RESPONSE-DEPENDENT SHOCK IN SECOND-ORDER FIXED-RATIO SCHEDULES OF FOOD PRESENTATION¹

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Three pigeons key pecked under second-order schedules in which the completion of two successive fixed-ratio 50 components constituted a reinforcement cycle. Tandem, chained, and brief-stimulus second-order schedules were studied when completion of the initial fixed-ratio 50 component delivered brief intense electric shock in every n th reinforcement cycle and n assumed values between one and nine. During sessions without shock, the brief-stimulus (unpaired with food) schedule generated higher rates of responding in the initial component than did the tandem schedule. Electric shock engendered increased time to the fifth response and a repeated pause-run pattern of not responding and responding, particularly in the initial component, even with shock scheduled in every ninth reinforcement cycle. The results were consistent with those reported for shock of a shorter duration scheduled in every reinforcement cycle. The overall rate of responding decreased as a function of increasing shock density and was lower in brief-stimulus than in tandem schedules.

When a stimulus follows a specific response in a pattern of responses generated by a schedule of positive reinforcement, and the probability of responding is subsequently reduced, the procedure may be characterized as a schedule of selective punishment. Dardano and Sauerbrunn (1964) studied selective punishment in fixed-ratio (FR) schedules of reinforcement, *i.e.*, schedules that deliver the reinforcer after a fixed number of responses, (Skinner, 1938). Under FR reinforcement, the response rate is usually bivalued, an initial pause before the first response, followed by an abrupt change to a very high rate of responding, the "ratio run". Dardano and Sauerbrunn made electric shock dependent on the first or twenty-fifth response in an FR 50 reinforcement schedule. Both instances may be specified in the tandem notation in that the requirements of two or more component schedules were sequentially joined to constitute a

single reinforcement cycle (Catania, 1968, p. 348). Punishment of the first response in FR 50, *tand* (FR 1:shock) (FR 49), increased time to the first response in the initial component. Punishing the twenty-fifth response, *tand* (FR 25:shock) (FR 25), generated repeated pause-run sequences in the initial FR 25 component, but had little effect on responding in the second FR 25 component of the tandem schedule.

The effects of selective punishment on both the pattern and rate of FR responding first observed by Dardano and Sauerbrunn have been extended to both longer (Dardano, 1970) and shorter (Church, 1969) tandem fixed-ratio schedules, and compared with responding generated by tandem variable-ratio cycles of shock and food (Dardano, 1972). The specific patterns of FR performance produced by selective punishment suggested the use of second-order schedules of reinforcement in which electric shock followed the initial component only occasionally. Second-order reinforcement schedules (Kelleher, 1966) treat the pattern of behavior engendered by a schedule as a unitary response that is itself reinforced according to some schedule. In the present work, two successive FR 50 components constituted a reinforcement cycle, *i.e.*, food followed completion of each FR 50 FR 50 sequence. Electric shock occasionally followed completion of the initial FR 50 component.

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METHOD

Subjects

Three adult male Silver King pigeons were maintained at 80% of free-feeding weights. Each bird had an extensive history with FR schedules of food and electric shock delivery.

Apparatus

A three-key response panel (Grason-Stradler Model E6446C) constituted one wall of a 12 in. (30 cm) long, 14 in. (34 cm) wide, by 11 in. (27 cm) high pigeon chamber. The center key, 2.5 cm in diameter, was transilluminated by either a red or white lamp. The side keys were covered with plastic tape. A 2 in. (5 cm) square opening centered 4 in. (10 cm) below the key provided occasional access to mixed grain for 4 sec. A white lamp over the food hopper provided illumination during reinforcement; at other times only the response key was illuminated.

A 60-Hz electric shock, 0.2 sec in duration, was delivered through a fixed resistance in series with the bird. Shock was delivered via stainless-steel wire electrodes, 0.025 in. (0.6 mm) in diameter, chronically implanted through the pubic arch (Azrin, 1959). Electrical impedance across the electrodes was measured by a 7-V, 60-Hz bridge circuit and ranged from 800 to 1500 ohms.

The experimental chamber was enclosed in a sound attenuating compartment ventilated by an exhaust fan. White noise served to mask most extraneous sounds. Scheduling and recording equipment were located in a separate room.

Procedure

Each daily session terminated after 2 hr or approximately 25 reinforcements, whichever occurred first. Weight and electrode impedance of each bird were determined before and after each session.

A summary of the number of sessions on each schedule is shown in Table 1. Responding was maintained on second-order FR 50 FR 50 schedules throughout the study. Brief electric shock and brief or continuous key-color changes occasionally followed completion of the initial FR 50 component. The first type of second-order schedule was *tand* FR 50 FR 50. In designated cycles of the tandem schedule, completion of the initial FR 50

Table 1

Sequence and number of sessions under each experimental condition.

