

## PUNISHMENT OF TEMPORALLY SPACED RESPONDING<sup>1</sup>

W. C. HOLZ,<sup>2</sup> N. H. AZRIN,<sup>2</sup> AND R. E. ULRICH<sup>3</sup>

ANNA STATE HOSPITAL

The responses of pigeons were maintained by a DRL schedule of food reinforcement. With this schedule, responses were reinforced only when a fixed period of time elapsed without an intervening response. Punishment of all responses reduced the frequency of these responses as a direct function of the punishment intensity. As a consequence of the increased temporal spacing of responses, more reinforcements resulted during punishment. Under progressively higher intensities of punishment, the reinforcement frequency increased to a maximum value and then decreased at the highest intensities. The increased frequency of reinforcement which resulted during punishment did not counteract the suppressive effect of punishment, nor did it lead to a low response rate after punishment was removed. Punishment did not reduce the inter-response time distribution uniformly, but rather especially reduced the number of short inter-response times. Even at the low punishment intensities, the number of short inter-response times was considerably reduced. After punishment was discontinued, performance recovered almost completely after a compensatory burst. The number as well as the temporal pattern of responses returned to normal.

Previous studies of punishment (Azrin, 1959b, 1960; Holz and Azrin, 1961) have found that the food reinforcement schedule which maintains responding partly determines the particular pattern of response reduction that results during punishment. The present study examines the effect of punishment upon responses which are maintained by a DRL (differential reinforcement of low rate) schedule.

### METHOD

#### *Subjects*

Three White Carneaux pigeons maintained at approximately 80% of free feeding body weight were used. Two had no previous experimental history. These were given 60 reinforcements on crf and then transferred directly to the DRL schedule. The third subject (B#38) had a previous history of punishment and VI reinforcement prior to being placed on the DRL schedule. A DRL 30 sec schedule was in effect throughout the experiment for all subjects. With this schedule, a response was reinforced only if 30 sec or more elapsed since the previous response. The sessions were

1.5 hr long and were arranged daily over a period of about eight months.

#### *Apparatus*

The experimental chamber was 13-by-14-by-15 in. high. The pigeons responded by activating a 3/4 in. diameter key with a peck of 12 gm force. Response feed-back was provided by a distinctive buzz (40 mscs in duration) which sounded with every response. Every response which met the DRL criterion was reinforced by a 3 sec presentation of grain. Punishment consisted of a .075 sec, 60 cps, AC shock which was delivered through electrodes implanted in the tail region of the pigeons (Azrin, 1959a). The resistance of the animal was approximately 1000 ohms (measured daily with a 50 milv. AC input). A 10,000 ohm series resistor completed the shock circuit. Each 10V of input voltage (rms) equalled approximately 1 ma of current flow through the subject.

Actual current flow was determined for two subjects by placing a milliammeter in the shock circuit and allowing current to flow through the subjects for a duration sufficient for reading the meter. Numerous determinations were taken at 10V steps between 10V and 50V. Within this range of voltages, the subjects' resistance was between two thirds and one half of that typically recorded with the 50 milv. AC, input. Actual current flow

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<sup>2</sup>Anna State Hospital, Anna, Illinois.

<sup>3</sup>Illinois Wesleyan University.

through the subjects was equal to  $I = .094E$ , where  $I$  = current flow in milliamps,  $E$  = input volts (rms) and .094 was a constant based upon the resistance of the subject, the 10,000 ohm series resistor, and all additional resistance such as the connecting cable, *etc.* For example, an input of 20V produced 1.88 ma.

The subjects were trained on the DRL schedule for at least 90 hr (60 sessions) to insure stable performance before punishment was introduced. Punishment was then delivered for every response. A new intensity of punishment was introduced after the pattern and number of responses per session showed no progressive change. At least eight sessions and usually more were given at each punishment intensity.

