

## FIXED-RATIO PUNISHMENT<sup>1</sup>

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Responses were maintained by a variable-interval schedule of food reinforcement. At the same time, punishment was delivered following every *n*th response (fixed-ratio punishment). The introduction of fixed-ratio punishment produced an initial phase during which the emission of responses was positively accelerated between punishments. Eventually, the degree of positive acceleration was reduced and a uniform but reduced rate of responding emerged. Large changes in the over-all level of responding were produced by the intensity of punishment, the value of the punishment ratio, and the level of food deprivation. The uniformity of response rate between punishments was invariant in spite of these changes in over-all rate and contrary to some plausible *a priori* theoretical considerations. Fixed-ratio punishment also produced phenomena previously observed under continuous punishment: warm-up effect and a compensatory increase. This type of intermittent punishment produced less rapid and less complete suppression than did continuous punishment.

During continuous reinforcement, the reinforcing stimulus is delivered for each response. Alternatively, during intermittent reinforcement, the reinforcing stimulus is delivered for some of the responses; the others go unreinforced. Similarly, every response may be punished (continuous punishment) or only some may be punished (intermittent punishment). At this time, little is known of the changes produced by different schedules of intermittent punishment. The present study investigated the use of fixed-ratio schedules of punishment wherein only every *n*th response was punished.

### METHOD

#### *Subjects*

Seven White Carneaux pigeons were maintained at about 85% of free-feeding weight. Because of the repeated use of the same subjects, body weight was redetermined before each experiment.

<sup>1</sup>This investigation was supported by a grant from the Psychiatric Training and Research Fund of the Illinois Department of Public Welfare, NSF grant G16357 and NIMH grant 4925.

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#### *Apparatus*

The experimental chamber measured 14 by 14 by 20 in. high and contained a translucent response key mounted 13 in. from the floor. A response consisted of a peck against this key. Responses were reinforced according to a variable-interval schedule for at least one month prior to the initial introduction of punishment. The reinforcing stimulus was the presentation of grain for 3 sec. The duration of each daily session was constant for a given subject, but was as brief as 1.5 hr and as long as 8 hr for different subjects. Similarly, the mean interval between reinforcements was constant for a given subject but was 1, 2 or 3 min for different subjects. (These differences in the reinforcement frequency were found to be relevant only to differences in the absolute level of response). Punishment was a brief (100 msec) electric shock that was delivered through a 10,000 ohm series resistor to electrodes implanted around the pubis bone in the tail region of the pigeon (Azrin, 1959). Every 10 volts was equivalent to approximately 1 ma., e.g. 80 volts equalled 8 ma. The food reinforcement schedule was in effect at all times. Figure 1 illustrates the main features of the fixed-ratio schedule of punishment.

Great care was necessary when introducing punishment to the subject for the first time. Previous study of continuous punishment

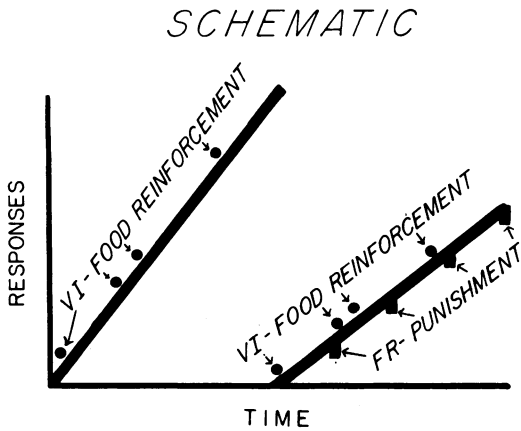


Fig. 1. Fixed-ratio punishment procedure. The responses are maintained by a variable-interval schedule of food reinforcement. Every  $n$ th response was punished.

