PUNISHMENT DURING FIXED-INTERVAL REINFORCEMENT¹

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When punishment is delivered after every response, the frequency of the responses is reduced. In itself, this statement does little more than define the punishment process. However, the way this reduction occurs appears to be a function of the type of reinforcement schedule which has been maintaining the responses. Under fixed-ratio reinforcement, for example, responses do not simply occur at a lower rate under punishment. Rather, the punishment selectively lengthens the pause preceding the usual ratio run of responses; the response run itself remains essentially unchanged by the addition of punishment (Azrin, 1959). Under variable-interval reinforcement, on the other hand, the addition of punishment does produce a general lowering of the response frequency (Azrin, 1960). This experiment investigates the effect of punishment upon responses maintained by a schedule of fixed-interval reinforcement.

METHOD

The subjects were two male, White Carneux pigeons maintained at approximately 75% of free-feeding weight. Variations in body weight were less than 15 grams for each of the birds throughout the experiment.

The apparatus was essentially the same as that used in earlier studies (Azrin, 1960). The experimental chamber was 14 by 14 by 16 inches high, and the 0.75-inch-diameter response key was mounted 12 inches above the floor. The reinforcement was a 3.5-second presentation of a tray of grain. Punishment consisted of the delivery of 60-cycle-per-second AC through a fixed resistor of 10,000 ohms to electrodes implanted in the tail region of the bird. The resistance of the subjects was approximately 1000 ohms as measured by a 50-millivolt AC input, and it varied less than ± 50 ohms from day to day. The intensity of punishment was specified in terms of the total potential drop across the secondary of the output transformer, but the potential drop across the bird was roughly 15% of the total potential drop. The duration of the shock was 100 ± 4 milliseconds. This brief electric shock was delivered immediately following every response during the periods of time designated as punishment.

Both subjects were experimentally naive at the start of the experiment. The daily sessions were 4 hours for one subject and 7 hours for the second subject. Approximately 2 months of conditioning under a 5-minute FI schedule of food reinforcement was given until the number and pattern of responses were fairly stable. We then studied Bird 15 continuously for 20 months, during which time punishment intensities from 0 to 180 volts were administered in various se-

quences; but we began to study Bird 45 only after the effects of punishment upon Bird 15 appeared consistent. Since the effects of punishment on Bird 45 were also consistent with the effects previously obtained with Bird 15, a shorter duration of study was used (6 months), with briefer periods of time allowed for performance to stabilize. At each punishment intensity, a sufficient number of sessions (minimum of five) was given to allow the over-all response rate, as well as the temporal response pattern, to become fairly stable.

RESULTS

Changes in the Over-all Number of Responses

Figure 1 shows the change in the number of responses per day as a function of the punishment intensity for one of the subjects. At all intensities of punishment, the number of responses was reduced; and the more intense the punishment, the lower the

Fig. 1. Changes in the number of responses per day under various intensities of punishment for one subject. The responses are reinforced on a 5-minute, fixed-interval food schedule. The punishment is delivered after every response, and 0 volts indicates no punishment.

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level of responding. At the relatively mild intensities of punishment (30 volts and 60 volts), the addition of punishment produced a large initial reduction of responding. On subsequent days, while this mild punishment after every response was maintained, the response rate recovered appreciably. At 30 volts, this recovery was virtually complete; at 60 volts, the recovery was only partial. At the higher punishment intensity of 90 volts, however, the reduction of responding was maintained for 17 days (120 hours), with no indication of recovery. When punishment was reduced from 90 volts to 60 volts, responding immediately increased. When the punishment was increased to 75 volts, the responding decreased to a level intermediate to that at 60 volts and 90 volts. The adjustment of responding to punishment was rapid at these higher punishment intensities and did not show the gradual recovery found at lower intensities. When the punishment was discontinued (0 volts), responding immediately returned to a high level. The second subject displayed the same general changes in responding.

Fig. 2. The temporal distribution of responses between reinforcements during a 5-minute, fixed-interval food schedule for two subjects. The parameter is the intensity of punishment which followed every response. Each point is the mean number of responses during the last 5-10 days of stable performance at the designated punishment intensity.

Temporal Distribution of Responses

Figure 2 shows the temporal distribution of responses during the 5-minute interval between reinforcements for both subjects at the various intensities of punishment. Each curve describes the average number of responses during the last 5-10 days of exposure to the designated punishment intensities. This figure shows that punishment reduced the number of re-

sponses in each portion of the 5-minute fixed interval, and the extent of the reduction is a direct function of the punishment intensity. The punishment does not appear to be acting selectively upon one portion of the fixed-interval responses: punishment appreciably reduced the terminal rate (during the 4th and 5th minutes), as well as the initial rate (during the 1st and 2nd minutes).

Fig. 3. Changes in the level of response compared with changes in the temporal distribution of responses for two subjects. Punishment follows every response during fixed-interval food reinforcement. The temporal distribution is quantified according to two separate measures.

