PUNISHMENT BY S^D ASSOCIATED WITH FIXED-RATIO REINFORCEMENT¹

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Two pigeons were trained with positive reinforcement on a multiple FR VI 2 schedule. The VI 2 component was held constant while the FR component was changed from ratios of 1 to 300. After responding had stabilized at each FR value, VI responses produced briefly either the fixed-ratio S^D or a stimulus uncorrelated with either schedule component. Compared to the effects of the uncorrelated stimulus change, the fixed-ratio S^D produced a decrease in VI responding proportional to the size of the FR requirement. It is concluded that stimuli associated with high FR schedules served as punishment for the ongoing behavior.

Recently, several investigators have reported that rats and pigeons, when working on fixed-ratio (FR) schedules for positive reinforcement, occasionally switch to a second operandum during the post-reinforcement pause to produce a timeout (TO) condition (Azrin, 1961; Appel, 1963; Thompson, 1964, 1965; Zimmerman and Ferster, 1964). During TO, extinction and its correlated stimulus, S^A , are in effect. Moreover, the frequency with which these TOs are produced has been found to increase as a function of the FR requirement (Thompson, 1964, 1965). This finding suggests that the response on the second operandum is reinforced by escape from the fixed-ratio S^D which is associated with some aversive aspect of the FR schedule; e.g., delay of food reinforcement. Further support for the notion of FR aversiveness is the finding that an avoidance response can be established and maintained when it prevents an increase in the ratio requirement (Findley, 1958).

The present investigation demonstrates that in addition to sustaining escape and avoidance behavior, stimuli associated with FR schedules can be used to punish ongoing performance, and that the degree of suppression is a function of FR magnitude.

METHOD

Two experimentally naive, adult, male, White Carneaux pigeons, P-1 and P-2, were maintained at 80% of their free-feeding weights. They were trained to peck a white key to gain 4-sec access to mixed grain in a standard pigeon box (Ferster and Skinner, 1957), connected to automatic programming and recording equipment. After a brief training on CRF, the schedule was gradually shifted to a variable-interval (VI) 2-min program. This schedule of reinforcement provides a stable and sensitive baseline against which punishment effects can be evaluated (Azrin, 1960).

Ten sessions of 40 reinforcements each were required before VI rate stabilized. At this point, the two test conditions were introduced. In half the test sessions, each response changed the key color from white to red for 0.3 sec; in the other test sessions, each response produced 0.3-sec green stimulus change (SC). These treatments were administered in a counter-balanced sequence—RGGR, GRRG—with the restriction that between any two successive tests, the no-SC condition was interpolated until baseline was recovered. The recovery criterion specified that the no-SC condition remain in effect until the total number of VI responses per session was well within the limits of baseline variation; i.e., within the range of the last four pre-test sessions. This procedure was followed until there were no appreciable differences in VI rate for the three

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types of sessions—red SC, green SC, and no SC. The purpose of this preliminary testing was to ensure that a given SC did not affect VI responding before it was paired with the FR schedule; *i.e.*, any effects due to novelty, color preferences, *etc.* would be adapted out during this time.

The experiment proper began when the schedule was shifted from VI 2 to Mult FR VI 2. The key during FR was red for one subject (P-1) and green for the other (P-2). White remained the VI 2 stimulus for both. During each session, there were 20 cycles of the two alternating schedule components. Within each cycle, the FR component remained in effect until the ratio requirement was completed, whereas the VI component terminated non-contingently after 2 min of elapsed time. Thus, during each session, there were 40 reinforcements delivered: 20 in the FR components and 20 in the VI components.

The effects of the SC conditions on VI rate were again compared at FR values of 1, 50, 150, and 300 (ascending sequence). The transition from one FR value to another was accomplished by gradually increasing the ratio requirement within and across sessions. Before the comparisons were made, VI performance was stabilized. In half the test sessions, each response during the VI component produced a 0.3-sec SC in which the stimulus *correlated* with the FR component (CSC) appeared. In the other test sessions, each VI response produced a 0.3-sec SC in which the stimulus *uncorrelated* with either schedule component (USC) appeared as a control for SC *per se*. The USC was green for P-1 and red for P-2, the

reverse of the CSC or the fixed-ratio SP. These SC conditions were tested in a counterbalanced sequence—CUUC, UCCU—with the requirement that between two successive tests baseline had returned to recovery criterion.

After the last test, the SC conditions were further compared at Mult FR 300 VI 2 by using a within-session “probe”. During the first seven cycles of the session, the no-SC condition was in effect. At this point, the baseline was probed with CSC, USC, CSC in that order for two cycles each. The baseline condition was then reinstated for the last seven cycles of the session.

The final phase of the investigation involved shifting to Mult FR 1 VI 2 in an attempt to determine whether performance at this FR value was recoverable. After allowing 10 sessions for recovery, the SC conditions were again tested for one session each in the following order: CSC, baseline recovery, USC. A summary of the experimental design, indicating the number of sessions that each subject spent in the various phases of the investigation, is presented in Table 1.