(Azrin, 1959) had shown that if a high intensity (80 volts or more) was used initially, the responses were likely to be completely and usually irreversibly, suppressed. If the initial introduction to punishment involved lower intensities (60 volts or less), performance was easily maintained even when the punishment was later increased to intensities as great as 130 volts (Azrin, 1960). The present study of fixed-ratio punishment also required that a low intensity be used initially. Thus, the subjects in this investigation all received their initial exposure to punishment at intensities less than 50 volts. Once the subject was exposed to progressively higher shock values, intensities as high as 300 volts could be introduced at a later time without causing complete disruption of the performance. Five of the seven subjects received their initial exposure to punishment at FR-1 punishment (continuous punishment). The fixed-ratio value was then increased progressively to 2, 5, 10, 20, 50, 100, 200, 300, 500, 1000 in that order. The other two subjects received their initial exposure to punishment at an FR-50 punishment and the FR value was increased from that point. The fixed-ratio value was decreased as well as increased for all subjects during the 24 month period over which the subjects were studied. Performance under a given fixed-ratio (punishment) was usually recoverable. Partial irreversibility of performance appeared to result primarily from the sudden introduction of high intensities of

punishment following a period of several weeks in which no punishment had been programmed.

## RESULTS

### *Introduction of Fixed-Ratio Punishment*

The introduction of fixed-ratio punishment produced a characteristic sequence of changes in the temporal pattern of responses of all subjects. Figure 2 illustrates these changes for a subject that had not been exposed to fixed-ratio punishment for 15 experimental sessions. (The same changes were observed with the two subjects that had not been exposed to punishment previously). In the absence of punishment (top curve), the responses were maintained at a high and uniform level by a 3 min VI schedule of food reinforcement. Punishment (240 volts) was then delivered for every 300th response (middle curve). The first punishment delivery (arrow) produced a complete cessation of responding for about 10 min, after which the responses gradually accelerated until a second punishment was delivered after 300 more responses. Again, the response rate decreased sharply following the delivery of punishment; again the responses were positively accelerated. This cycle was repeated. After each of the punishment deliveries, the responses were suppressed but gradually increased in frequency until another punishment was delivered. It can be seen that with successive punishment deliveries, there was a progressive reduction of the suppression which followed each punishment. Concurrently, there was a reduction in the degree of positive acceleration. The end result of these changes was a reduced level of responding showing no systematic acceleration or deceleration between the deliveries of punishment.

When the same intensity of punishment (240 volts) was introduced at a later date for every response, the reduction in responding was immediate. Whereas the FR-300 punishment had suppressed the responses only partially, FR-1 punishment suppressed the responses almost completely.

### *Fixed-Ratio Requirement for Punishment*

Figure 3 shows segments of the cumulative response records for one subject under various fixed-ratio requirements for punishment. The