## RESULTS AND DISCUSSIONS

### Stable Performance

Before the introduction of punishment, the stable DRL performance manifested the inefficient pattern characteristic of pigeons on this reinforcement schedule (Reynolds and Catania, 1961). The rate of response was above the level typically found with other species such as the monkey or rat on similar DRL food reinforcement schedules (Conrad, Sidman and Herrnstein, 1958). Although the absolute rate of responding (3 to 10 responses per min) was low in comparison with the rates maintained by certain other reinforcement schedules with pigeons, responding exceeded the ideal rate of 1 response every 30 sec which would have led to optimum reinforcement. Because the response rate greatly exceeded the optimal level, few reinforcements resulted (about 1% of the responses were reinforced for B#83 and B#510 and about 5% for B#38). The average number of responses and reinforcements per session are shown in Fig. 1 above the ordinate value of 0V (*i.e.*, no punishment). Session-to-session variability was relatively small for a given subject. The rate of response per session did not vary more than approximately  $\pm 8\%$  of the mean rates.

Within a given session responding was fairly uniform. Only occasionally did bursts of five or more responses occur. Typical cumulative response curves appear in Fig. 4 (top and bottom curves); the arrow in the bottom curve points to a typical response

burst. The time intervals between successive responses, called the "inter-response times" (IRT's), were recorded within class intervals of 5 sec. Analysis of the distribution of IRT's indicated that well over half of the responses were separated by less than 15 sec. Average relative frequency distributions of IRT's are shown in the top row of Fig. 5 (IRT's are grouped into 10-sec class intervals in this figure). In 95% of the cases, the scores for a given day did not vary from the average values shown by more than five percentage points. The major day-to-day variability resulted from a shifting of IRT's between the 0-5 sec cell and the 5-10 sec cell.

### Changes in Response and Reinforcement Frequency During Punishment

Figure 1 (upper portion) shows that as the punishment intensity was increased, a reduc-

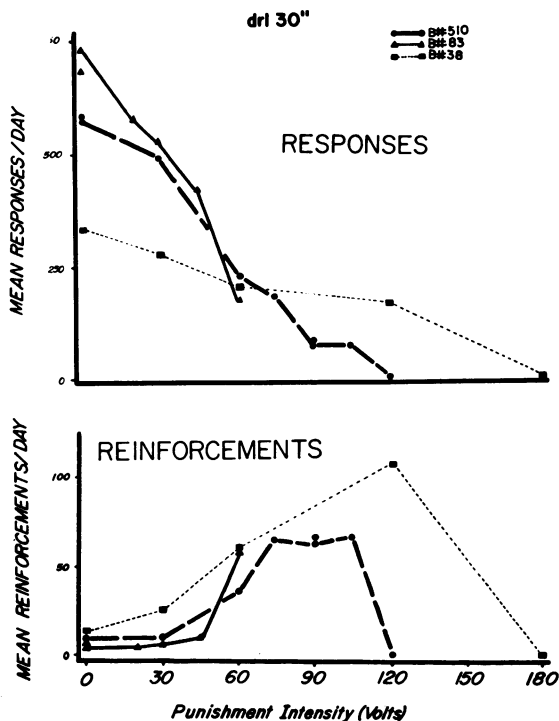


Fig. 1. Changes in the mean number of responses and reinforcements as a function of punishment intensity. Every response which occurred on the DRL 30-sec reinforcement schedule was punished with the shock intensity indicated on the abscissa. Each point represents the mean of the final 5 to 10 sessions (1.5 hr in duration) of stable responding. Connected points represent the initial determinations at each intensity; unconnected points represent later determinations at these values.

tion of responses resulted. Reinforcement frequency, shown in the lower portion of Fig. 1, increased as the responses were reduced, but then dropped to zero when responding was obliterated by the punishment.

Since response rate is ordinarily a direct function of the frequency of reinforcement (Skinner, 1938) an increase in the number of reinforcements could be expected to increase the frequency of the response. We anticipated that the increased frequency of reinforcement, which resulted during the punishment of DRL responses, might counteract the suppression produced by punishment. If this were the case, higher intensities of punishment would be necessary to suppress DRL responding than are necessary with other schedules, where reinforcement frequency is not increased by a lower response rate. Yet, the absolute values of the punishment intensities used to suppress

responding on the DRL schedule were within the range of intensities necessary to suppress responding under other reinforcement schedules (Azrin, 1959b, 1960; Azrin and Holz, 1961). It appears that a given punishment intensity remains equally effective regardless of whether the punishment increases or decreases the frequency of reinforcement. (Of course, this equivalence presupposes the use of equivalent associated procedures, such as body weight, implanted electrodes, etc). For one subject, B#38, an intensity of 180 volts was necessary to completely suppress responding. While this intensity is somewhat higher than is usually necessary to produce complete suppression, this subject previously had been found to respond at approximately 10% of his unpunished rate when punished with 160V punishment on a 1 min VI schedule of food reinforcement.

