STIMULUS ASPECTS OF AVERSIVE CONTROLS: THE EFFECTS OF RESPONSE CONTINGENT SHOCK¹

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A tone ending with electrical shock was periodically presented to pigeons while they pecked a key for food. Pairs of birds were run simultaneously under a yoked program which insured that both birds received the same number and temporal distribution of shocks. For one of the birds, shock was always initiated by a peck; for the other, shock was unavoidable. Both procedures led to reduced rates of pecking in the presence of the tone, and gradients of stimulus generalization were obtained. But the effects of response contingent shock extinguished more rapidly than the effects of unavoidable shock. In general, birds exposed to unavoidable shock tended to respond at intermediate rates throughout tone, whereas those exposed to response contingent shock ceased to peck for part or all of the tone period.

Punishment can be defined as a procedure in which the advent of noxious stimulation (for example, electrical shock) is contingent upon the occurrence of a given response. Since this procedure necessarily involves the presentation of a noxious stimulus, it is similar to a large variety of techniques for the establishment of aversive control. Its distinction lies in its use of a response contingency. Its specific effects on behavior should, theoretically, be mediated by this contingency. Several investigators have sought to isolate these effects by comparing procedures involving response contingent shock with procedures in which the presentation of shock was independent of ongoing responses. (See Church, 1963, for a comprehensive review of this literature.) But in all of these studies, the temporal distribution of shocks was not equated under the several experimental conditions. The purpose here is to compare these procedures under conditions in which all aspects of the occurrence of the noxious stimulus are equated. To accomplish this, a yoked design was employed in which a punishment subject programmed shock for itself as well as for a second (paired) subject. An additional purpose was to measure the stimulus generalization occurring under these procedures. Several papers have been con-

cerned with the generalization of the effects of punishment (Honig and Slivka, 1964; Brush, Bush, Jenkins, John, and Whiting, 1952) but none has compared them to the effects of conditioned suppression procedures.

METHOD

Subjects

Six experimentally naive homing pigeons, descendants of birds originally obtained from the Army Signal Corps at Fort Monmouth, N. J., were used. They were approximately 2 yr old at the start of this research.

Apparatus

The experimental apparatus and associated equipment have been fully described elsewhere (Hoffman and Fleshler, 1961; Hoffman, Fleshler, and Jensen, 1963). Briefly, they consisted of two Foringer pigeon chambers, equipment to program reinforcement and tones, cumulative recorders, printout counters, and special purpose connectors (Hoffman, 1960) to deliver shock to subjects via permanently-worn wing bands. Shock was generated by an Applegate constant current stimulator.

Tone frequencies were 450, 670, 900, 1000, 1100, 1500, and 2300 cps. When arranged on a logarithmic scale, the 450, 670, 1000, 1500, and 2300 cps tones lie at approximately equal intervals and the 900 and 1100 cps tones are roughly equidistant from the central tone (1000 cps). The intensity of each tone was set to a value which yielded a reading of 80 db

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re .0002 dynes per cm^2 on the C scale of a General Radio sound survey meter when the microphone was placed in the position typically occupied by the subject's head.

Procedure

All subjects were treated alike during the several training stages which preceded the initiation of the aversive procedures. They were first deprived to 80% of free-feeding weight and adapted to the apparatus, wing bands, and shock connector. They were then trained to key peck and brought to a stable performance. During this and during all subsequent phases, reinforcement consisted of a 3.5-sec exposure to the grain mixture recommended by Ferster and Skinner (1957).

In developing the key peck, each subject passed through a series of progressive steps which began with short exposures (about 1 hr per schedule) to small valued FR schedules (FR 2, FR 10, FR 30), and terminated with extended exposure (approximately 100 hr) to the VI schedule which was to serve as the baseline for the assessment of conditioned suppression. The exposure to the FR schedules was included to generate efficient response topographies. The terminal schedule was a VI 3-min. This schedule consisted of a random sequence of 25 different intervals, generated by a special progression (Fleshler and Hoffman, 1962). With VI schedules derived from this progression, the probability of reinforcement as a function of time since reinforcement tends to remain constant. As a result, the schedule optimizes the conditions necessary for the establishment of stable response rates within the limitations imposed by the use of interval tape programmers.

