PREFERENCE FOR LOCUS OF PUNISHMENT IN A RESPONSE SEQUENCE¹

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Food-deprived pigeons pecked a key under a schedule in which grain was made available after the seventieth peck. In each sequence of 70 responses, either the first, middle, or final response was followed by electric shock. Before the first response of each sequence, each response on a second key changed the color of the food key and the schedule of shock that was correlated with the food key color. Each pigeon preferred a schedule of shock, in that each of the three shock schedules did not occur equally often. The preferred shock schedule and the strength of the preference varied among the pigeons. The overall rate of responding by a pigeon under a given shock schedule was directly related to the pigeon's relative preference for that schedule, except when shock after the first response in the sequence was the most preferred schedule.

The delivery of a noxious stimulus in a response sequence can influence both the temporal pattern of responding and rate of responding within the sequence. Investigations have shown that punishing either the initial, middle, or final response of sequences maintained under fixed-ratio (FR) reinforcement schedules differentially modifies the typical bi-valued performance (Dardano, 1970; Dardano and Sauerbrunn, 1964; Holz, 1967). In general, these studies have shown that the punishing stimulus exerts a strong effect on pre-punishment responses, less on the punished responses, and little effect on the post-punishment responses of the sequence. Church (1969) reported a greater suppression of mean response rate when punishment was scheduled on the first response than when scheduled on a later response in the sequence.

The greater suppression of performance when punishment occurs early in the sequence implies that the degree of aversiveness of a given punishing stimulus depends partly on when it is delivered. The present study attempted to specify any differences in the aversiveness of response-dependent shock when scheduled on the first, middle, or final response

of a sequence of 70 responses by using a procedure to identify relative preferences. This procedure, which permitted the subject to select among alternative events, required the establishment and maintenance of discriminative behavior based on the inevitable onset of a punishing stimulus event. The investigation also compared the degree of suppression of response rate under each of these punishment schedules for each pigeon and related the suppressing effects of the schedules to the relative preferences for the schedules.

METHOD

Subjects

Seven experimentally naive White Carneaux cocks, 3 to 4 yr old, were maintained at 80% of free-feeding weights. Grit and water were continuously available in the home cage.

Apparatus

A 13 by 15 by 13 in. (33 by 38 by 33 cm) experimental chamber was furnished with a speaker for masking noise, a relay for response feedback, two translucent response keys (R. Gerbrands) each having a required force of 18 g (0.176 N), 7.5-w houselights, and a grain dispenser. The response keys were mounted 10 in. (25.4 cm) above the grid floor and 2.5 in. (6.3 cm) apart center to center. The "food" key was centered on the front panel and the "switching" key was left of center. The switching key was transilluminated by a white light,

¹Research supported by Grants NsG 189-61 and NGR 21-001-069 from the National Aeronautics and Space Administration. Appreciation is expressed to E. Taylor and J. Puckett, for assistance in running the experiments. Reprints may be obtained from the author, Room 719, The Traylor Building, 720 Rutland Avenue, Baltimore, Maryland 21205.

the food key by a red, orange, or green light. All lights were type GE C7 $\frac{1}{2}$ w. An aperture, 3 in. (7.6 cm) above the grid floor, provided access to mixed grain for 3 sec in accordance with the reinforcement schedule. The experimental chamber was set within a sound-attenuating, ventilated enclosure.

The shock circuit included a step-up transformer, auto-transformer, milliammeter, and 10,000-ohm resistor. A 50-msec shock (60 Hz ac) was delivered to the pigeon by electrodes around the pubis bones (Azrin, 1959). Shock intensity was determined by pre-setting the scheduled intensity on the milliammeter with the output shorted. Impedances of the pigeons varied from 600 to 2000 ohms as measured by a bridge circuit with a 7-v 60-Hz input.