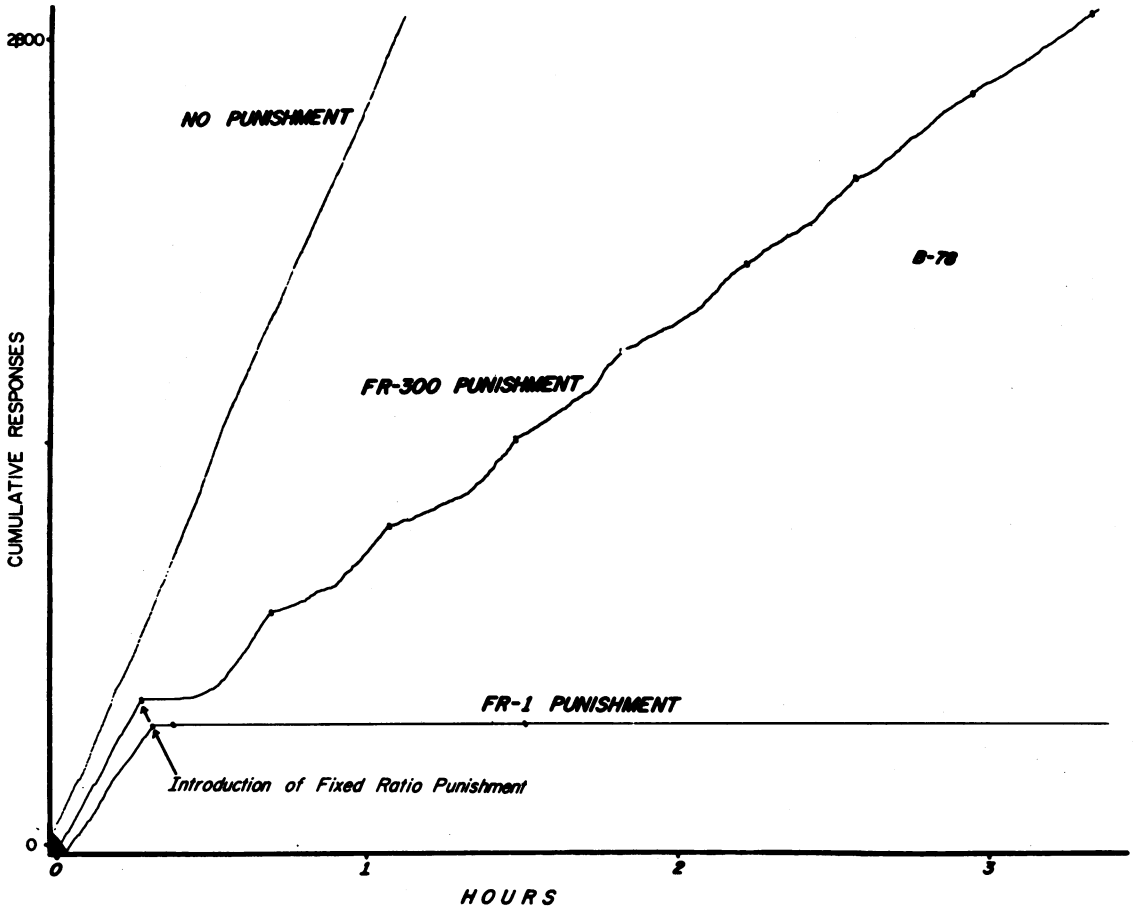


Fig. 2. Introduction of fixed-ratio punishment. The oblique lines on the response curve indicate the delivery of a punishment (240V) after every response (FR-1) or after every 300 responses (FR-300). The food reinforcements (not indicated) are being delivered according to a 3 min variable interval schedule. No punishments had been delivered prior to the arrow.

shock intensity was 240 volts and a 3 min VI schedule of food reinforcement was in effect. At least 100 hr of exposure had been given at each of the fixed-ratio values. This figure shows that the suppression was a direct function of the proportion of responses that were punished. When every response was punished (FR-1), suppression was almost complete; when every 100th response was punished, the responses were reduced to approximately 20% of the unpunished rate; when every 1000th response was punished, the responses were reduced to approximately 40% of the unpunished rate. All values of fixed-ratio punishment produced a uniform reduction in the rate of responding between the successive deliveries of punishment. The size of the fixed-ratio requirement determined the extent

of the reduction but the uniform pattern of responding remained the same.

#### *Intensity of Punishment*

Variations in the intensity of punishment did not alter the uniformity of response rate during fixed-ratio punishment. Figure 4 presents a segment of the cumulative response record from the start of different experimental sessions. A 1 min VI schedule of food reinforcement was used and the punishment was delivered from every 50th response. It can be seen that a shock intensity of 160 volts produced a uniform, but reduced level, of responses. At a lower intensity of 120 volts, the responses were less suppressed but still occurred at a uniform rate between successive presentations of punishment. At a still lower

intensity of 90 volts, suppression was restricted to the initial portion of the session. Within this initial period of suppression, the response rate generally remained uniform within the period between any two successive presentations of punishment.

Occasionally, negative acceleration of responses was observed between successive presentations of punishment. For example, slight negative acceleration was observed between the first and second shock delivery at 90 volts and between the second and third presentation at 120 volts.