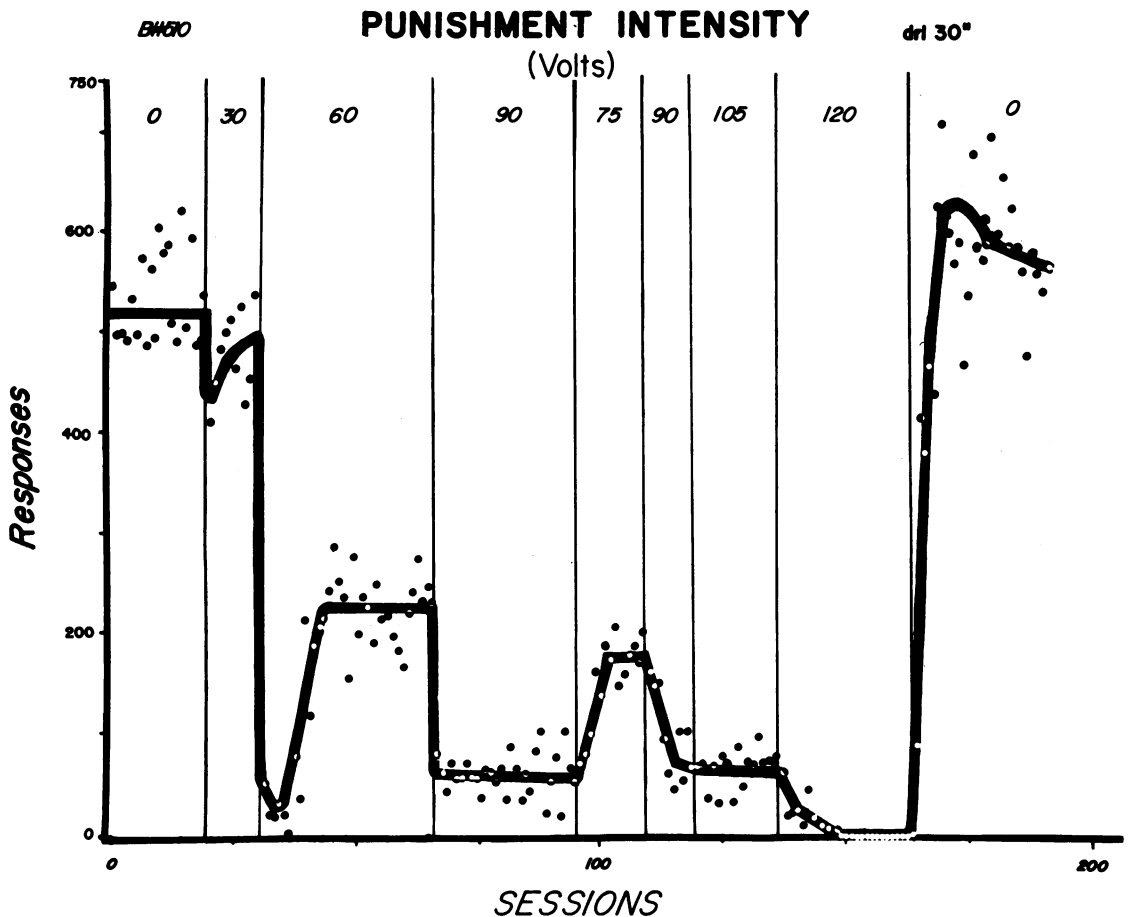


Fig. 2. Sequential changes in responding by a single subject following the introduction of different punishment intensities. Every response which occurred on the DRL 30-sec reinforcement schedule was punished with the shock intensity indicated. Each point represents the total number of responses emitted during a 1.5-hr session.