During fixed-interval reinforcement, the responses were characterized by positive acceleration between reinforcements. One may ask whether punishment has any effect in altering the extent of this temporal patterning. Two measures have been developed recently to quantify the degree of this temporal change in responding: the Quarter-life measure of Herrnstein and Morse (1957) and the Curvature Index of Fry, Kelleher, and Cook (1960). We used both of these measures in this study to evaluate more precisely the effect of punishment upon the pattern of responding between reinforcements. Figure 3 shows that the punishment produced very little change in the temporal response pattern as measured by either of the indices. For Bird 15, both the Quarter-life and the Curvature Index remained virtually constant as a function of the various punishment intensities. For Bird 45, the punishment produced a very slight increase of these two measures; however, the number of responses was

reduced considerably. Although the punishment reduced the total number of responses to less than 10% of the unpunished level, the degree of curvature, or temporal discrimination, remained fairly invariant.

The changes in performance that were produced by punishment can be seen more clearly in the individual cumulative-response records. Figure 4 presents typical records taken from the start of a session under each of the punishment intensities administered to one of the subjects. These records show that the over-

Fig. 4. Sample cumulative-response records of one subject at various intensities of punishment concurrent with a 5-minute fixed-interval food schedule. The records are taken from the start of the experimental session. Delivery of the food reinforcements is indicated by the small diagonal marks on the response record.

all rate of response is negatively accelerated in the absence of punishment. Characteristically, in the first two or three intervals at the start of the session without punishment, a relatively brief pause occurred after reinforcement; thereafter, long pauses followed each reinforcement. Under punishment, however, an increased response level was no longer associated with the start of the session. Figure 4 shows that long pauses followed each of the first few reinforcements during each of the sessions under punishment. Therefore, the effect of punishment appears to be greatest at the very beginning of the session. At relatively mild intensities (30 volts), this initial reduction of responding largely disappeared within 1 hour, after which the level of responding under mild punishment (30 volts) differed little from the level of responding without punishment. No change is evident in the terminal response rate that immediately preceded the delivery of the reinforcement.

At the higher intensities of punishment, the reduction of responses extended throughout the session, and the terminal rate of response was reduced. At 50 and

75 volts, the terminal rate was slightly but consistently lower than the terminal rate without punishment. At 120 volts and more, the terminal rate was but a small fraction of the terminal rate in the absence of punishment. This reduction in the terminal rate of response accounts for most of the decrease of the total number of responses. Punishment also produced a slight increase in the postreinforcement pause, as can be seen clearly at the higher intensities of punishment. At 150 and 180 volts, for example, the first response after reinforcement typically did not occur until well after the 3rd minute of the 5-minute interval. In the absence of punishment, the first response after reinforcement typically occurred about 2 minutes after reinforcement. This lengthening of the postreinforcement pause as well as the reduction in the terminal rate served to reduce the total number of responses.

The addition of punishment did not appreciably change the number of reinforcements the subject obtained. Only rarely did the response fail to occur within a few seconds after the 5-minute fixed interval had elapsed. In the period represented in Fig. 4, for example, 21 out of a possible 22 reinforcers were actually obtained under the most severe punishment intensity (180 volts), despite the large reduction in the level of responding.

Fig. 5. Transient changes in fixed-interval performance immediately following an increase of the intensity of punishment. The large arrow designates the moment at which the punishment was increased. The small arrows designate the occurrence of "premature" responses.

Figure 1 has shown that a change in the intensity of punishment produced an immediate change in the total number of responses per day. Figure 5 shows the immediate changes in responding when the punishment intensity was increased during the session. At an intensity of 30 volts, a consistent pause of at least 2 minutes followed each reinforcement; and after it, very few responses were made before the moderate terminal rate emerged. When the punishment was increased (to 75 volts at the large arrow), a typical sequence of changes occurred. In the first phase, behavior was almost completely reduced as in the first 5-minute interval following the increase of punish-

ment. The second phase was a temporary reduction of the postreinforcement pause. During this phase, responses were made (small arrows) within the first 2 minutes after reinforcement. During the third phase, the postreinforcement pause progressively lengthened, the terminal rate gradually increased, and a stable—but reduced—temporal pattern of responding emerged. This initial disruption and subsequent recovery of the temporal response pattern had also occurred when intense noise was used as the punishing stimulus during fixed-interval reinforcement with humans (Azrin, 1958).