When the baseline rate was stable, subjects were subjected to a period of tone adaptation. This had two phases: adaptation to the tone which was to be paired with shock (1000 cps) and adaptation to the entire series of generalization test tones. In each of 10 sessions, a 2-min, 1000 cps tone was presented seven times at intervals of 10 min. In each of the next three sessions, the entire series of seven different test tones was presented. A latin square was used to equalize the distribution of stimuli within these sessions. The procedure of adapting subjects to the 1000 cps tone and to the several test tones was employed to mitigate any suppression that might be produced

by the presentation of novel stimuli (the tones with new frequencies) during subsequent tests for stimulus generalization. It also provided a test for the stimulus generalization of adaptation. The effects of the adaptation procedures were the same as found in earlier experiments (Hoffman and Fleshler, 1961). The 1000 cps tone produced a slight reduction in peck rate during its first few presentations, but with repeated exposure to the tone, adaptation occurred and this effect generalized completely to all of the other test stimuli. Thus, by the end of this phase, the subject's pecking behavior was very stable and unaffected by the presence of tone, regardless of frequency.

After completion of the adaptation sequence, the programs for the two chambers were yoked and a series of 1000 cps tones was again presented. This time, the tone served as a warning of impending shock. In this phase, subjects were run in pairs initially arranged so that those with comparable base rates of pecking (estimated from the rates during the final adaptation series) were partners. The assignment of conditions within pairs was random, but once the pairs were arranged, a given subject always had the same partner and always received the same experimental condition.

Each session had the following pattern: the two subjects in a given pair were placed in separate chambers with lights off and maintained in this state for at least 20 sec. The session began with the onset of lights and establishment of the reinforcement contingencies. The first tone was presented after 10 min of pecking on the VI schedule. When the tone had been on for 2 min, a 2-min shock contingency period was initiated. During this period, the delivery of shock for both subjects was determined by whether or not the punishment member of the pair pecked the key. If a peck was emitted during the contingency period, 2-sec shock was automatically delivered to both subjects and the tone was terminated. If no peck occurred, the tone remained on until the end of the contingency period and neither subject received shock. The next tone was presented 20 min later and the cycle continued until four tones had been presented. Ten minutes after the last tone was presented, all lights were extinguished and the session ended.

Separate tape programmers controlled the schedule of positive reinforcement for key pecking in the two chambers. These program-

mers were independent of each other and of the yoked program which controlled tones and shocks. Thus, either subject might obtain food reinforcement at any time during tone, during shock, or during the interval between tones. Training sessions were conducted every other day for a total of 44 sessions. During the first 24 sessions, shock intensity for all subjects was 1 ma. During session 25 and thereafter, shock intensity for all subjects was raised to 2 ma.

Tests for stimulus generalization were begun on the day after the aversive procedures were completed. These tests had the same format as the previous tests for stimulus generalization of adaptation. During the tests, the wing bands and special connectors were in place, grain was delivered on the previously established schedule of reinforcement, but subjects never received shock. Each tone lasted 2 min and the interval between tones was 10 min. The entire series of seven test tones was presented during each of three daily sessions with the order of tones within a given session arranged by selecting successive rows from a latin square.

Results

Only two of the three pairs of subjects were carried through all phases of training and testing. The baseline behavior of the punished member of the third pair was almost completely eliminated by shock. As a result, both members of the pair received less than 20% of the scheduled shocks and neither gave any evidence that the tone was acquiring the capacity to modify their behavior one way or the other. These subjects were dropped from the experiment after 24 sessions of training. The baseline behavior of the others was less sensitive to the introduction of shock, and responding during the pretone periods was maintained.

Figure 1 summarizes the gross features of the development of stimulus control for each of the four subjects that completed the experiment. In this figure the index of suppression for a given subject and a given tone is expressed arithmetically as a ratio:

$$\frac{\text{Pre-Tone } R_s - \text{Tone } R_s}{\text{Pre-Tone } R_s}$$

Pre-tone R_s = the number of key pecks in the 2 min which end with the tone onset, and Tone

R_s = the number of key pecks during the 2 min which preceded the onset of the shock contingency period.