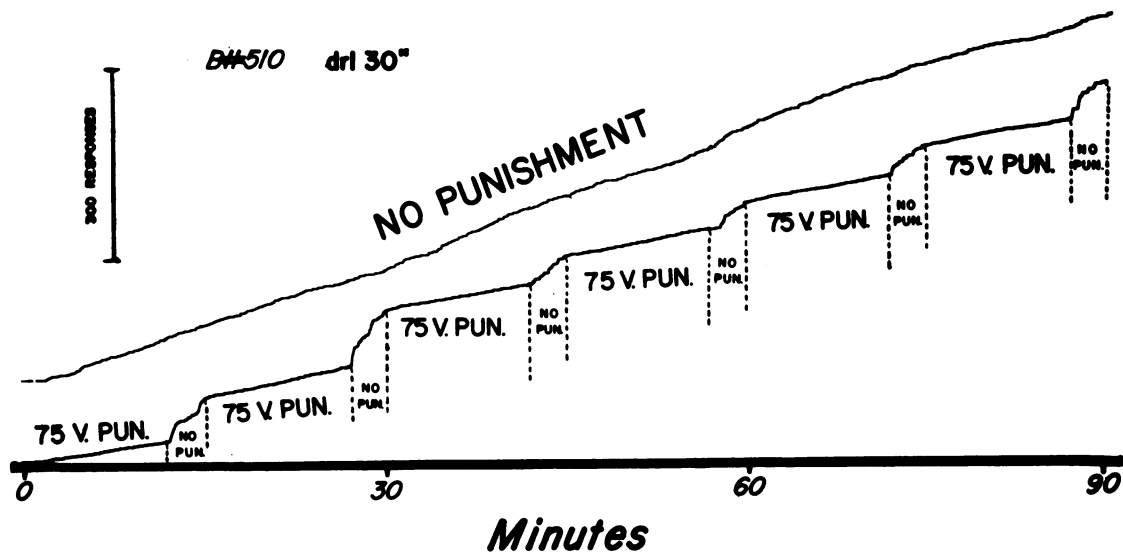


Fig. 3. Compensation: the increase in response which results upon the removal of punishment. The upper response curve is typical of the DRL 30-sec food responses prior to the introduction of punishment. The lower curve shows the effect of alternating 12-min periods of 75 volt punishment and 3-min periods of no-punishment. During the periods designated as punishment, the punishment was delivered for every response. Reinforcements are not indicated on these cumulative response curves.

#### *Sequential Changes in Response Frequency During Punishment*

Figure 2 illustrates typical sequential changes in responding which resulted as the intensity of the punishment was varied. Although the particular voltages necessary to produce the sequential changes varied somewhat from subject to subject, the intensities may be described in rather gross terms as "mild", "moderate", and "severe". The sequential changes observed with the DRL were similar to those found when punishment was applied to behavior maintained by other reinforcement schedules (*e.g.*, Azrin, 1960, Azrin and Holz, 1961). The following similar features may be noted. A moderate increase in the intensity of punishment at the lower intensities produced initial suppression below the stable level of responding which later resulted (recovery). This occurs at the 0 to 30V transition (Fig. 2) when the first session was the lowest observed at that intensity. Responding was greatly suppressed at the beginning of this session but considerable recovery had occurred before the end of that session. When the intensity was raised from 30V to 60V, great suppression existed for several days before responding partially recovered. On the other hand, a moderate increase in intensity at the

higher punishment intensities produced an immediate drop in responding to a lower level without subsequent recovery. This type of change may be seen at the 60V to 90V transition. A slight decrease in intensity led to a gradual, rather than abrupt, increase in responding to a higher level. This may be seen when the punishment intensity was lowered from 90V to 75V. A slight increase at the higher intensities led to a gradual, rather than abrupt, fall to a lower level. The transition from 75V to 90V for example, is quite different from the transition seen from 30V to 60V or from 60V to 90V. The complete removal of punishment (from 120V to 0V) led to an increased response rate which temporarily overshoot the prepunishment level (compensation). The day-to-day increase in responses after the punishment was terminated was due to a gradual decrease in the time required for responding to begin at the start of each session. Once responding commenced within each session, it continued at a relatively high rate.