Procedure

The key-peck response was shaped, then the response requirement for food was increased over several sessions up to an FR 70 under which food was delivered after the seventieth key peck. A minimum of 30 sessions were scheduled under FR 70 with the color of the food key remaining either red, orange, or green during the entire session in the initial 12 sessions, then alternating after each reinforcement for the next 18 sessions. When mean response rate, the number of responses in the session divided by duration of the session, appeared stable over 10 consecutive sessions, the shock condition was scheduled concurrently with the FR 70 food reinforcement schedule. Each color of the food key was correlated with a given schedule of response-dependent shock; shock was delivered after the first response when the key color was red (R-1 shock), the thirty-fifth response when the key was orange (R-35 shock), and the seventieth response when the key was green (R-70 shock). In this report, references to a change of key color also denote a change to the correlated shock schedule. With the switching key still covered and with the food key color changing after every five reinforcements, the shock intensity was increased gradually over 10 to 30 sessions from 2 mA to an intensity that suppressed responding to approximately 50% of the pre-shock response rate. Subjects were maintained for 20 to 40 sessions at the higher shock level; the intensity varied, when necessary, to maintain a strongly suppressed performance until each shock schedule differentially modified the pat-

tern of responding during a ratio as reported in an earlier study (Dardano and Sauerbrunn, 1964).

In the next phase of training, the switching condition was introduced. The shock intensity was reduced to a level that produced a mean response rate approximately 80% of the pre-shock rate, and the switching key was uncovered. Each response on the switching key changed the color of the food key in accordance with the sequence red (R), orange (O), green (G), R, G, O, G, R, O. Responses on the switching key were effective only after reinforcement and before the first response on the food key. During this interval, the switching key was illuminated; the first response on the food key darkened the switching key. The shock intensity was increased gradually over a series of sessions until the mean rate was approximately 60% of pre-shock rate. After the pigeon switched consistently to a particular shock schedule over a few sessions, an automatic change of key color was added. If a given number of consecutive ratios were completed without an effective switching response, the key color changed to the next color in the sequence. The maximum number of ratios before the automatic change initially was set at 10, then 5, and then 3. This completed the preliminary training and brought the subject to testing conditions. Shock intensities were adjusted for each subject, if necessary, to a level that produced clear suppression and similar inter-session response rates. The intensities were: B-29, 13 mA; B-16, 8 mA; B-25, 10 mA; B-169, 9 mA; B-193, 16 mA; B-167, 16 mA; B-18, 5 mA.

In the main part of the study, the three schedules of shock were studied until the switching performances and the number of ratios completed under each shock schedule appeared stable over 10 consecutive sessions. In the second part, each combination of two shock schedules was studied until the performances under each pair of shock schedules were similar over five consecutive sessions. Presenting the shock schedules in pairs for each subject furnished an index of the reliability of any preferences found in the three shock schedules procedure and also permitted a direct comparison of less-preferred shock schedules. In the final part of the study, any differences in mean rate under each shock schedule were assessed by presenting a single shock schedule

for an entire session with the switching key covered. The shock schedules were alternated in successive sessions until a subject had a minimum of 10 sessions under each and mean rates under each schedule had stabilized.

The subjects were studied daily. Each session terminated after 40 reinforcements or 1 hr, whichever occurred first. Electrical impedance of the pigeon was measured before and after each session, and experimental weights were maintained by post-session feeding.

RESULTS

The results are summarized in Table 1 which lists the proportion of sequences completed under each shock schedule when three shock schedules were available in a session (averaged over the final 10 sessions), when a pair of shock schedules was available in a session (averaged over the final five sessions), and the mean response rate under each shock schedule relative to the pre-shock rate when a single schedule was in effect during the session (mean rate over the final 10 sessions as a proportion of mean pre-shock rate). The number in parentheses listed with each set of proportions is the mean number of switching responses in a session during the various phases

of the experiment. These data show differences in the relative frequencies of occurrence of the shock schedules for the pigeons, with no single shock schedule occurring most or least frequently for all pigeons, and a partial relationship between the relative frequency of occurrence of a shock schedule and the response rate under that schedule.

The performances of each pigeon under three shock schedules and under the pairs of shock schedules showed that the relative frequencies of occurrences of the shock schedules were a consequence of responding on the switching key. As seen in Table 1, the differences in relative frequencies of each schedule varied widely among the pigeons, ranging from the large differences between all the schedules for B-29 to the single small difference for B-18. Four of the pigeons (B-29, B-16, B-25, B-169) exhibited an order in the relative frequencies of occurrence of the three shock schedules, two pigeons (B-193 and B-167) showed a less frequently occurring schedule, and B-18 showed a consistent difference of relative frequencies only between the R-35 and R-1 schedules.

