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A COMPARISON OF SEVERAL PROCEDURES FOR ELIMINATING BEHAVIOR[1]

W. C. HOLZ[2] AND N. H. AZRIN

ANNA STATE HOSPITAL, ANNA, ILLINOIS

The pecking response of pigeons was reinforced when a minimum period of time had elapsed since the last response (DRL schedule of food-reinforcement). Punishment, satiation, extinction, and stimulus change were employed separately to reduce responding. When the effects of the four procedures were compared, punishment was found capable of producing a more immediate, complete and long lasting response reduction than the others. Punishment had its maximum effect on the responses that were least relevant to reinforcement. The punishment reduced the frequency of the short inter-response times to a greater extent than did either extinction or satiation. In this way, punishment actually increased the efficiency of the DRL responding.

Punishment, satiation, extinction, and stimulus change are four methods of reducing the frequency of an operant response. This experiment compares the effect of these four reductive procedures on responding which is maintained by a schedule that differentially reinforces low rates of response (DRL).

METHOD

Subjects

Four adult, male, White Carneaux pigeons were employed. Two of these subjects (B #510, B #83) completed all of the experimental procedures as described below. The other two subjects were used to replicate specific phases of the experiment.

Apparatus

The experimental chamber was 13 by 14 by 15 in. high. The subjects responded by pecking a .75 in. diameter plastic disc with a force of at least 12 g. A distinctive buzz, 40 msec in duration, provided feedback for each response. Reinforcement for the response consisted of 3 sec access to a grain mixture of 40% vetch, 50% Kaffir corn, and 10% hemp seed. This mixture also served as the subject's maintenance diet. Water and grit were always available in the home cages. Punishment was a 60 cps ac shock, .075 sec in duration, delivered through a 10,000 ohm resistor to electrodes implanted around the pubis bones of the pigeons (Azrin, 1959). Punishment intensity was regulated by a variable voltage transformer.

Procedure

All subjects were reinforced on a DRL 30 sec schedule: a response was reinforced if 30 sec or more had elapsed since the preceding response. Experimental sessions were 1.5 hr in duration and were provided daily. The subjects were exposed to the DRL reinforcement schedule for at least 60 hr (40 sessions) to assure stable performance before the experimental procedures were introduced. During this period, the subjects were maintained at 80% of their free-feeding body weight. The response rate was then manipulated by four experimental procedures.

(1) *Punishment.* During the punishment procedure, the responses were reinforced according to the DRL 30 sec schedule and body weight was held at 80% of free-feeding weight. Several intensities of punishment were employed so that several degrees of response reduction could be observed. Previous experience (Azrin, 1959, 1960) had shown that the sudden introduction of high intensity shocks (*i.e.*, in excess of 10 ma) usually resulted in complete, and potentially irreversible, elimination of responding. Since we were interested in assessing several levels of

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[2]Now at Harvard University.

Reprints may be obtained from W. C. Holz, Committee on Programmed Instruction, Harvard University, Cambridge 38, Mass.

response reduction, care was taken to increase the intensity of the punishment gradually. Low intensity shocks (15 to 30v) were used initially, and the intensity was increased only after performance had stabilized. At least eight sessions, and usually more, were provided at each of the intensity levels. With two subjects, (B #510, B #38) punishment intensity was increased until all responding had ceased for at least 10 days. With a third subject (B #83), punishment intensity was increased until a 75% reduction in responding resulted. Punishment was then discontinued.

(2) *Satiation*. During the satiation procedure, no punishment was given and the responses were reinforced according to the DRL 30 sec reinforcement schedule. The subjects were satiated by providing extra grain in their living cages after each session. The amount of extra grain was increased by small amounts, (about 2 g every fourth day for B #510, about 4 g every fourth day for B #83) until the amount was too great for the subject to consume during the 22.5-hr period between sessions. After at least 10 days of this free feeding, the amount of extra grain was reduced by small amounts. The subjects' weights were in this way again reduced to the original 80% level. The total cycle extended over a period of 6 months for B #510 and 4 months for B #83.

(3) *Extinction*. During the extinction procedure, no punishment was given and the weight of the subjects was maintained at 80% of free-feeding weight. The experimental sessions were conducted as usual, except that the food magazine was disconnected. After nine of these extinction sessions, the magazine was again connected.