The compensation phenomenon, noted above, seemed a rather unstable and tenuous result of punishment removal. This instability seems reasonable when one considers that the compensatory increase in responding completely removes the possibility of reinforce-

ment on the DRL schedule. The extinction which results from the high response rate would counteract the tendency for the rate to increase. In order to assess this phenomenon further, we arranged a procedure which had displayed compensation more vividly with other reinforcement schedules. First, responding was reduced to a fairly low level by punishment (75 volts was found to reduce the responding of B#510 to about one-third of the unpunished level). Next, punishment was removed for brief periods during these 75-volt punishment sessions. The results are illustrated in Fig. 3. In this figure, it is clear that the removal of punishment led to a response rate well above the prepunishment rate. Again the compensation phenomenon did not prove completely stable. Upon continued repetition of this procedure, the response rate during the no-punishment periods returned to the

"normal" no-punishment level after about four sessions (6 experimental hr). These results were replicated with B#83.

Figure 4 illustrates the stable intrasession response pattern found with several punishment intensities. Punishment reduced the response rate in a uniform manner; no disruptions of the temporal pattern of responses, such as might have resulted in short bursts and pauses occurred. Indeed, the short bursts of responses (see arrow), which were occasionally found in the absence of punishment, quickly disappeared, and were virtually nonexistent even with very low intensity punishment. A slight trend toward positive acceleration (recovery) within a session, which has been found with other reinforcement schedules, was apparent at the lower punishment intensities. This may be seen in the third curve down (60V) in Fig. 4, where many rein-