The ratio is numerically equal to 1 when there are no Tone R_s (complete suppression); it is zero when Tone R_s = Pre-tone R_s and it is negative when Tone R_s exceed Pre-tone R_s .

As seen at the left in Fig. 1, at first subjects exposed to unavoidable shocks showed much more suppression than their punished partners. When, however, shock intensity was increased from 1 ma to 2 ma the punished member of both pairs exhibited systematic increases in suppression and beginning with the ninth block of sessions, all four subjects showed about the same degree of suppression.

At the bottom of the graphs, the number of shocks per block is shown. Under the training procedures, shock was not presented on a given trial if the punished subject failed to respond during the final 2 min of the tone; an instance of this behavior constituted an avoidance of shock (passive avoidance). The frequency of avoidance shows similar trends to those seen in the suppression ratios. Only after the increase in shock does avoidance begin. In the final three blocks of sessions, avoidance

Fig. 1. Mean suppression ratios for the punished subjects and their yoked partners during training. AD refers to the final four sessions of adaptation to the tone. The arrow indicates the point at which shock intensity was raised from 1 ma to 2 ma. The bottom rows of figures indicate the total number of shocks delivered to the members of each pair during each block of four sessions.

Fig. 2. Sections from the cumulative records from the punished subjects and their yoked partners, showing the second trial from the second session of each block of four sessions. The heavy vertical lines above the records indicate the onsets of the pretone, tone, and shock contingency periods respectively. The numbers below the records indicate the session in which the trial occurred.

reaches a level of 46% for Bird 19 and 35% for Bird 15.

Striking differences in behavior produced by the two procedures are seen in the cumulative records. Figure 2 shows the cumulative records for the second stimulus in the second session of each block of four sessions for each pair of subjects. The marks above the recordings indicate the onset of the pre-tone, tone, and shock contingency periods respectively. During the pre-tone period, the yoked subjects' response rates become somewhat depressed and variable. This tendency persisted with increased training. The onset of tone initiates a short period of negative acceleration, which quickly brings response rate to a low level, and a rough grain, low response rate then prevails throughout the tone. The punished subjects showed little change in behavior during the pre-tone periods. The effects of punishment on behavior during the tone are first seen as very rough grain—sudden oscillations from high rates to low or zero rates of responding. With more training, the pauses in responding become longer. Rate changes seldom occur with the onset of tone, and aside from very short periods of negative acceleration, no intermediate rates are seen. The in-

sets illustrate the basic features of the differences in suppression during the tone.

The complete cumulative record for the last training session is presented in Fig. 3 and 4 for each of the pairs of subjects. These records are typical of the behavior produced in the last several sessions. They once again reveal distinctive behavior patterns under the two conditions. Large amounts of post-trial suppression occur for both the punishment and the conditioned suppression subjects and it is noteworthy that it occurs after trials on which shock is avoided as well as on those trials in which shock occurs.

The yoked subjects typically respond in a fixed way during tone. Tone onset produces an immediate rate reduction which persists as long as the tone sounds. On one occasion the rate reduction is slight (Bird 18 trial 1), but such trials are unusual for this stage of training. In contrast to the yoked subjects the punishment subjects tend to produce three patterns of responses during the tone. On avoidance trials, responses persist through the onset of tone and after a brief period of negative acceleration, a long pause in responding persists for some time after the offset of tone. On nonavoidance trials, the behavior in the

Fig. 3. Complete cumulative records of the last session of training for Birds 14 and 15.

Fig. 4. Complete cumulative records of the last session of training for Birds 18 and 19.

initial part of the tone is the same, but in certain cases no pauses (Bird 15, trial 3) or short pauses (Bird 19, trial 1) occur, and shock occurs at the beginning of the contingency period while the subject is responding at high rates. This same behavior pattern occurred during intermediate levels of training. The other type of nonavoidance trials are those in which long pauses are interrupted by a single response which is punished. (Bird 15, trial 2 and Bird 19, trial 3) The fact that responses after pauses have a high probability of being punished might help explain why avoidance pauses do not terminate with the offset of tone. (The latter two kinds of trials serve to maintain the avoidance behavior, the first by punishing high rates continued too long into the tone, and the second by occasionally punishing responses which follow a long pause.)

