FIXED-RATIO PUNISHMENT BY TIMEOUT OF CONCURRENT VARIABLE-INTERVAL BEHAVIOR¹

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Pigeons' responding was maintained by two concurrently available variable-interval reinforcement schedules. A fixed-ratio punishment schedule of timeout periods from the concurrent reinforcement schedules was arranged for responding during one of the variable-interval schedules. The greater the probability of a timeout after a response on the punished variable-interval schedule (the smaller the fixed ratio that produced timeout), the greater the decline in the relative punished response rates. Relative reinforcement rates remained invariant when relative response rates declined. Both behavioral contrast and induction effects were observed on the unpunished variable-interval schedule as a function of timeout punishment of the other schedule.

A period of timeout from an ongoing positive reinforcement schedule can function as an effective aversive or punishing stimulus. The literature indicates, for example, that timeout can suppress ongoing behavior in a manner similar to electric shock (McMillan, 1967), suppress behavior during a pre-timeout stimulus (Ferster, 1957, 1958, 1960; Ferster, Appel, and Hess, 1962; Miller and Zimmerman, 1966), decrease incorrect responding in matching-to-sample performance (Ferster and Appel, 1961; Zimmerman and Baydan, 1963; Zimmerman and Ferster, 1963), aid in response extinction (Baer, 1961; Wolf, Risley, and Mees, 1964), and change selectively various interresponse times (Ferster, 1958).

Timeout may be a more effective punishing stimulus if there is an alternative response available which is unpunished and which will produce the same reinforcement (Azrin and Holz, 1966; Holz, Azrin, and Ayllon, 1963). The present study examined the punishing effects of timeout (TO) on responding maintained by variable-interval reinforcement scheduled concurrently with unpunished responding maintained by an independent but identical variable-interval reinforcement schedule. Another aspect of the study related behavioral changes on the concurrent sched-

ules to the probability and duration of timeout.

METHOD

Subjects

Three adult male homing pigeons, designated 21, 22, and 23, were maintained at approximately 80% of their free-feeding weights. All three subjects had extended experimental histories on various reinforcement schedules.

Apparatus

The experimental space was a Lehigh Valley Electronics pigeon chamber containing two response keys which could be operated by a force of 15 g or more. A feedback relay located behind the response-key wall operated with each recorded response. Masking noise was continuously provided through a speaker in the chamber by a white-noise generator. The chamber was located in a darkened room which also attenuated most extraneous sounds. Scheduling was accomplished automatically by switching relay and timing circuits located in a separate room. Data were recorded on cumulative recorders and magnetic impulse counters.

Procedure

Each daily experimental session terminated after fifty 4-sec presentations of mixed grain reinforcements or 2.5 hr, whichever occurred first. Both response keys were transilluminated

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with colored lights and these, as well as the house light, went off simultaneously with the 4-sec operation of the grain feeder and illumination of the grain by the feeder light. Each session was preceded and followed by a blackout condition, variable in duration, during which all lights in the experimental chamber were off and responses had no scheduled consequences.

The subjects initially performed on concurrent variable-interval (VI) schedules. The VI schedules were arranged such that the first response to occur after varying periods of time was reinforced. The 11 actual time periods, occurring in an unsystematic order, ranged from 0 sec to 360 sec in multiples of 36 sec and had a mean of 180 sec. The concurrent scheduling was the switching- or changeover-key procedure described by Findley (1958). Each of the two independent VI schedules operated continuously and associated with each schedule was a different color on the right-hand key, the VI response key. Responses on the VI key produced reinforcements according to one of the VI schedules when the VI key was transilluminated with yellow light and produced reinforcements according to the other VI schedule when the key was transilluminated with green light. Responses on the left key, the changeover key, changed the VI schedule and key color on the VI key from one schedule to the other. The changeover key was transilluminated with white light. The changeover key procedure is functionally equivalent to a two-operandum concurrent procedure (Catania, 1966). A changeover delay (COD) of 3 sec was always in effect and was timed from each response on the changeover key. The changeover delay was arranged so that responses on the VI response key within 3 sec after a response on the changeover key could not produce reinforcement. Reinforcements, once they became available according to one VI schedule, remained available until produced by a response even if the subject switched to the other VI schedule and then switched back.

Following stabilization on the concurrent VI schedules, the subjects were exposed to a fixed-ratio (FR) schedule of TO periods during one of the VI schedules. Initially, every fiftieth unreinforced response (FR 50) on the VI schedule associated with yellow light produced a 30-sec TO. A reinforced response could not produce a TO. During timeout, all

lights in the experimental chamber were off, responses had no scheduled consequences, and both VI schedules stopped. Next, every twenty-fifth unreinforced response (FR 25) on the VI schedule associated with yellow light produced a TO, then every tenth unreinforced response (FR 10), and then every second unreinforced response (FR 2). If a subject switched from the VI schedule associated with yellow light in the middle of a TO ratio, the ratio remained partially completed until the subject switched back to that VI schedule. Further responses in the schedule associated with yellow light would then complete the TO ratio. Following the FR schedules of TO presentation, subjects were returned to the original concurrent VI schedules without timeouts. They were again exposed to the FR 50, 25, 10, and 2 schedules of TO presentation as before during the VI associated with the yellow light; however, TO duration was 2 min. The subjects were then returned to the concurrent VI schedules without the occurrence of TOs.