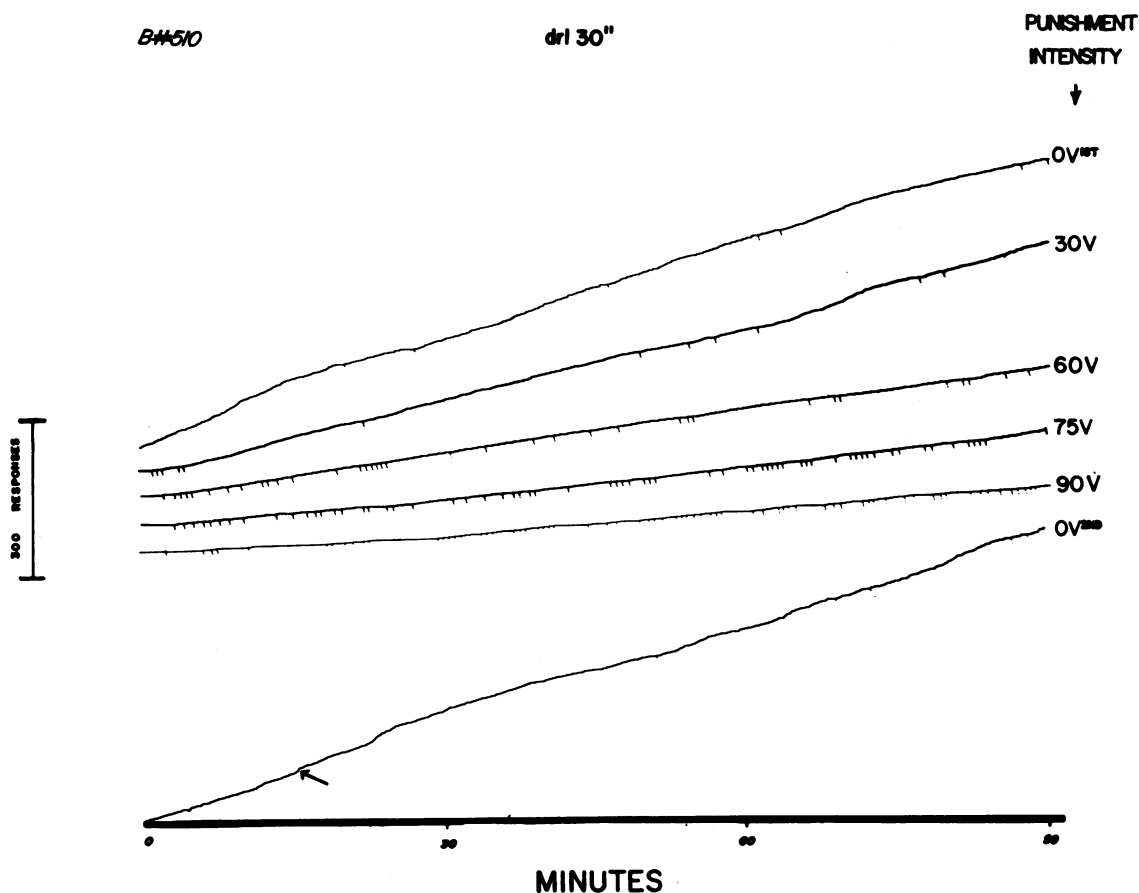


Fig. 4. Cumulative response curves under different punishment intensities. A DRL 30-sec reinforcement schedule was in effect at all times; reinforced responses are indicated by the diagonal lines on the curves. Every response was punished with the shock intensity indicated. The top curve (0v 1st) is a typical session prior to the introduction of punishment. The bottom curve (0v 2nd) is a typical session after punishment was discontinued.

forcements were received in the first part of the session. As the rate recovered fewer reinforcements occurred. The stable response pat-

tern after punishment was removed (see lowest curve, Fig. 4) was the same as before punishment was introduced.