The results of the tests for stimulus generalization are shown in Fig. 5. These gradients are less orderly than those typically observed, but as in previous research on stimulus generalization (Hoffman and Fleshler, 1961), the degree of suppression controlled by a given tone seems to be a function of that tone's similarity to the training tone. To test this

hypothesis, a nonparametric test for an ordered hypothesis involving related groups (Jonckheere, 1954) was used. A related group consisted of the ratios for the three stimuli on a given side of the gradient (*e.g.*, 450, 670, 900) for a given session and the ordered hypothesis was that the tones closer in frequency to the 1000 cycle tone produce greater suppression (*e.g.*, $900 > 670 > 450$). For a given subject there are two comparison groups for each of the three sessions. Tests for two punishment subjects were combined as were those of the yoked subjects; both tests were significant ($Z = 2.36$, $p < .01$ for the punishment subjects and $Z = 2.86$, $p < .01$ for the yoked subjects).

The left side of Fig. 5 shows the mean suppression ratio across the seven test tones for each of the three test sessions. Since shock was disconnected during these tests, the trends represent extinction of suppression during tests for stimulus generalization. The punishment subjects appear to extinguish very rapidly while no apparent extinction seems to have occurred for their yoked partners. To evaluate the significances of these trends, another nonparametric test for an ordered hypothesis was performed. For this test, the related groups were ratios for the same test tone

Fig. 5. Mean suppression ratios for the punished subjects (Birds 15 and 19) and for their yoked partners (Birds 14 and 18) during tests for stimulus generalization. The right side of the figure shows the gradient of generalization for each subject where the several points represent mean suppression ratio across three testing sessions. The left side of the figure shows mean suppression ratios across all tones during each testing session.

for each of the three sessions and the ordered hypothesis was that suppression would be highest for the first session and lowest for the third. The test for the two punishment subjects combined was significant ($Z = 2.38$, $p < .01$) but the tests for the yoked subjects combined were not ($Z = -1.59$, $p > .50$). Thus, the punished subjects show extinction within the three test sessions and the yoked birds do not.

Although further comparisons of the intrinsic nature of the generalization of punishment and that of conditioned suppression are of theoretical interest, it seems apparent that they are precluded here by the rapid extinction for the punishment subjects.

DISCUSSION

Comparisons between relative effects of discriminated punishment and conditioned sup-

pression procedures must at this point be very tenuous; the effects that they produce are quite varied and depend upon a constellation of experimental details. At one extreme, if shock is too intense and/or is massed, the background behavior is obliterated and subjects stop responding for entire sessions. (Indeed, baseline loss represents a very serious problem for researchers in this area.) At the other extreme, noxious stimuli intense enough to modify behavior within the context of certain aversive training procedures (*e.g.*, escape and avoidance) have been observed to produce little or at best temporary effects within conditioned suppression and punishment paradigms (Annau and Kamin, 1961; Azrin, 1960). In between these extremes, the warning signal suppresses behavior and several differential effects are found:

(1) The two procedures yield distinctive patterns of behavior during the warning stimulus. Birds exposed to punishment exhibit an abrupt cessation of responding for part or all of the warning stimulus, whereas conditioned suppression procedures generally yield either no responding or responding at a reduced rate throughout the warning period. In this respect it is relevant to note that the behavior during tone of the present punishment subjects is identical to the behavior reported by Azrin, (1956) when fixed interval punishment was preceded by a warning signal.

(2) When compared to discriminated punishment, conditioned suppression procedures tend to suppress the nontone, baseline responding, especially when shock is first introduced. These findings are in substantial agreement with those reported by Hunt and Brady (1955) and by Azrin (1956).

(3) The effects of discriminated punishment extinguish faster than those of conditioned suppression procedures. This finding is also in agreement with those reported by Hunt and Brady (1955). In their study, however, unequal numbers of shocks were delivered to the two groups and the rapid extinction for the punished animals is consistent with the fact that these subjects received relatively few shocks. The results of the present study indicate that even when the number and temporal distribution of shocks are equated, the effects of punishment extinguish more rapidly than the effects produced by conditioned suppression procedures.

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