These results did not identify a particular shock schedule as the most or the least frequently occurring schedule for all pigeons. Among the group of pigeons, each shock sched-

Table 1

Proportion of response sequences completed under each shock schedule with three shock schedules available and with two shock schedules available. Lowest section lists the average punishment response rate as a proportion of the average pre-punishment response rate when a single shock schedule was in effect during a session. Numbers in parentheses denote the average number of switching responses in a session when each set of schedules was in effect.

<i>Shocked Responses</i>	<i>Subjects</i>						
	<i>B-29</i>	<i>B-16</i>	<i>B-25</i>	<i>B-169</i>	<i>B-193</i>	<i>B-167</i>	<i>B-18</i>
Three Shock Schedules Available							
First	0.08(28)	0.29(15)	0.47(7)	0.26(8)	0.42(6)	0.41(6)	0.27(4)
Middle	0.12	0.49	0.38	0.30	0.21	0.41	0.39
Final	0.80	0.22	0.15	0.44	0.37	0.18	0.34
Two Shock Schedules Available							
First	0.01(19)	0.20(23)	0.54(2)	0.43(5)	0.60(7)	0.48(1)	0.41(6)
Middle	0.99	0.80	0.46	0.57	0.40	0.52	0.59
First	0.01(21)	0.77(17)	0.80(9)	0.08(15)	0.52(2)	0.90(14)	0.50(2)
Final	0.99	0.23	0.20	0.92	0.48	0.10	0.50
Middle	0.11(14)	0.77(18)	0.70(18)	0.20(14)	0.43(10)	0.87(13)	0.51(1)
Final	0.89	0.23	0.30	0.80	0.57	0.13	0.49
Relative Responses Rate Under Each Shock Schedule							
First	0.38	0.69	0.50	0.55	0.56	0.50	0.61
Middle	0.61	0.79	0.81	0.61	0.46	0.54	0.73
Final	0.69	0.56	0.73	0.85	0.65	0.41	0.74

ule was represented both as the most or least frequent schedule. There was no obvious relationship between the particular schedule occurring most frequently for a pigeon and other properties of the performance such as pre-punishment response rate, degree of the suppression by punishment, or frequency of switching responses.

The results for a given subject under the three shock schedules procedure and the two shock schedules procedure were consistent: any marked differences in the relative frequencies of occurrence of the schedules under the three shock schedules procedure persisted, and often were more discrepant, under the two shock schedules procedure. Also, in those cases where an ordering of the shock schedules was masked by the frequent production by the pigeon of a particular shock schedule, larger differences in the relative frequencies of the two remaining schedules emerged when this pair was presented under the two shock schedules procedure. For example, the more frequent production of the R-35 shock schedule relative to the R-1 schedule was observed in B-29 only when the R-70 schedule was not included in the procedure.

The switching response data listed in Table 1 show that differences in the relative frequencies of occurrence of the shock schedules were related to the number of switching responses in those sessions. When the relative frequencies of occurrence of the different shock schedules were similar, it resulted from fewer switching responses by the pigeon rather than from a large number of switching responses occurring equally often under each shock schedule. The occurrence of switching responses primarily during the key color associated with the less frequently occurring schedules is illustrated by the data in Table 2 showing the number of times that each shock schedule remained in effect for three successive ratios, the maximum

permitted by the automatic change condition. The entries are the total frequencies from the final 10 sessions under the three shock schedules procedure. A comparison of these results with the proportions under the three shock schedules procedure in Table 1 shows a direct relationship between the relative frequency of occurrence of a shock schedule and the frequency of occurrence of three successive ratios under the schedule. The shock schedule that occurred with the highest relative frequency was seldom changed by a switching key response. In the 70 sessions represented in Table 2 below, a switching response terminated the most frequently occurring schedule only nine times.

Some temporal properties of the performances are illustrated in Figure 1 by the cumulative response recording (upper record) and the four-channel event recording (lower four record segments) of B-29 during a session with three shock schedules available. The cumulative response record shows the persistence of the temporal characteristics of FR performance under this experimental procedure, the lack of excessive switching responses and also ineffective switching responses (after a response on the food key), and the initiation of responding on the food key shortly after responding on the switching key. All pigeons exhibited these properties in their performance except for B-167 and B-193 whose performances under R-1 shock showed brief post-reinforcement pauses and a break of several seconds after approximately 10 responses in the ratio. The four-channel event recording, which shows certain temporal relations in greater detail, is read in the following manner. When the sessions started, the food key color was red, indicating a scheduled shock on the first response in the sequence (R-1 shock). After approximately 20 sec, B-29 responded on the switching key twice which changed the food

Table 2

The number of times each shock schedule was present in three consecutive ratios for each subject. Each entry is the total frequency from the final 10 sessions under the three shock schedules procedure.