(4) *Stimulus Change*. During the stimulus change procedure, no punishment was given. The body weight of the subjects was maintained at 80% of free-feeding weight and the food reinforcement was delivered as usual according to the DRL 30 sec schedule. Thirty minutes after the start of the session, illumination of the response key was changed from the usual white to a novel green. One hour later, the original white illumination was reinstated and the novel green light was terminated. The session was 2 hr in duration.

The order of the procedures varied from subject to subject. Before and after each procedure, at least 30 hr were allowed for stabilization on the basic schedule (DRL 30 sec, 80% body weight, no punishment). No effect of the sequence could be determined. The order of presentation for B #510 was: 1. conditioning and stabilization (75 sessions); 2. punishment (150 sessions); 3. stabilization (50 sessions); 4. satiation (140 sessions); 5. stabilization (30 sessions); 6. extinction (9 sessions); 7. stabilization (20 sessions). The effect of the novel stimulus was assessed after this. The order of presentation for B #83 was: 1. conditioning and stabilization (40 sessions); 2. extinction (9 sessions); 3. stabilization (25 sessions); 4. punishment (90 sessions); 5. stabilization (40 sessions); 6. satiation (100 sessions); 7. stabilization (20 sessions). B #38 was conditioned and allowed to stabilize for 75 sessions. This bird completed a sequence of punishment intensities (150 sessions) but subsequently became ill and died (cause unknown).

A fourth subject (B #119) was used to replicate specific aspects of the performance of the other subjects. The procedure followed for this subject was essentially an abbreviation of the procedure used with the others. B #119 was conditioned and allowed to stabilize for 40 sessions. His body weight was elevated and subsequently lowered by gross amounts (20-30 g at a time). The total satiation-deprivation cycle included approximately 75 sessions. The effect of a novel stimulus was assessed in one session and extinction was initiated two sessions later. Extinction was carried out in 10 successive sessions separated by only 5 min. Punishment was introduced five sessions later, and the punishment intensity was adjusted to display the performance at several levels of response reduction. The punishment cycle included approximately 20 sessions.

RESULTS

Changes in Response Rate

Figure 1 shows the response rates and inter-response time distributions during punishment, satiation, and extinction. The five rows show the performance at five levels of responding. The column of numbers on the right (changes in the rate) show that each of the three procedures effectively reduced responding.

Extinction had little immediate effect on responding. On the first day (not shown), re-

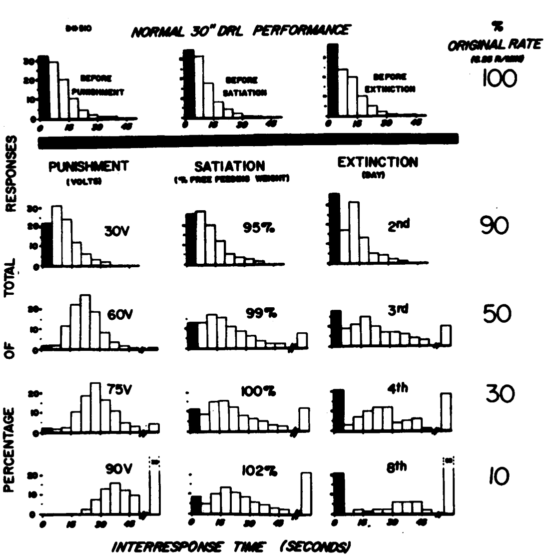

Fig. 1. The temporal distribution of responses during punishment, satiation, and extinction for one subject. Each distribution shows the relative frequency of responses in successive 5-sec intervals. The 0-5 sec interval is darkened. The top row shows the distributions before each of the reductive procedures was introduced. The distributions which resulted during each procedure are given in separate columns. In each row the rate of response was equal for each distribution. Rows are arranged from top to bottom according to decreasing rates of response; the column of numbers to the far right gives the rate of response as a percentage of the original rate.

sponding was the same as it had been during reinforcement. On the second day, responding still occurred at 90% of the original reinforced rate. However, responding then decreased more rapidly. The rate was reduced to 50% on the third day, and 30% on the fourth day. Thereafter, the extinction again increased slowly, reaching a level of 10% on the eighth day. By this time, spontaneous recovery at the beginning of each session accounted for the majority of the responses.