Figure 4 illustrates a characteristic feature of the performance under fixed-ratio punishment: the "warm-up period" at the start of the session. It can be seen that the response rate was suppressed initially at a punishment intensity of 90 volts but recovered completely

within 15 min after the start of the session. At 120 volts and 160 volts, no warm-up period appeared. This initial warm-up period characterized the performance at lower punishment intensities but did not appear at the higher intensities.

#### Food Deprivation

In a previous study (Azrin, 1960), slight changes in food deprivation produced unusually large changes in the degree of suppression. Figure 5 shows the effects of food deprivation during fixed-ratio punishment (FR-100). A 3 min VI schedule of food reinforcement was used throughout. The punishment intensity was 160 volts. A typical segment of the response record is shown for different levels of food deprivation. The body weight of the subject had been gradually reduced over a

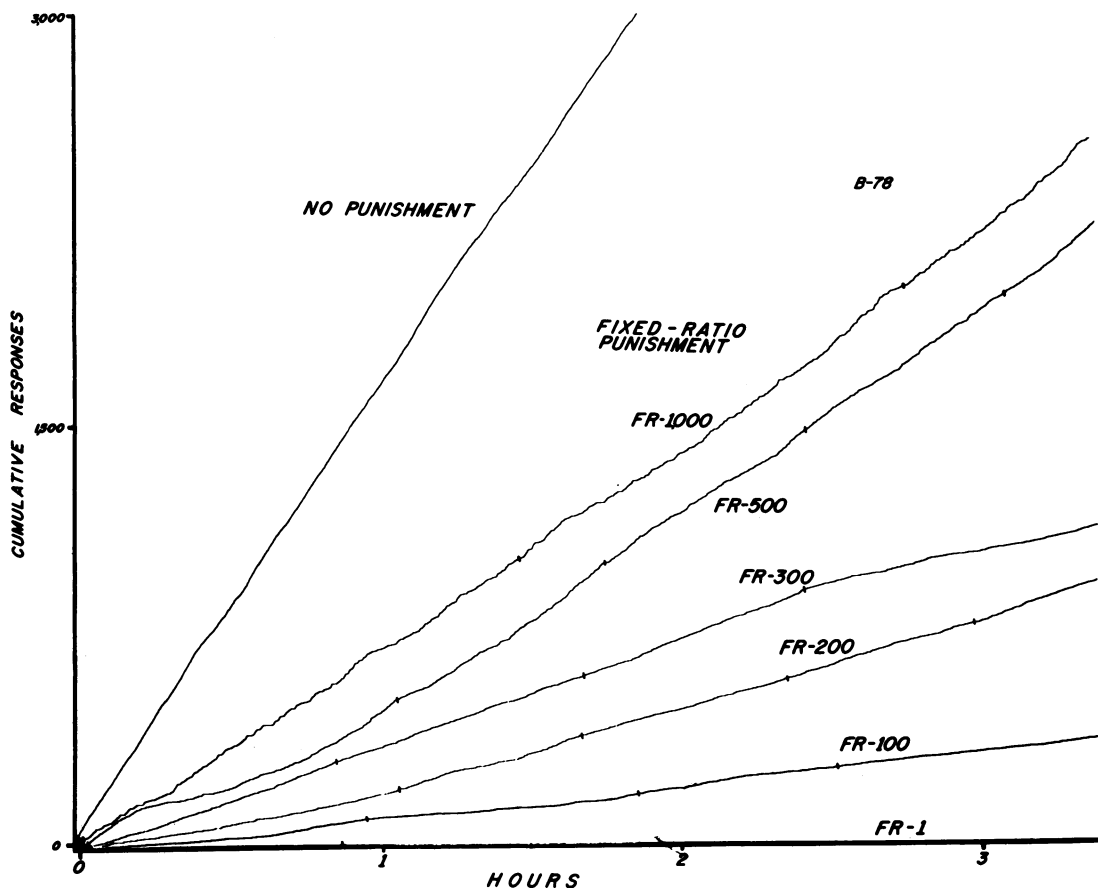


Fig. 3. Stable performance during fixed-ratio punishment at several fixed-ratio values from FR-1 to FR-1000. The oblique lines on the response curve indicate the delivery of a punishment (240V). The food reinforcements (not indicated) are being delivered according to a 3 min variable interval schedule.