RESULTS

The main findings of the experiment are shown in Fig. 1. The overlapping data points from preliminary testing indicate that before a given key color was paired with FR, it had virtually no effect on VI rate. With regard to the ascending FR sequence, it should be noted that for both subjects, VI baseline responding systematically increased as the FR requirement increased. This schedule interaction

Table 1
Order and Duration of Experimental Conditions

PROCEDURE	FR VALUE	NUMBER OF SESSIONS			
		Bird P-1		Bird P-2	
		Baseline	Testing*	Baseline	Testing*
Preliminary Training	0	10	17	10	22
	1	14	19	10	25
Ascending Sequence	50	18	23	16	28
	150	15	20	14	21
	300	15	19	13	27
Probe	300	one session		one session	
Recovery	1	10	3	10	3

*Includes interpolated baseline sessions

("behavioral contrast") can be readily accounted for in terms of an increase in the relative frequency of reinforcement in the VI component as a function of FR magnitude (*cf.*

Reynolds, 1961). However, the interaction complicates the analysis since the SC effects must now be evaluated against a shifting VI baseline.

Fig. 1. Effects of correlated and uncorrelated stimulus change on VI baseline as a function of FR requirement. The first panel, at the extreme left, shows the number of VI responses per 40 min made by each subject during the last three sessions of preliminary testing. Panels 2-5 show the mean (solid dot) and range (vertical bar) of the last four pre-test baseline sessions and the four tests of each stimulus change at each FR value.

Fig. 2. Cumulative records of bird P-1 during preliminary testing and the ascending FR sequence. At VI 2, the last session of baseline (B), of red SC (C), and of green SC (U) are presented; in the Mult FR VI 2 conditions, the last pre-test baseline session and the first test session of CSC and USC are shown at each FR value. Each curve is the first excursion (475 responses) made during a given session. The diagonal marks indicate reinforcements; the solid dots above the FR 1 curves indicate the FR components.

At FR 1, the CSC produced an initial increase in VI responding, with respect both to baseline and to the USC condition, but with successive testing this facilitative effect diminished in size or disappeared completely. At FR 50, neither type of SC seemed to affect VI rate. This should be contrasted to the effects of CSC at FR 150, where substantial and consistent suppression was found. Note that USC also produced a decrease in VI responding, but to a much lesser extent. Finally, at FR 300, both the suppressive effects and the difference between CSC and USC were accentuated.

Cumulative records for P-1, representing performance during preliminary testing (VI 2) and the ascending-sequence procedure (Mult FR VI 2), are shown in Fig. 2. In addition to noting behavioral contrast and suppressive effects, inspection of the FR 1 (C) curve indicates that the greatest amount of facilitation generally occurred at the beginning of the VI component; this "reversed scallop" pattern was also found with P-2.

The facilitative and suppressive effects can be more clearly seen in Fig. 3. Although the average percentage reduction from VI baseline produced by CSC was greater at FR 300 than at FR 150 for only P-2 (Fig. 1), the difference between CSC and USC increased with higher FR values for both subjects (Fig. 3).

Figure 4 presents the data from the within-session probe at FR 300 for P-2; again P-1 showed similar results. The effects from this type of manipulation resembled the effects of

the between-session testing, with two exceptions. First, the relative amount of USC suppression was greatly reduced. Secondly, the return to baseline (cycle 14) was accompanied by a compensatory increase in responding, similar to the "overshooting" effect typically found when electric-shock punishment is removed (Azrin, 1960). Recovery during between-session testing showed no signs of overshooting and was usually complete within two days, irrespective of the FR value or the type of SC tested.

When the schedule was shifted back to Mult FR 1 VI 2, the VI baseline gradually decreased during the 10-day recovery period to within its previous range of variation for each subject. Moreover, the initial effects of the SC conditions at FR 1 were found to be completely recoverable.

DISCUSSION

The results indicate that the brief response-contingent presentation of a stimulus associated with FR either facilitates or suppresses VI performance depending on the value of FR. The reason for the facilitative effect of CSC at FR 1 apparently stems from the fact that the FR schedule was not studied in isolation, but rather as a component of a multiple schedule. Since SC was originally shown to be neutral (during preliminary testing), the facilitative effect suggests that as a fixed-ratio S^D the stimulus gained conditioned reinforcing

Fig. 3. Average response deviation from VI baseline as a function of the FR requirement for correlated (C) and uncorrelated (U) stimulus-change conditions. At a given FR value, each data point indicates the difference, in terms of absolute number of responses, between the mean of the four pre-test baseline sessions and the mean of the four tests of a given SC condition.

Fig. 4. Effects of correlated (C) and uncorrelated (U) stimulus change on VI baseline (B) as measured by a within-session "probe" at Mult FR 300 VI 2 for bird P-2.

properties, perhaps because of the higher rate of reinforcement in its presence. The transitory nature of this effect is consistent with a large body of evidence dealing with the dura-

bility of positive conditioned reinforcement (cf. Kelleher and Gollub, 1962).

An evaluation of the suppressive CSC effects is complicated both by the shifting VI base-

line and by the fact that USC produced a decrease in VI responding at higher FR values. Several explanations for the USC reduction of VI rate are possible. The most likely is that SC *per se* produces an alteration in response topography. Subjects were frequently observed to turn away from the key or otherwise change position each time SC appeared. Such behavior would be expected to lengthen interresponse times (IRTs). This effect is perhaps not apparent at low FR values because the IRTs were rather long anyway. On the other hand, when VI baseline increased at higher FR values, the longer IRTs resulting from this effect would lower response rate considerably. It is clear, however, that the decrease in responding produced by CSC at high FR values was greater, both absolutely and proportionally, than that produced by USC. Since the only difference between CSC and USC was the association with the FR schedule, it is reasonable to conclude that stimuli associated with high FR schedules served as punishment for the ongoing behavior.

In general, the results of the present experiment, together with those of avoidance (Findley, 1958) and escape (Thompson, 1964, 1965) procedures, all point to the conclusion that

stimuli associated with high ratio requirements are aversive.

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