Nor did the satiation procedure immediately reduce the rate of response. Responding was reduced to 90% of the original rate only after the body weight of the subject was raised from 80 to 95% of the initial free-feeding level. It was necessary to raise the body weight to 99% before a response reduction of 50% occurred. Responding was down to 10% of the original level when the body weight was 102% and complete cessation of responding (not shown in this figure) occurred when the body weight reached 109%. Since the free-feeding body weight had been determined several months previously, it is not surprising that at this later date the body weight exceeded the previously determined weight by some slight amount (c.f. Ferster and Skinner, 1957, p. 366).

In contrast to satiation and extinction, the introduction of punishment produced an immediate reduction of responding. Even the mildest intensity of 30 V produced an initial suppression of 50%, even though responding ultimately recovered to the final level shown in Fig. 1, which was 90% of the pre-punishment rate. The recovery of responding is described in greater detail in a previous article (Holz, Azrin, and Ulrich, in press). The same immediate reduction in rate was observed each time the punishment intensity was increased by a sizable amount. At punishment intensities of 60, 75, and 90 V, the final response level was 50, 30, and 10%, respectively, of the original rate. An intensity of 120 V (not shown in this figure) reduced responding to zero.

The general results in Fig. 1 for the first subject were replicated with the other three subjects. See Fig. 2 for a detailed description of the results obtained from a second subject.

Figure 3 illustrates the effect of a novel stimulus upon response rate. At the end of

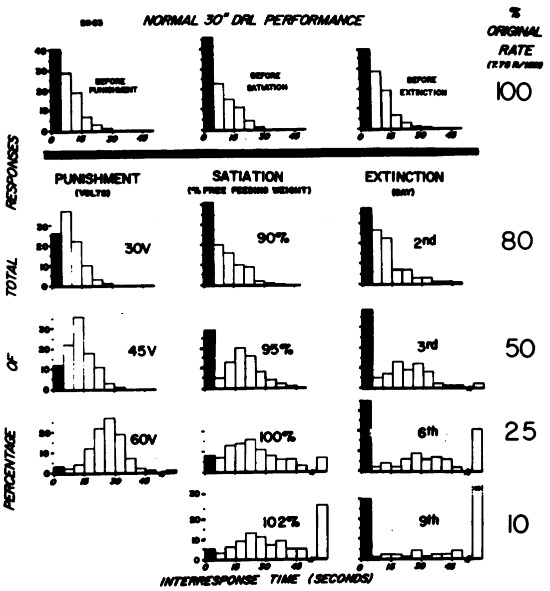

Fig. 2. Temporal distribution of responses during punishment, satiation, and extinction for a second subject. Same comments apply as in Fig. 1.

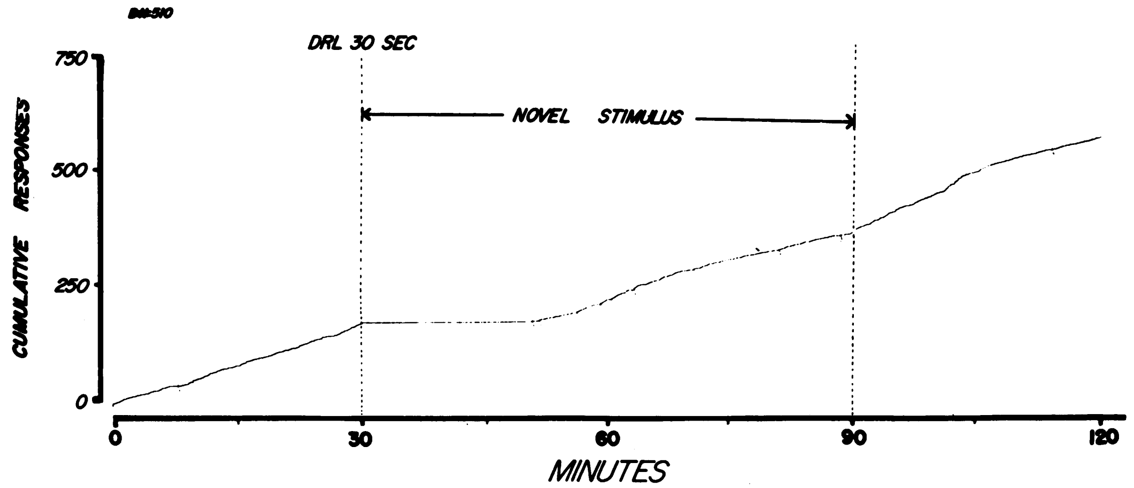

Fig. 3. Reduction of responding by stimulus change. A novel stimulus, green response key, was presented between minutes 30 and 90. The cumulative response curve shows the abrupt cessation, and later recovery, of responding. Downward deflections from the curve indicate reinforcements.