Procedures	Number of Sessions		
	Bird 6565	Bird 1313	Bird 1453
<i>tand</i> (FR 50)(FR 50)			
Control (no shock)	22	20	21
FR 4 shock	25	19	24
FR 9 shock	18	11	19
FR 6 shock	10	11	12
FR 3 shock	16	12	16
FR 1 shock	13	8	13
<i>chain</i> (FR 50)(FR 50)			
Control (no shock)	16	18	16
FR 4 shock	36	4	28
FR 9 shock	19	10	19
FR 6 shock	13	21	9
FR 3 shock	14	16	10
<i>tand</i> (FR 50:S)(FR 50)			
Control (no shock)	16	10	15
FR 4 shock	25	5	22
FR 9 shock	13	10	34
FR 6 shock	13	14	18
FR 3 shock	12	17	10

component changed the key color from white to red for 0.5 sec, with electric shock delivered in the final 0.2 sec. During other cycles of the schedule, the key color remained white and no electric shock was delivered. The second type of schedule was *chain* FR 50 FR 50. Completion of the initial FR 50 component of the chained schedule changed the key from red to white. In designated cycles of the schedule, completion of the initial FR 50 component delivered a 0.2-sec shock. The final type of second-order schedule was *tand* (FR 50:S) (FR 50). A brief, 0.5-sec, key-color change from white to red followed completion of the initial FR 50 component but was accompanied by a 0.2-sec electric shock only during designated cycles.

With each type of second-order schedule, a number of sessions without shock preceded sessions in which electric shock was intermittently presented when the initial component was completed. Individual cycles of second-order schedules were designated for electric shock according to fixed-ratio schedules; *i.e.*, shock was delivered during every *n*th sequence of components and *n* was at various times, either 1, 3, 4, 6, or 9. Shock intensity was gradually increased to 8 mA across FR 4 shock sessions of each type. The intensity of electric

shock was constant at 8 mA during all other sessions with FR shock. Responding did not necessarily stabilize before the shift from FR 4 *shock* to FR 9 *shock*; other changes from one FR *shock* schedule to another followed observation of a stable rate of responding across at least three consecutive sessions.

RESULTS

Typical fixed-ratio performance was observed in cumulative records of terminal control (no shock) sessions shown in Figure 1 for Bird 1453. The occasional delivery of electric shock after the initial FR 50 component was completed (shown as an oblique downward deflection of the cumulative recorder pen) prolonged initial pauses and produced a rough-grained pause-run pattern of responding. Sometimes, in tandem and brief-stimulus schedules, the pause-run pattern continued into the second FR 50 component. Early in some sessions, ratio performance was emitted without disruption before delivery of the first shock. Also, prolonged pauses following electric shock were occasionally observed. Cumulative records for FR 1 *shock* are not shown because responding ceased after five to nine sessions. Cumulative records for Birds 6565 and 1313 were comparable to those shown in Figure 1 for Bird 1453.

Overall rates of responding during the last three sessions with each schedule are shown in the upper panel in Figure 2. During control sessions without shock, the brief-stimulus procedure produced higher overall rates of responding than did the tandem procedure for Birds 6565 and 1313, and nearly identical rates of responding for Bird 1453.

In general, the overall rate of responding was reduced directly as a function of the density of scheduled shock. Further, the various second-order schedules exerted differential control over responding during intermittent shock sessions. During tandem schedules, overall rates of responding exceeded those observed with brief-stimulus schedules. Rates of responding with the chained procedure were intermediate and overlapped occasionally with rates observed under the other two procedures, particularly at FR 6 *shock* for Birds 6565 and 1313.

An increase in time to the fifth response was observed when shock occasionally followed the

fiftieth response (Figure 2, lower panel). However, comparison of the upper and lower panels of Figure 2 suggests that orderly decreases in the overall rate of responding were only in part the result of increased time to the fifth response. For example, for Birds 6565 and 1453, time to the fifth response and overall rate of responding were consonant functions of shock density. For Bird 1313, time to the fifth response was an orderly function of shock density under brief-stimulus and tandem schedules, but was little changed by the shift from FR 6 *shock* to FR 3 *shock* under chained schedules.

The mean rate of responding in 20 successive five-response blocks across the FR 50 FR 50 reinforcement cycle is shown in Figure 3. In control schedules, responding accelerated over the first three to five five-response blocks, but sometimes decelerated before food reinforcement. Responding during the last five to six five-response blocks of the initial component (Blocks 1 to 10) of the brief-stimulus schedule was consistently more rapid than during an equivalent portion of the initial component of the tandem schedule. Responding during an equivalent portion of the chained schedule was intermediate for Birds 1313 and 1453, but slightly lower than in the tandem schedule for Bird 6565.