Shocked Response	Subject						
	B-29	B-16	B-25	B-169	B-193	B-167	B-18
R-1	4	25	63	28	55	52	31
R-35	7	62	49	34	27	54	50
R-70	97	20	14	56	46	12	46

Fig. 1. Cumulative response recording (upper record) and four-channel event recording (lower four record segments) for B-29 during a complete session under the three shock schedules procedure. In the cumulative response recording, the response pen resets to the baseline after each reinforcement, the deflection of the response pen during each excursion denotes shock delivery, and the deflection of lower pen denotes a response on the switching key (upward pointing arrows added to aid localization). An automatic change to another shock schedule after three consecutive reinforcements without a response on the switching key is indicated by each of the nine arrows above the record. In the four-channel event recording, the lowest pen deflected with each response on the switching key. Each of the upper three pens represents a particular key color and associated shock schedule, which is noted on the left of each segment. When the food key was a particular color, the corresponding pen deflected downward and remained displaced until the color of the key changed. Each reinforcement is indicated by the deflection of the displaced pen and the number of that reinforcement above the channel. To aid inspection, dots were added when the pen was displaced.

key color to orange (R-35 shock) then to green (R-70 shock). Three response sequences were completed under this shock schedule, then the key color was automatically changed to red (Shock R-1). After approximately 12 sec, pigeon B-29 responded on the switching key once and changed the color to green (R-70 shock), etc.

The part of the study that compared overall mean response rates under each of the shock schedules revealed that, for the group, shocking the first response of the FR 70 produced greater suppression of responding than either of the other shock schedules. Calculation of the arithmetic averages of the relative response rates across subjects for each of the shock schedules (last three rows in Table 1) showed that shocking the initial response in the sequence suppressed responding to 0.50 of the pre-punishment mean rate, whereas shocking the middle or final response in the sequence suppressed responding to 0.65 and 0.66 of the pre-punishment rates. However, these group averages were not very representative of the individual mean rates. The average deviations from the group mean were 7.6 for R-1 shock, 10.9 for R-35 shock, and 10.4 for R-70 shock. In some cases, the mean response rates of a pigeon under R-35 and R-70 shock were very discrepant; also, the mean response rate under R-1 shock of three of the pigeons was not the lowest of the rates under the three punishment schedules.

With one exception, frequencies of occurrence of the various shock schedules for the pigeon were directly related to the mean response rate under each of the three shock schedules. The response rate of the pigeon was highest under the most frequently occurring shock schedule and lowest under the least frequently occurring shock schedule. The average relative rate for the group of pigeons was 0.76 for the most frequently occurring schedule and 0.52 for the least frequently occurring schedule. The exception to this relationship occurred when shock after the first response was the most frequently occurring schedule or shared this rank. These three pigeons (B-25, B-193, B-167) did not exhibit a correspondingly high response rate under the R-1 shock schedule. As seen in Table 1, for B-25, the R-1 shock schedule occurred most frequently but the mean response rate was lowest under this schedule; for B-193, the relative frequencies of

the R-1 and R-70 shock schedules were similar but the response rate was lower under the R-1 schedule; for B-167, the relative frequencies of the R-1 and R-35 schedules were similar but the mean rate was lower under the R-1 schedule.

The performances of each pigeon remained stable during the test sessions under the various conditions. No consistent intra-session shifts occurred in the switching of particular shock schedules, and switching responses were not more frequent in one part of the session. No marked inter-session changes were apparent in mean response rate, frequency of switching responses, and relative frequency of occurrences of the shock schedules.