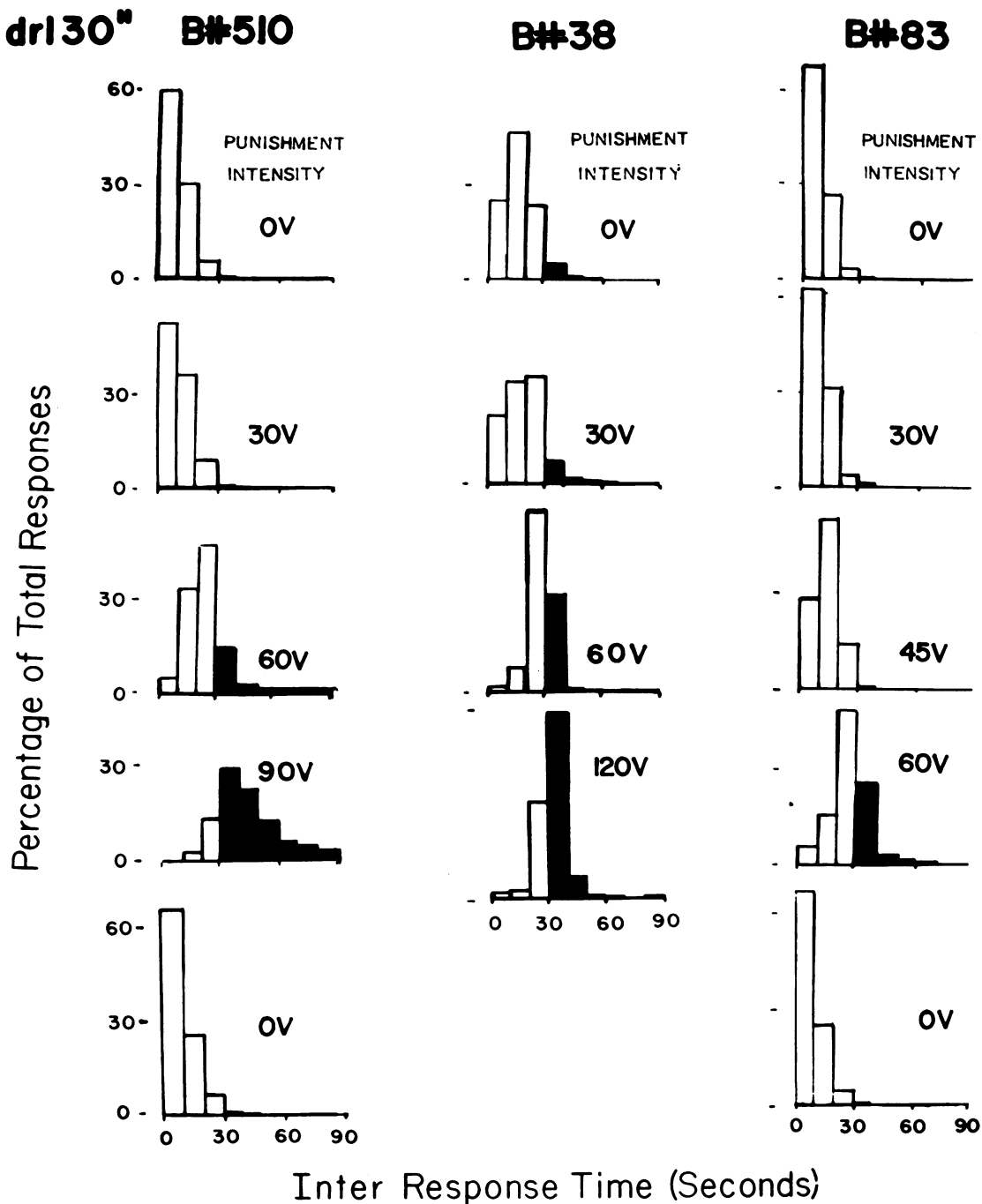


Fig. 5. The effect of punishment intensity on the inter-response times (IRT). Inter-response times are grouped into 10-sec class intervals, and relative frequency is given. IRT's which meet the DRL 30-sec reinforcement criterion are indicated by the black bars. The top and bottom distributions represent the stable performance before and after punishment, respectively. Illness and subsequent death of B#38 precluded redetermination of the no-punishment performance for this subject.

The recovery of the responses after punishment has special significance insofar as the possible irreversibility of the effects of punishment is concerned. As was seen above, punishment reduced the level of responding and as a consequence, increased the frequency of reinforcement. This low level of responses might have persisted even after punishment was removed, since a high frequency of reinforcement was associated with the response sequence of "waiting and then pecking". Any increase of responding (*i.e.*, a foreshortening of the waiting period) necessarily reduced the frequency of reinforcement. In spite of the opposing influence of reduced reinforcement, responding immediately increased after punishment was terminated, and the original DRL pattern recurred. Thus the effects of the prior history of punishment quickly disappeared even though the punishment had acted "in the best interest" of the subject.

*Changes in Inter-response Times During Punishment*

Figure 5 illustrates the detailed changes of the interresponse times during punishment. Punishment severely reduced the number of responses with extremely short inter-response time, and as a consequence, moved the median inter-response time to progressively longer durations. The displacement of the distribution to the longer inter-response times was continuous from the very low to the very high intensities. A shifting of the relative frequency distribution was apparent at the low punishment intensities (second row, Fig. 5) before there was a change in reinforcement frequency. When punishment was removed, the inter-response time distribution returned to the values found before punishment was introduced.

*Superstitious Chaining*

One subject, B#83, developed a peculiar pattern of behavior, while being studied in a later DRL experiment. This subject paced back and forth in the rear of the experimental chamber before each peck on the response key. This pattern of behavior was quite different from the pattern usually observed. The other subjects, and B#83 during his first 10 months on this reinforcement schedule, typically would stand relatively motionless in front of the response key before

making the pecking response. The behavior of pacing back and forth appeared to be a "superstitious" response chain, a result which has been reported with rats on the DRL sched-