30 min, the illumination of the response disc was changed to green. Responding stopped abruptly. After about 20 min exposure to the novel stimulus, the first response occurred and was reinforced. This reinforcement reinstated responding and the previous pattern of response soon reappeared in the presence of this new stimulus. At the end of 90 min, the original illumination of the response disc was reinstated; responding continued at the normal rate. This procedure was conducted with two other subjects, and analogous results were obtained. For all three subjects responding stopped abruptly when the novel stimulus was introduced. The first response occurred within 1 hr and the normal response rate resulted shortly thereafter. Removal of the novel stimulus had no disruptive effect.

Changes in Inter-response Times (IRT)

The top row of Fig. 1 shows the IRT distributions that resulted when body weight was maintained at 80% of free-feeding weight, no punishment was given, and food was scheduled according to the 30 sec DRL procedure. It can be seen that the short IRTs occurred very frequently; the longer the IRT, the less frequently did it occur. Since reinforcement resulted only after the longer IRTs (> 30 sec), this pattern of responding was grossly inefficient: only about 1% of the responses were reinforced. The shorter and more inefficient IRTs predominated.

Each distribution in this top row shows the "normal DRL" performance just before the introduction of the reductive procedure in the column below. Each distribution is an average of five days of responding. The distribution shown above the satiation column was obtained following the punishment procedure. The distribution shown above the extinction column was obtained following the satiation procedure. The distribution above the punishment (Fig. 2) column was obtained following the extinction procedure. The similarity of the distributions in the top rows of both Fig. 1 and 2 shows that none of the three procedures produced irreversible effects. The average response rates, on which these distributions were based, did not differ by more than 5%.

Punishment produced an orderly change in the IRT distribution as may be seen in the first column of Fig. 1. The extremely short inter-response times were especially affected. At 30 V punishment intensity, the relative frequency of responses in the first cell (0-5 sec IRTs) was reduced by about 10% and accounted for most of the reduction in the overall rate. At an intensity of 60 V punishment, these extremely short IRTs were nearly eliminated whereas the overall reduction in rate was only 50%. As the intensity of the punishment increased, more of the short IRTs dropped out, resulting in a shifting of the mode of the distribution to the longer IRTs.

The satiation procedure did not affect these extremely short inter-response times as severely. When the body weight of the subject reached 102% of the free-feeding level, the overall response rate had been reduced to 10%; however, the percentage of IRTs in the first cell (0-5 sec) remained at 25% of their original level. During the successive stages of satiation, the IRTs tended to become uniformly distributed, without the exaggerated "peak" in the distribution found during punishment.

Extinction also produced a more uniform distribution of the IRTs. The principal difference was that the extremely short IRTs tended to remain at a high relative frequency. The slight reduction of total responses on day two of extinction did not lead to any decrement in the percentage of these short IRTs. When responding was decreased to 10% of its original level (day eight), the relative frequency of these short IRTs still exceeded 50% of the original value.

Figure 2 shows that comparable changes resulted with the second subject. Punishment greatly reduced the relative frequency of the very short IRTs, and produced a "peaked" distribution. Satiation did not affect the short IRTs as severely and led to a general flattening of the distributions. Extinction led to a high relative frequency of short IRTs and a similar flattening of the distributions. The other subjects (B #38 and B #119) showed these same effects on the procedures which they completed.

Stimulus change resulted in such rapid changes in response rate that analysis of IRTs was not feasible.