Punishment During Extinction

It has been seen that punishment of sufficient intensity clearly and permanently reduces the level of responding under fixed-interval reinforcement for as long as the punishment is maintained. In order to

Fig. 6. The effects of extinction of fixed-interval responding at various intensities of maintained punishment. No food reinforcement is available after the first reinforcement at the start of the session. Punishment is being delivered after every response.

ascertain the effects of punishment during extinction, several probes were made in which the food magazine was disconnected after the first reinforcement at the start of a session. During these extinction periods, the punishment was still delivered following each response. Figure 6 shows the effects of extinction upon the punished responses for one of the subjects. As the punishment intensity was increased, the number of extinction responses decreased. In the 3-hour period shown, approximately 5000 extinction responses were made in the absence of punishment, whereas only half that number occurred under a punishment intensity of 50 volts. At an intensity of 90 volts, less than 1000

extinction responses were made; and at 120 volts, only 200 responses were made. The time taken to extinguish is also an inverse function of the intensity of punishment. In the absence of punishment, a moderate level of responding was still being maintained at the end of 3 hours, whereas responding had stopped almost completely within 50 minutes at a punishment intensity of 120 volts. Thus, punishment reduces the number of responses during extinction, as well as the time required to extinguish.

The temporal pattern of the punished responses during extinction was similar at all of the punishment intensities. Following the single delivery of reinforcement at the start of the session, the usual pause occurred, after which the responses were emitted at the same rate as during reinforcement (prior to arrow). Periods of no response then alternated with periods of responding. The periods of responding became progressively briefer, whereas the periods of no response became longer (Ferster & Skinner, 1957). The local rate of responding during extinction did not exceed the terminal rate of response during reinforcement.

DISCUSSION

The effects of punishment on fixed-interval responding are similar in many respects to the effects observed when the punished responses are maintained by other reinforcement schedules. The addition of punishment produces a large initial reduction of responding. At mild intensities of maintained punishment, the level of responding recovers almost completely, whereas at moderate intensities of punishment, the level of responding recovers only partially. At severe intensities of punishment, little or no recovery occurs and the punished responses are reduced in frequency for as long as the punishment is maintained. Regardless of intensity, the addition of punishment produces no increase in the variability of the punished performance. During extinction, the punishment reduces the number of extinction responses and considerably shortens the time necessary to extinguish the responses. These effects of punishment on the over-all level of responding apply equally well to variable-interval, fixed-interval, and fixed-ratio reinforcement.

The changes produced by punishment in the temporal patterning of performance, however, appear to be characteristically different for different reinforcement schedules. In this experiment, the punishment produced a general depression of the responses throughout the interval between reinforcements. The normally high terminal response rate, as well as the low postreinforcement response rate, were reduced proportionately by punishment, so that the degree of temporal patterning was unchanged. This general depression of responding by punishment was also found to characterize the changes induced during variable-interval reinforcement (Azrin, 1960) in contrast with the selective action of punishment during fixed-ratio reinforcement (Azrin, 1959).

Electric shock possibly possesses some unique characteristics that account for the general reduction of responding. Unlike some other aversive stimuli, such as noise, electric shock produces strong skeletal reactions which may be expected to reduce the free-operant responses through sheer physical incompatibility. Such seemingly incompatible reactions are easily observed upon the delivery of shock: The tail of the bird twitches, the wings occasionally jerk slightly, and there often appears to be a temporary imbalance of posture.

The apparent incompatibility of these reactions may be illusory, however, since these reactions did not interfere with the very high (about 3 per second) response rates under fixed-ratio reinforcement. Certainly, aversive stimuli other than electric shock should be used in order to ascertain the effects of other types of punishment upon the temporal pattern of response. At this time, however, the seemingly "competing" reactions produced by shock are conspicuously ineffective in reducing the high response runs under fixed-ratio reinforcement. On the other hand, the slightly lower terminal response rate under fixed-interval reinforcement is clearly altered by punishment. Therefore, the nature of the reinforcement schedule would appear to explain these changes in the temporal patterning of responses.

SUMMARY

Punishment was delivered after every response during fixed-interval food reinforcement. The gross

changes in the over-all level of responding were similar to the changes previously observed when punishment was delivered during fixed-ratio and variable-interval reinforcement. When punishment was delivered during extinction, the higher intensities of punishment produced fewer extinction responses and shortened the time required to completely extinguish. Under maintained reinforcement, the punishment decreased the high response rates at the end of each fixed interval as well as the low response rates at the beginning of each fixed interval. As a consequence, the temporal patterning of responses was unaffected by punishment regardless of the punishment intensity.

REFERENCES

- Azrin, N. H. Some effects of noise on human behavior. *J. exp. Anal. Behav.*, 1958, **1**, 183-200.
- Azrin, N. H. Punishment and recovery during fixed-ratio performance. *J. exp. Anal. Behav.*, 1959, **2**, 301-305.
- Azrin, N. H. Effects of punishment intensity during variable-interval reinforcement. *J. exp. Anal. Behav.*, 1960, **3**, 123-142.
- Ferster, C. B., and Skinner, B. F., *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Fry, W., Kelleher, R. T., and Cook, L. A mathematical index of performance on fixed-interval schedules of reinforcement. *J. exp. Anal. Behav.*, 1960, **3**, 193-199.
- Herrnstein, R. J., and Morse, W. H. Effects of pentobarbital on intermittently reinforced behavior. *Science*, 1957, **125**, 929-931.

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