When shock occasionally followed completion of the initial FR 50 component, the pattern of responding in five-response blocks varied with the second-order schedule. In chained schedules, responding was uniformly reduced before the shift from red to white key color, then responding accelerated more rapidly with FR 9 *shock* than with FR 3 *shock*. In tandem schedules, responding increased slowly and reached slightly higher momentary rates at FR 3 *shock* than FR 9 *shock* for Birds 1313 and 1453. In brief-stimulus schedules, responding accelerated somewhat more slowly than in tandem schedules. The relatively smooth averaged curves shown in Figure 3 are only partly representative of the repeated pause-run response sequences seen in cumulative records (Figure 1) of the same performance.

Figure 4 shows mean rates of responding during each FR 50 component for successive reinforcement cycles between shocks (FR 6 *shock*). During the initial FR 50 component, Bird 1313, and to a lesser extent Bird 1453,

1453

Fig. 1. Cumulative records of responding for Bird 1453 during nonshock and FR shock sessions. Deflections of the recorder pen indicate shock delivery. The pen reset at reinforcement.

showed successive reductions in responding across reinforcement cycles between shocks. During the second FR 50 component follow-

ing delivery of electric shock in every sixth reinforcement cycle, Birds 1453 and 6565 frequently showed reduced responding.

Fig. 2. Average overall rates of responding in the final three sessions at each experimental condition (upper panel). Average time to the fifth response in the final three sessions at each experimental condition (lower panel).

Fig. 4. Rates of responding during the first and second FR 50 components under each experimental condition. Response rates were averaged for successive reinforcement cycles between FR 6 shocks over the final three sessions at each experimental condition.

Fig. 3. Rates of responding averaged over five-response blocks during the final three sessions at each experimental condition.

DISCUSSION

A disrupted pattern of second-order FR performance, typical of results reported by Dardano and Sauerbrunn (1964), was evident in the present results even when shock was delivered only once for each 900 responses (FR 9 shock). The present results differ from those of Dardano and Sauerbrunn only in that complete suppression of responding was obtained when shock was delivered in each ratio in the present work. The difference may be the result of longer shock duration (0.2 sec) in the present work. Electric shock delivered occasionally at completion of the initial component of a second-order schedule controlled both the rate and pattern of responding over long, orderly sequences of behavior. Between FR 6 shocks, responding during the initial FR 50 component was in some cases progressively reduced across the intershock reinforcement cycles, or in other cases reduced to a low rate in each intershock reinforcement cycle.

Overall responding was reduced as a direct function of scheduled shock density, but shock density had rather complex effects on the components of overall response rate. Time to the fifth response in the initial FR 50 component was generally a function of shock density. Occasionally, however, momentary response rates for later five-response blocks during the initial FR 50 component tended to be low independent of shock density. Response rates in the second FR 50 component were related to shock density only in the chained condition.

Stubbs and Silverman (1972) used shock as a brief stimulus unpaired with food in a second-order schedule. Shock increased patterning within components of the schedule but reduced responding as a function of shock intensity. In the present work, responding was reduced as a function of shock density and pause-run sequences reduced responding differentially in the initial, occasionally punished, component. The Stubbs and Silverman (1972) work differed from that reported here in both the schedule and number of second-order components in each reinforcement cycle. Nevertheless, present comparison of tandem and brief-stimulus schedules without shock showed increased responding in the initial FR 50 component before a brief key-color change unpaired with food.

The effects of response-dependent shock fol-

lowing completion of the initial component in a chain FR 50 FR 50 schedule contrasts with the effects of a 1-min pre-aversive stimulus for response-independent shock superimposed on fixed-ratio performance (Lyon, 1964). Responding was suppressed to zero when a 1-min pre-aversive stimulus for response-independent shock was presented early in the fixed ratio. In the present work, periods of responding and not responding, a repeated pause-run sequence, occurred during the initial component of the schedule when response-dependent shock was occasionally presented. Response-dependent shock disrupted control by the fixed-ratio reinforcement schedule without producing complete suppression.

In the present experiment, as in FR punishment of variable-interval performance (Azrin, Holz, and Hake, 1963), overall response rate was a direct function of scheduled shock density. However, in fixed-ratio schedules, a reduced rate of responding results in a reduced rate of reinforcement. Time to the first response in FR performance appears to be a function of interreinforcement time (Neuringer and Schneider, 1968), while responding later in the ratio appears to be a function of the ratio requirement (Killeen, 1969). Aversive effects of shock reduced responding, in turn decreased reinforcement density, and perhaps only indirectly increased the duration of the initial pause. The role of increased interreinforcement time in generating the effects reported for selective punishment of FR performance remains to be assessed.

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