DISCUSSION

The extinction, satiation, and punishment procedures led to different IRT distributions when the overall rates of response were equated. The distributions that occurred during satiation and extinction were considerably flatter than the distributions resulting during punishment. Although knowledge of the factors influencing DRL responding is admittedly limited, a possible explanation of these differences can be suggested. These differences may have resulted from changes in the IRT-reinforcement relationship and the effectiveness of the reinforcer, *i.e.*, the degree to which the food will maintain responses. A minimum duration between responses (IRTs) is necessary for DRL reinforcement. But, the number of reinforcements will be reduced if very long IRTs emerge. Thus, the number of very long IRTs could be expected to be minimized because of the decrease in the number of reinforcements per hour that would otherwise result (Anger, 1956). However, satiation reduces the very effectiveness of food as a reinforcer of responses; thereby the longer IRTs may emerge. Extinction results in a loss of the IRT-reinforcement relationship, because no responses are reinforced, regardless of the duration between responses. Again, long IRTs may be expected because reinforcements per hour no longer exert control. The emergence of long IRTs during satiation and extinction may thus be responsible for the flattened appearance of the IRT distribution. During the punishment procedure, the food retained its effectiveness as a reinforcer and the IRT-reinforcement relationship remained in effect. Thus, the lengthier IRTs were still kept at a minimum and no flattening of the distribution resulted.

A second problem exists in accounting for the more rapid reduction of short IRTs by punishment. This reduction appears to be accounted for on the basis of an interaction between punishment and rate of reinforcement. Extremely short IRTs are never reinforced, and indeed, serve only to delay the occurrence of reinforcement. Since their elimination does not reduce the rate of reinforcement, they appear to be relatively more sensitive to punishment. In general then, the punishment appeared to produce a temporal pattern of responding that minimized the reduction of reinforcement while allowing a large reduction of punishments. This reduction of short IRTs led to a much more efficient pattern of response on the DRL schedule.

A point to be considered is that extinction led to a high incidence of response burst (short IRTs). Sidman (1956) found that the probability of a burst on the DRL schedule increases as a function of the time since the preceding response. That is to say the probability of a burst was low following short IRTs, but became higher at the longer IRTs. This relationship held until the reinforced IRTs were reached. But for IRTs exceeding the minimum DRL requirement, the probability of a burst was again low. With the DRL schedule, reinforcement follows the responses which meet the minimum IRT criterion. The occurrence of the reinforcer would serve to interrupt any potential burst following these responses. The interruption may be responsible for the low probability of a burst following long IRTs. Since the extinction procedure prevents such an interruption, the basis for the low probability of burst at the longer IRTs is removed. The high incidence of bursts during extinction, therefore, may represent a continuation of the relationship between IRT duration and probability of a burst.

The preceding discussion compared punishment, satiation, and extinction with respect to the differences in the IRT distributions. For purposes of that discussion the IRT distributions for each procedure were examined at overall rates of response that were equated for the three procedures. However, the overall rate was also altered in a manner that was distinctive for each procedure. Let us now analyze the three procedures as well as the procedure of stimulus change in terms of the degree to which responding was eliminated. The criteria for response elimination to be used will be whether a procedure: 1) reduces the response rate immediately upon the introduction of that procedure, 2) reduces the responses for as long as the procedure is in effect, 3) reduces the response rate to zero while the procedure is in effect, and 4) maintains the response reduction after the procedure is discontinued. These four criteria are used to evaluate each of the reduction procedures. Table 1 summarizes this evaluation when extreme values of each procedure are considered. In addition to the data of this experiment, we shall draw upon the results of other experiments. The current experiment has the advantage of comparing the performance of the same organisms while constant associated procedures were maintained. However, other experiments show the generality of the phenomena and provide additional information on the effects of the procedures.

Consider stimulus change as a means of eliminating responses. If the degree of stimulus change is great, then the responses are reduced immediately upon the introduction of the novel stimulus. As seen in Fig. 3, however, this reduction does not endure. As soon as a few responses were reinforced during the novel stimulus, complete recovery resulted. The inevitability of this recovery has necessitated the concurrent use of the extinction procedure in studies of novel stimuli (Guttman and Kalish, 1956). The effect of stimulus change alone has typically been transient even when such extreme changes have been used as the repeated delivery of intense, but unavoidable shocks (Azrin, 1956). Stimulus change then produces no lasting response reduction either during or after the use of a novel stimulus.