Table 1

Sequence and number of sessions on each schedule for three subjects.

Timeout	Schedule of Timeout Punishment	Pigeons		
		21	22	23
(No TO)	—	41	42	42
30 sec	FR 50	20	20	19
	FR 25	23	23	23
	FR 10	20	20	21
	FR 2	21	20	21
(No TO)	—	18	19	18
2 min	FR 50	22	23	22
	FR 25	23	22	25
	FR 10	22	22	22
	FR 2	18	18	18
(No TO)	—	24	22	22

The sequence and number of sessions on each schedule are presented in Table 1 for the three subjects. The subjects were exposed to a particular schedule until the daily response rates showed no systematic trend.

RESULTS

Figure 1 shows the relative response rates on the punished VI schedule

$$\left(\frac{\text{punished VI rate}}{\text{punished VI rate} + \text{unpunished VI rate}} \right)$$

as a function of the FR value of TO for the two TO durations. All values presented in this and other figures are the medians of the last five sessions on each condition. As the two VI schedules were continuously available, response-rate measures were obtained by dividing the number of responses in the presence of each key color by the total session duration (*cf* Catania, 1963). Response-rate measures obtained by dividing the number of responses in the presence of each key color by the time spent in the presence of each key color showed rate changes similar to those based on total session time. The rationale for analyzing the data in terms of total session time (overall rate measures), rather than in terms of local rate measures in the presence of each stimulus, has been presented previously (Catania, 1966). Timeout duration was not included in the total session time. The isolated points in Fig. 1 indicate the relative response rates of the punished schedule when no TOs were arranged. The points fall rather close to 0.50, indicating approximately equal response rates on both VI schedules. As the FR value of TO was decreased from FR 50 to FR 2 the relative response rates of the punished schedule declined. The decline was obtained with both TO durations. For Subject 21, there was a greater decline in the relative response rates of the punished VI schedule when the TOs were

2 min in duration than when they were 30 sec. The greater decline in relative response rates with the longer TO did not occur with the other two subjects.

Fig. 1. Relative response rates of the punished variable-interval schedule as a function of the fixed-ratio schedule of timeout for two timeout durations, for each of three subjects.

Fig. 2. Response rates (responses per minute) of the punished and unpunished variable-interval schedules as a function of the fixed-ratio schedule of timeout for two timeout durations, for each of three subjects.

Fig. 3. Segments of cumulative records of Subject 21 on the concurrent punished and unpunished variable-interval schedules for the no timeout condition and each of the fixed-ratio schedules of the 2-min timeout. Pips indicate grain reinforcements. The recorder motor was disconnected during timeouts.

23

Fig. 4. Segments of cumulative records of Subject 23 on the concurrent punished and unpunished variable-interval schedules for the no timeout condition and each of the fixed-ratio schedules of the 30-sec timeout. Pips indicate grain reinforcements. The recorder motor was disconnected during timeouts.

Figure 2 shows the absolute response rates of the punished and the unpunished schedules as a function of the FR value of TO for the two TO durations. For Subject 21, shown in the top frame of Fig. 2, the punished-schedule response rates declined as a result of decreasing the FR value of TO, and at the same time response rates on the unpunished schedule generally increased. The increase in unpunished response rates was also obtained as the punished-schedule response rates declined with Subject 22 for the 30-sec TO condition. Figure 3 presents segments of cumulative records of Subject 21 showing performances on the punished and the unpunished VI schedules for each of the FR schedules of the 2-min TO. The increase in the unpunished-schedule response rates as the punished-schedule response rates decline may be seen in the records. For Subject 23, shown in the lower frame of Fig. 2, as the punished-schedule response rates declined as a result of decreasing the FR value of TO, the response rates on the unpunished schedule also decreased. The unpunished response rates of Subject 22 also declined with the decline in the punished response rates for the 2-min TO condition. Cumulative records of Subject 23, showing performances on both VI schedules for each of the FR values of the 30-sec TO, are shown in Fig. 4.

The proportion of time spent in the presence of the key color associated with the time-

out-punishment schedule is shown for the three subjects in Fig. 5 as a function of the FR value of TO for the two TO durations. The isolated points indicate that the subjects spent approximately equal time in both VI schedules when no TOs were arranged. The relative time spent in the presence of the punished schedule generally increased as the FR value of a TO following an unreinforced response decreased for that schedule. There were no systematic differences in the proportion of time spent in the punished VI schedule as a function of TO duration.