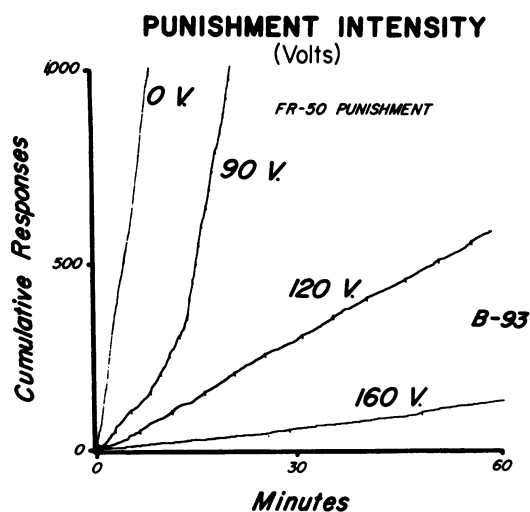


Fig. 4. Effect of punishment intensity during fixed-ratio punishment. Every 50th response is being punished at the moment indicated by the oblique lines on the response curves. Each response curve represents the performance during the first 60 min of different sessions. The food reinforcements (not indicated) are being delivered according to a 1 min variable interval.

period of one month from 85% to 60% by limiting the usual feeding after each session. The body weight was then gradually returned to 85% over a period of about one month by increasing the amount of food given after each session. It can be seen that the responses were almost completely suppressed by the fixed-ratio punishment at 85% of body weight. At 60% of body weight, about 3000 responses per hour were emitted. Changes of only 5% in body weight produced several-fold changes of the response rate. In spite of these large changes in the over-all level of response, the extent of food deprivation did not alter the uniformity of response rate between successive deliveries of punishment.

#### *Termination of Fixed-Ratio Punishment*

Figure 6 shows the changes in response rate when a fixed-ratio schedule of punishment was terminated. A 2 min VI schedule of reinforcement was used throughout. A long history of fixed-ratio punishment (FR-100) had been in effect prior to the 6 hr period depicted in Fig. 6. The punishment intensity was 80 volts. When the fixed-ratio punishment was terminated (dotted line), the response rate gradually increased from approximately 20 responses per min to more than 60 per min during a

period of 2 hr. During the third hour, the response rate rose still higher, achieving a level (130 responses per min) that exceeded the usual unpunished level of responding. By the fourth hour, the response rate had returned to the usual unpunished level of about 105 responses per min.

The above results demonstrated the complete recovery of responding after fixed-ratio punishment was terminated. Figure 7 of the same subject shows that a period of response suppression reappeared at the beginning of each session in spite of the complete recovery during the preceding session. It can be seen that the initial period of suppression became progressively briefer during consecutive days without punishment. This initial period of suppression persisted for many days. The responses were still greatly suppressed during the first 5 min of the sixth day even after five daily sessions during which time there were over 150,000 unpunished responses. During the third day, the session was interrupted for a period of 5 min by blacking out the experimental chamber (see arrow "A"). This brief interruption reinstated the period of suppression that was seen previously at the start of the session.

#### DISCUSSION

The introduction of fixed-ratio punishment produced an initial phase in which the responses were positively accelerated between successive deliveries of punishment. Under maintained fixed-ratio punishment, the degree of positive acceleration progressively diminished until a reduced, but uniform, rate of response emerged. Instances of negative acceleration between punishments were relatively rare and did not persist regardless of the particular subject, the punishment intensity, the value of the punishment ratio, the duration of exposure to a given ratio value (up to 300 hr), the level of food deprivation, or the underlying frequency of food reinforcement.