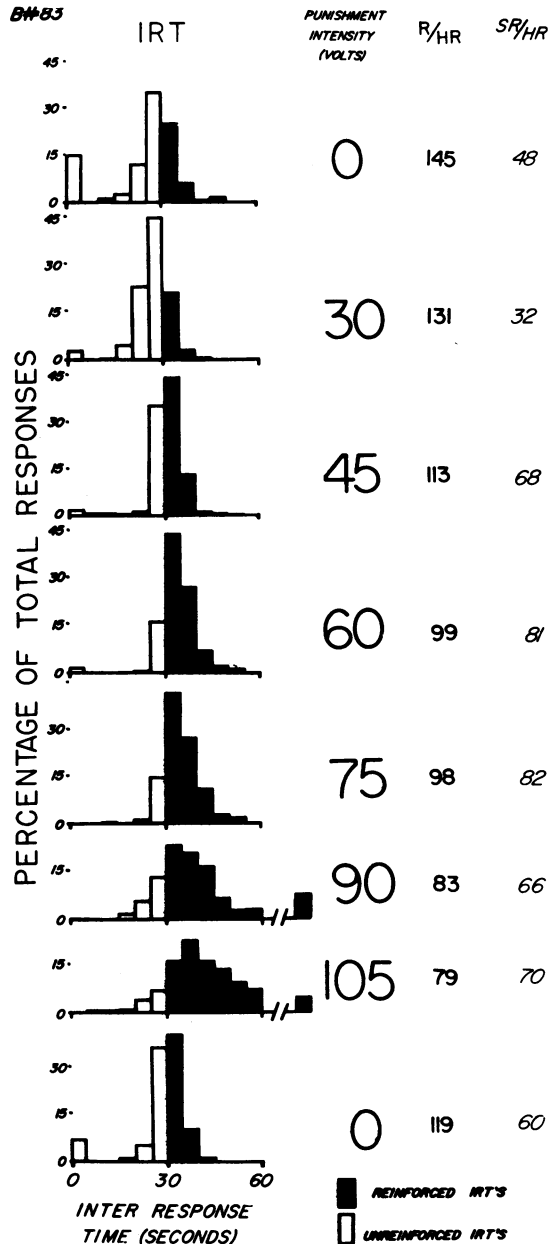


Fig. 6. Inter-response time distributions of one subject that developed a "superstitious chain" of behavior between successive responses. IRT's which meet the DRL reinforcement criterion are indicated by the black bars. The top and bottom distributions represent the stable DRL 30-sec performance before and after punishment. Each IRT distribution between shows the stable effects of a different punishment intensity.

ule (Wilson and Keller, 1953). The basis for the emergence of this response pattern could not be determined; however, a much more efficient DRL performance resulted. Before this pattern occurred, B#83 had a rate of about 8 responses per min, and less than 1% of these responses were reinforced. After this response chain developed, responses occurred at the rate of about 2 per min and over 30% of these responses were reinforced.

The IRT distribution of the pecking response for this "superstitious" performance is shown in the top graph (Ov.) of Fig. 6. A number of short IRT's occurred, but then response frequency remained low until shortly before the 30 sec period required for reinforcement, when many responses occurred. This distribution of inter-response times is quite different from those typical of pigeons (top graphs of Fig. 5), but actually is similar to those found with other species such as monkeys and rats (Conrad, Sidman, and Herrnstein, 1958).

Because this subject developed such an atypical response pattern, we attempted to replicate the previously noted effects of punishment with him. Punishment was introduced, and the intensity increased in the same manner as was reported in the preceding sections of this paper. The effect of several punishment intensities are shown in Fig. 6. It is clear that the basic effects of punishment which were observed when there was no superstitious behavior, also occurred when superstitious behavior was present. The short IRT's were maximally suppressed and the median IRT of the distribution was moved progressively to the longer intervals as the

intensity of the punishment was progressively increased. Responses were reduced as a direct function of punishment intensity. At progressively greater intensities of punishment, the reinforcements progressively increased, after an initial drop at 30V, and then fell to zero when responding was completely suppressed. Complete suppression resulted at a punishment intensity of 120 volts. Again, the effects of punishment were largely reversible. The fact that punishment has such similar effects in this case, where the unpunished IRT distribution is more typical of other species than it is of the pigeon, suggests that the findings may be general to the other species as well.

#### REFERENCES

- Azrin, N. H. A technique for delivering shock to pigeons. *J. exp. Anal. Behav.*, 1959, **2**, 161-163. (a)
- Azrin, N. H. Punishment and recovery during fixed-ratio performance. *J. exp. Anal. Behav.*, 1959, **2**, 301-305. (b)
- Azrin, N. H. Effects of punishment intensity during variable-interval reinforcement. *J. exp. Anal. Behav.*, 1960, **3**, 123-142.
- Azrin, N. H., and Holz, W. C. Punishment during fixed-interval reinforcement. *J. exp. Anal. Behav.*, 1961, **4**, 343-347.
- Conrad, D. C., Sidman, M., and Herrnstein, R. J. The effects of deprivation on temporally spaced responding. *J. exp. Anal. Behav.*, 1958, **1**, 59-65.
- Reynolds, G. S. and Catania, A. C. Behavioral contrast with fixed-interval and low-rate reinforcement. *J. exp. Anal. Behav.*, 1961, **4**, 383-386.
- Skinner, B. F. *The Behavior of Organisms*. New York: D. Appleton Century Co., 1938.
- Wilson, M. P. and Keller, F. S. On the selective reinforcement of spaced responses. *J. comp. Physiol. Psychol.*, 1953, **46**, 190-193.

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