented 10 times. All

choice responses during probes produced a 3-sec blackout, during which keys and house-lights were off.

Fixed-ratio probes were studied next. These consisted of replacing an FR 10 trial with FR 12, 14, 16, 18, or 20, with each response producing a 1.4-sec (Birds C1 and C3) or 1.5-sec (Bird C4) blackout, or replacing an FR 20 trial with FR 10, 12, 14, 16, or 18, with each response producing a 0.5-sec blackout. Each of the 10 probes was presented once per session, in a randomized order, with a minimum of three nonprobe trials between probe trials. These sessions continued until each FR had been presented 10 times. Again, all choice responses during probes produced a 3-sec blackout.

Throughout the discrimination procedures, sessions consisted of 40 trials each of FR 10 and FR 20. The FRs were presented in a repeating block of 20 randomized trials, with the restriction that no more than three identical trials could occur in succession. Three different random orders were changed every 10 sessions. Each session was preceded by 10 warmup trials that were not included in the data. Warmup trials consisted of five trials each of FR 10 and FR 20 presented in a mixed order.

RESULTS

The effect of manipulating FR 10 blackout duration on the per cent of correct choice for all three birds is shown in Figure 1. Figure 1A shows that during the last 20 sessions, when all responses were followed by 0.5-sec blackouts, systematic changes in accuracy did not occur. The mean accuracy across the last five sessions was between 90% and 92% for the three birds.

As the blackout duration correlated with FR 10 was lengthened, accuracy decreased, with the most marked decrease exhibited by Bird C3 (Figure 1B). When the mean time to complete FR 10 was equated with the mean time to complete FR 20 (Figure 1C), accuracy across the last five sessions ranged from 89% to 98% for the three birds.

The mean time to complete the FR 10 and FR 20 schedules over the last five sessions of the two conditions appears in Table 1. When responses during both ratios were followed by a 0.5-sec blackout, the time to complete FR 20 was about twice that to complete FR 10. The times were equated successfully by increasing blackout durations correlated with FR 10. Responses during blackouts always were infrequent.

Fig. 1. Per cent correct choice for individual subjects. "A" refers to the last 20 sessions when responses were followed by 0.5-sec blackouts regardless of ratio size; "B" refers to sessions during which the FR 10 blackout duration was increased by 0.1 sec per session; "C" refers to the equated time to complete FR 10 and FR 20 condition.

Table 1

Mean time to complete FRs when the blackout duration was 0.5 sec for both ratios and when FR 10 blackouts were lengthened to produce equated times to complete FR 10 and FR 20.

Subject	Schedule	Time to Complete FRs with 0.5-sec Blackouts (sec)	Time to Complete Equated FRs (sec)
C1	FR 10	8.7	18.8
	FR 20	17.7	18.3
C3	FR 10	9.8	19.1
	FR 20	20.0	19.8
C4	FR 10	9.5	20.9
	FR 20	19.6	20.4

The probe results are shown in Figure 2. The per cent left-key choice, rather than per cent correct, is presented because during probes, no side key was correct and no side-key response was reinforced. For all birds, choice increasingly changed from the right key on FR 20 trials to the left key as blackout duration was increased. The same was true during FR 10 trials for Birds C3 and C4; for Bird C1, however, the blackout probes during FR 10 had no effect.

During FR probes, when 0.5-sec blackouts followed responses, the per cent left-key choice increased as the FR size decreased. However, when blackouts of 1.4 sec (Birds C1 and C3) or 1.5 sec (Bird C4) followed FR probes, essentially no effect upon choice was obtained.

DISCUSSION

Several aspects of the present results suggest that the number of responses did not control side-key choice. First, when the blackout duration was gradually lengthened during the FR 10 component, the disruption of choices suggested that time represented a source of stimulus control. Although the increase in blackout duration potentially may have disrupted control by the number of responses, the slow increase in blackout duration and the prolonged lowered accuracy for Bird C3 make this unlikely.

Secondly, when the mean time to complete FR 10 and FR 20 was equated, the probe data suggested that control of choice responding

Fig. 2. Per cent left-key choice for individual subjects during blackout probes (left panels) and fixed-ratio probes (right panels). For blackout probes, triangles represent FR 10 and squares represent FR 20. For fixed-ratio probes, triangles represent 1.4-sec (Birds C1 and C3) or 1.5-sec (Bird C4) blackout durations and squares represent 0.5-sec blackouts for all birds. Each filled data point represents 10 probe trials, and open data points represent the mean of nonprobe trials during probe sessions.

transferred from the time to complete ratios to blackout duration. During probes, intermediate values of two of the possible sources of control, blackout duration and number of responses, were scheduled. Control by either would be indicated by a shift from the choice of one side key to the other as the probes changed in duration or number from one training value toward the other. For Birds C3 and C4, increases in the blackout duration produced a change in choice from the right key to the left. However, the FR probes had little effect upon choice. These results suggest that control of side-key choice transferred to blackout duration. For Bird C1, only blackout probes during FR 20 produced a clear shift in side-key choice.

The absence of an effect upon choice of blackout probes during FR 10 for Bird C1 and the small but consistent effect of FR probes paired with short blackouts for all three birds is difficult to explain. One possibility is that increased training with equated

time to complete both ratios would have decreased this effect. Alternatively, these probes may represent sufficiently novel trials so that stimuli other than those produced by the ratio performance, such as side-key location, may have controlled choice. Such preferences have been reported during acquisition (Lydersen and Perkins, 1974) and when the difference in size between two FRs is decreased (Pliskoff and Goldiamond, 1966; Rilling and McDiarmid, 1965).

The present conclusion that time controlled responding differs from Rilling (1967). He found that, for a given FR, the median time between the first and last response in the ratio did not systematically differ on correct and incorrect trials, and thus appeared not to control choice responding. Rilling did not, however, go beyond a correlational analysis to demonstrate control by responses. Because of the considerable number of procedural differences between the present study and that of Rilling, the apparently differing results cannot at present be accounted for.

The present results provide a further analysis of the Neuringer and Schneider (1968) blackout procedure. Clearly, the appropriate selection of blackout durations permitted the independent control of time to complete ratios in the present mixed FR 10 FR 20 schedule. However, it appears that achieving temporal control in this manner changed the task considerably. Given that the blackouts gained control over choice, it does not seem possible to consider the present procedures as equivalent to simple mixed FR FR schedules. It may also be the case that Neuringer and Schneider's (1968) use of blackouts transforms a simple FR schedule to the extent

that inferences to FR schedules without such blackouts must necessarily be limited.

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