Two considerations might have led one to expect negative acceleration to have been the rule rather than the exception. The first of these considerations is the approach-avoidance conflict postulated by Miller (1944) in which approach behavior in a runway decreased as the subject approached the spatial locus of aversive stimulation. Similarly, under fixed-

ratio punishment the emission of successive responses might be viewed as bringing the subject progressively closer to the punishment. Fixed-ratio punishment might be expected to produce a gradient along the behavioral dimension analogous to the gradient hypothesized for the spatial dimension. Hence, negative acceleration of the responses might have been expected between successive punishments.

Negative acceleration might also be expected on the basis of a second consideration. During FR-200 punishment, for example, 199 unpunished responses occur between the successive deliveries of punishment. The delivery

of a punishment was the occasion upon which the immediately succeeding responses were not punished. A discrimination could have been formed on this basis and resulted in a decreased level of response immediately preceding the next delivery of punishment. This result might be expected on the basis of a previous procedure in which punishments were delivered according to a fixed-interval schedule (Azrin, 1956).

Negative acceleration of the responses would appear likely, then, on the basis of two theoretical considerations; yet negative acceleration was absent. An explanation of the

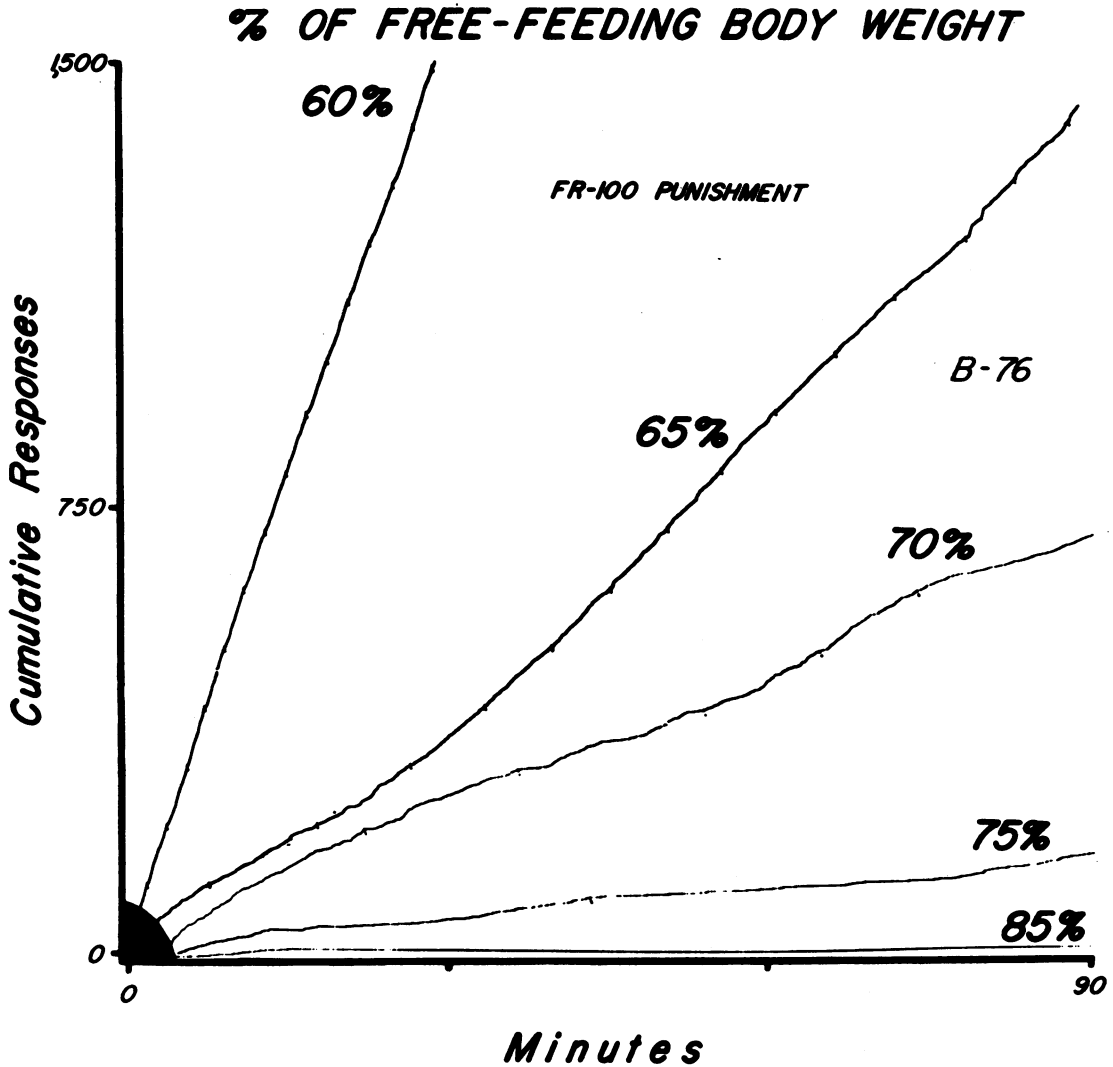


Fig. 5. Effect of food deprivation during fixed-ratio punishment of food reinforcement responses. Every 100th response is being punished (160V) at the moment indicated by the short oblique lines on the response curves. The food reinforcements (not shown) are being delivered according to a 3 min variable schedule.