DISCUSSION

The disrupting influence of aversive stimulation on discriminations involving appetitive behavior (*e.g.*, Hearst, 1965; Powell, 1971) raises a question about the feasibility of comparing the aversiveness of different punishment schedules with a procedure requiring discriminative behavior. The procedure used in this study involved conflict situations not only under the food schedule, where production of an aversive stimulus was a prerequisite for food, but also under the switching schedule, where all the alternative conditions included an inevitable punishing stimulus. Furthermore, a well-established FR performance is markedly suppressed only under intense punishment; so, the demonstration of continued punishing action required a high shock intensity for each subject. Despite these potentially disruptive conditions, the long-term stability of the switching performances and the continued coordination of switching key and food key responses indicated the successful maintenance of discriminative behavior based on key color and punishment schedule. The failure of response-dependent shock to produce a sustained disruption of an appetitive discrimination also has been reported by Hearst (1965).

The term "preference", as used here, refers to a measurable aspect of the performances; namely, the relative frequencies of occurrence of different punishment schedules which could be determined by the pigeon. Any statements of preference are limited by the particular procedure yielding the results; so, the failure

of all pigeons to show a preference for the same punishment schedule in this study does not deny the possibility of a common preference. The intersubject variation could be due, in part, to the values of parameters in the experiment such as size of the FR, intensity of the punishing stimulus, and deprivation level of the subject. Also, preference for wave length (Karr and Carter, 1970; Oppenheim, 1968) and/or intensity of light, could have influenced the switching of food key colors. Evidence against any influential effect of such preferences on the performances include the similar mean response rates under each food key color without the punishment condition, the absence of switching responses with no punishment; and, the reported negation of color preferences by reinforcement (Karr and Carter, 1970). The intersubject variation in preferences could also reflect constitutional differences among the subjects. For example, if a pigeon were extremely reactive to electric shock, the disruption of the behavior resulting from the elicitation of incompatible respondents would render R-70 punishment less favorable because of the delay in arrival at the grain dispenser.

On a speculative level, arguments can be raised for the preference of punishment after one or another response in a sequence. The demonstrated maintenance of avoidance responding by a delay in shock onset without a reduction in shock rate (Hineline, 1970) might underlie a preference for punishment at the end of the sequence. Another viewpoint might claim that punishment of the initial response in the sequence would be preferable because its maximum predictability permits preparatory responses by the subject. Although the mode of shock delivery made the intensity and duration of the shock pulse independent of postural changes, the author has observed that some pigeons markedly change their pecking style before and during the punished segment. An adjustment of response topography in the vicinity of shock has a parallel in the reported increase in frequency of off-key pecking under punishment of VI performance where each response is punished. (Dunham, Mariner, and Adams, 1969). An opposing viewpoint would consider punishment of the initial response least preferable because the certainty of the next response being punished would generate

strong pre-aversive stimuli. Another possibility, related to the procedure, would be the additional time available for other responses, including a switching key response, during the extended post-reinforcement pauses that occur during R-1 punishment.

The differences in the overall suppressing effect of the punishment schedules on mean response rate found in this study agreed with the findings of a similar study using rats, in which punishment of the initial response of the sequence had a greater suppressing effect on response rate than punishment of the middle or final response in the sequence (Church, 1969). As noted in these results, the average relative response rate for the group under each punishment schedule did not accurately represent the relative rates of individual subjects under the schedule. Considering the differences in the preferences of the subjects, the intersubject variation in the relative suppressing effects of the punishment schedules is not surprising.

Assuming that relative preferences for punishment schedules and the relative suppressing effects of the schedules both reflect the differential aversiveness of punishing different responses in the sequence, the highest response rate should occur under the most preferred schedule and lowest rate under the least preferred schedule. Generally, this was the case, except for the three pigeons that showed a preference or shared preference for punishment after the first response in the sequence. This result, along with the lower average rate of the group under R-1 shock, suggests that reduction of response rate resulting from punishment of the initial response in the sequence is not solely a function of the aversiveness of the punishing stimulus. Other factors interact with the action of the punisher to enhance the apparent suppressing effect. One such factor might be the maximum probability of punishment when it is contingent on the first response, as suggested by Church (1969) who reported that an increase in the discriminability of the punished response at a later point in the sequence produced greater suppression. Another possible factor is the minimum probability of a response at the start of the FR, described by Ferster and Skinner (1957), which would make this location most susceptible to the suppressing influence of punishment.

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Received 5 April 1971.

(Final acceptance 21 October 1971.)