Figure 6 shows the relative reinforcement rates of the punished schedule as a function of the FR value of TO. The absolute reinforcement rate measures were obtained by dividing the number of reinforcements obtained in the presence of each key color by the total session time. The relative rates of reinforcement did not deviate from 0.50 by more than ± 0.02 for any of the FR values of TO for either of the TO durations.

There was no indication of gradual recovery in response rates during TO sessions or increases in response rates above the unpunished levels after TO punishment ("punishment contrast") was removed.

DISCUSSION

Timeout operated as an effective punishing stimulus in that response rate was reduced when the responses produced the TO stimulus (*cf* Azrin and Holz, 1966). The results show

Fig. 5. Relative time spent in the punished variable-interval schedule as a function of the fixed-ratio value of timeout for two timeout durations, for each of three subjects.

Fig. 6. Relative reinforcement rate of the punished variable-interval schedule as a function of the fixed-ratio value of timeout for two timeout durations, for each of three subjects.

that the effects of TO as a punishing stimulus may be extended to concurrent reinforcement schedules and indicate that orderly changes in behavior maintained by concurrent VI schedules occur as a function of TO punishment.

The punishing effects of the TO stimuli in the present study were directly related to the FR schedule of punishment. The response suppression was inversely related to the size of the FR producing the TO. This relationship has been found with TO punishment for S^A responding in matching-to-sample (Zimmerman and Baydan, 1963; Zimmerman and Ferster, 1963). The results of scheduling the TO stimuli according to a fixed-ratio schedule of punishment are similar to results of fixed-ratio scheduling of electric shock punishment on variable-interval performance (Azrin *et al.*, 1963). The greater the number of shocked responses, the greater the response suppression. In the present study there was a relatively uniform rate of responding between successive occurrences of the TO stimuli. This uniformity has also been reported on variable-interval schedules when response-produced shocks are presented according to a fixed-ratio punishment schedule (Azrin *et al.*, 1963), although recovery within a session produced some curvature.

The punishing effects of the TO stimuli were not systematically related to the duration of the TO stimuli. The changes in relative response rates were related in an orderly manner to TO duration for one subject, however. If one considers the dimension of duration for TO to be similar to the intensity of other types of punishing stimuli (*cf* Zimmerman and Baydan, 1963), the effects are not in accord with the research literature. Studies of the intensity of punishing stimuli have indicated that the greater the intensity of the punishing stimulus, the greater the reduction of the punished responses (Azrin and Holz, 1966). Previous research has shown that behavior is indeed sensitive to the dimension of TO duration (Ferster and Appel, 1961; Thomas, 1965; Zimmerman and Baydan, 1963; Zimmerman and Ferster, 1963). When TO is increased from relatively short durations to long durations, accuracy or rate changes usually change in one direction (*i.e.*, increase) up to some maximum TO duration. With TO durations longer than the maximum, the behavioral changes produced by TO usually reverse di-

rection (*i.e.*, decrease in accuracy or rate) (Ferster and Appel, 1961; Thomas, 1965; Zimmerman and Ferster, 1963). It is possible that the two TO durations employed in the present study were about the same distance on both sides from the maximum TO duration for punishment effects on concurrent VI schedules and produced about equal reduction of the punished responses.

The reduced response rates in the punished schedule were apparently due directly to the aversive properties of the TO stimuli, rather than to any indirect effects of induced changes in reinforcement rates. The changes in the proportion of time spent in the punished schedule and changes in the relative response rates, both of which have been related to manipulated changes in relative reinforcement rates (Catania, 1966), were obtained with invariance in the relative reinforcement rates. The increase in the relative time spent in the presence of the punished schedule, and the reduced relative response rates in the punished schedule with no changes in the relative reinforcement frequency, suggests that the suppression was due to the TO punishment contingency. Reduction of responses by shock punishment with interval schedules is accompanied by little or no reduction in rate of reinforcement, except when responses are almost completely suppressed (Azrin and Holz, 1966).

The increase in response rates on the unpunished schedule, when responding on the concurrent schedule was punished by the TO stimuli, may be related to the increase in response rates in the unpunished component of a multiple schedule, when behavior in the other component is punished (Brethower and Reynolds, 1962), and to the increase in rates in the initial link of one of concurrent two-component chain schedules when responding in the terminal link of the other chain schedule is punished (Reynolds, 1963). The increase in the rate of unpunished behavior, when other behavior decreases as a result of punishment, may be classified as a type of behavioral contrast (*cf* Brethower and Reynolds, 1962), which is not related to changes in reinforcement frequency. The fact that a decrease in the rate of unpunished responding was also observed when concurrent responding was punished, or behavioral induction, indicates that the contrast effect does not always occur in such situations.

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