uniform rate actually obtained under fixed-ratio punishment might be that punishment produced a generalized suppression which prevented any precise discrimination. Yet previous findings have shown that precise discriminations may be formed through punishment (Azrin, 1956; Holz and Azrin, 1961). Apparently, the fixed-ratio schedule of punishment itself operates in some manner to attenuate any response fluctuation attributable to behavioral proximity to the punishment.

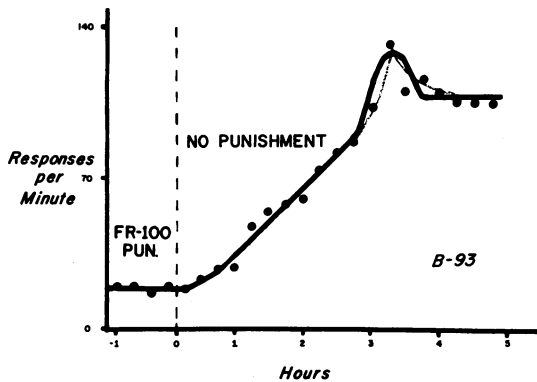


Fig. 6. Gradual recovery and compensatory increase of responses following a long history of fixed-ratio 100 punishment (80V). The changes in rate occurred during a single 6 hr session. A 2 min VI schedule of food reinforcement was used.

The observed effects of fixed-ratio punishment may be analyzed by comparison with the effects of fixed-ratio positive reinforcement. Under fixed-ratio reinforcement, the higher the response rate, the greater is the frequency of reinforcement. The increased frequency of reinforcement in turn would be expected to produce a still higher rate of responses. Presumably, because of this mutually facilitating relation, the response rate reaches a maximum level of occurrence (Ferster and Skinner, 1957). Fixed-ratio punishment may be analyzed in the same terms. Under fixed-ratio punishment, the higher the response rate, the greater is the frequency of punishment. However, the increased frequency of punishment would be expected to produce a lower rate of response. Any tendency for the response rate to increase would be counteracted, therefore, by the resulting increase in punishment. Conversely, any temporary tendency to decrease the response rate would reduce the frequency of punishment and allow the response rate to

recover. The result appears to be a state of dynamic equilibrium in which any changes in the response rate would be opposed by the resulting changes in the frequency of punishment.

The present results revealed several differences between continuous punishment and intermittent punishment. First, the rapidity of suppression following the introduction of punishment was greater for continuous than for intermittent punishment. Secondly, continuous punishment produced greater suppression for as long as the punishment was maintained. With respect to the termination of punishment, recovery occurred very suddenly after continuous punishment, but only after a few unpunished responses were emitted (Azrin, 1960). After intermittent punishment was terminated, recovery occurred very gradually and appeared to begin only after a few omissions of the scheduled punishment.

Previous studies of continuous punishment (Azrin, 1960) have revealed a temporary but immediate "compensatory" increase of responding when the continuous punishment was terminated. The temporary increase of

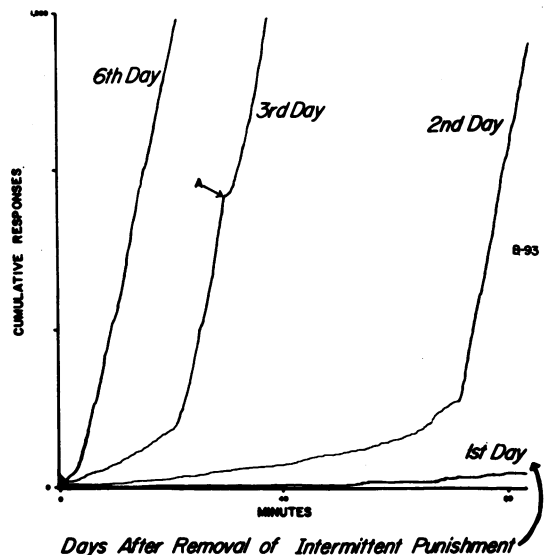


Fig. 7. Reappearance of suppression at the start of successive sessions following the termination of fixed-ratio 100 punishment (80V). Each response curve is taken from the start of a session of 7 hr duration. At the moment indicated by arrow "A", the session was interrupted by a "black-out" of the experimental chamber for a period of 5 min during which time the recording paper did not move. A 2 min VI schedule of food reinforcement was in effect.

unpunished responses appeared to result from the contrast with the preceding period of continuous punishment. This punishment contrast effect has been obtained when different types of food reinforcement schedules were used to maintain the punished responses (Azrin, 1961). The present results appear to extend the generality of this punishment contrast effect. The major difference was that after the fixed-ratio punishment was eliminated, the compensatory increase did not occur immediately. It would appear that no contrast existed until several of the normally scheduled punishments had been omitted.

It was found that mild intensities of fixed-ratio punishment produced temporary suppression at the start of each experimental session. This warm-up phenomenon had been noted previously under continuous punishment (Azrin, 1960). One possible interpretation of this warm-up period is that sensory adaptation had resulted from the frequent administration of shock. Under intermittent punishment, however, the shocks were necessarily separated in time and little sensory adaptation could be expected. Also, the warm-up period persisted for several days after the punishment was discontinued. It appears, therefore, that the warm-up or recovery phenomenon is not attributable to sensory adaptation. Rather this phenomenon appears to be a general reaction to a situation involving aversive stimulation. The stimuli associated with the beginning of an experimental session appeared to exert a persistent effect upon responding. It was found that suppression gradually disappeared during an experimental session when the intermittent punishment was discontinued. However, suppression reappeared at the start of the following session. This reappearance of suppression at the start of each session appears to be comparable to the spontaneous recovery phenomenon (Pavlov, 1927) in which responses reappear at the start of successive ex-

inction sessions (see also Skinner, 1938). This initial period of suppression became briefer with succeeding sessions in much the same way as does the phenomenon of spontaneous recovery. When the experimental session was interrupted and restarted, this brief period of suppression reappeared. Hence, it seems that the initial period of suppression is under the control of the stimuli associated with the start of each session. The persistence of this initial suppression necessitated sessions of long duration in the present investigation. Failure to provide long durations often resulted in the maintenance of behavior that was primarily under the control of the stimuli associated with the start of each session rather than the stimuli being programmed during the session.

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Received April 10, 1962