The satiation procedure appears to be more desirable than stimulus change as a method of eliminating responses. Like stimulus change, satiation reduced responding immediately upon introduction of the procedure. In the present study, a reduction of responses typically resulted on the very first day after the daily ration was increased by a large amount. Common laboratory observation has repeatedly confirmed this immediate reduction of response when a subject has been accidentally overfed. Skinner (1938, Fig. 140, 141) also noted an immediate reduction of responses following pre-feeding of a food-reinforced subject, although extensive training on a VI schedule has been found to attenuate this reduction (Ferster and Skinner, 1957, Fig. 448 and 450). When satiation has been continued, the response reduction endures for as long as the satiation procedure remains in effect (second column, Fig. 1 and 2; also

Table 1
A comparison of several procedures which reduce response rate

Procedure	*Immediate Effect*	*Enduring Effect*	*Complete Suppression*	*Irreversible Effect*
Stimulus Change	Yes	No	No	No
Extinction	No	Yes	No	No
Satiation	Yes	Yes	No	No
Physical Restraint	Yes	Yes	Yes	No
Punishment	Yes	Yes	Yes	Yes

Skinner, 1938, Fig. 144). However, satiation does not seem to produce a zero rate (Skinner, 1938, Fig. 144) unless the responses had a zero unconditioned level. Nor does the effect of satiation endure after the satiation procedure is discontinued. The response rate typically recovers quickly and completely when deprivation is resumed. (Top distribution third column, Fig. 1; also Skinner, 1938, Fig. 139.) Satiation and stimulus change both reduce responses immediately, but satiation will maintain this reduction as long as the satiation is in effect. Neither procedure will maintain the responses at a zero level; nor will either procedure maintain a response reduction after the procedure is terminated.

Extinction appears to be very similar to satiation in terms of its overall effectiveness. Like satiation, extinction reduces responses for as long as the procedure is in effect (column 3, Fig. 1; also Skinner, 1938, Fig. 7). Indeed, the extent of reduction by extinction increases as the extinction procedure is continued. Extinction also resembles satiation in that both procedures produce very low rates that never reach zero unless there existed a zero operant level prior to conditioning. Typically, extinction will not produce a reduction of responses to the operant level because of the phenomenon of "spontaneous recovery" of responses at the start of each session (Skinner, 1938, Fig. 9). The extinction procedure also resembles satiation in not maintaining response reduction after the procedure is terminated. Just as responding resumes completely after the subject is again deprived of the food reinforcement, so does reconditioning produce complete and often immediate recovery once a few reinforcements have been obtained (top distribution column 1 of Fig. 2; also Skinner, 1938, Fig. 10). Presumably, the response reduction could endure indefinitely after extinction was terminated if a zero operant level existed and if extinction were carried out for a long period. No such instance appears to have been reported. It is in terms of the immediacy of response reduction that extinction appears to be inferior to satiation. As was noted above satiation produced an immediate reduction of responses. In contrast, extinction produces no discernible reduction of responses during the initial moments of the extinction procedure. When extinction is introduced after intermittent reinforcement, thousands of responses may occur prior to any substantial response reduction (Skinner, 1950, Fig. 10). In the present study, for example, the overall rate on the day prior to extinction was 7.8 responses per minute; during the first day of extinction (1.5 hr) the rate was 8.0 per min. Even when extinction is most rapid—after continuous reinforcement—many responses have occurred following the initial introduction of extinction (Skinner, 1938, Fig. 7). Extinction appears to be potentially as effective as satiation in reducing responses but suffers mainly from the delay in achieving its effect.

As a method of eliminating responses, punishment appears to be potentially more effective than either stimulus change, satiation, or extinction. At low intensities, punishment offers only the advantage of immediacy of effectiveness. The response rate does not reach a zero level, nor is the reduction enduring. Inspection of the cumulative records in the present study revealed an immediate reduction of responses upon the initial introduction, or increase in intensity, of punishment. The immediacy of this reduction has been noted at all punishment intensities if the punishment was at all effective (Holz, Azrin, and Ulrich, in press). At very high punishment intensities, only a few responses have been emitted before the response level was reduced to zero (Azrin, 1959; Masserman, 1946; Appel, 1961). In our experience, this absolute elimination of responses occurs even when there was an unconditioned level of responding (see also Baron and Antonitis, 1961). At moderately severe punishment intensities, the responses remain near a zero level for as long as the punishment procedure is in effect (Azrin, 1960). At very severe intensities, the complete reduction of responses prevents the subject from ever discriminating when the punishment has been removed. Hence, the punishment procedure differs from satiation, stimulus change and extinction in producing a response reduction that endures even after the reductive procedure has been terminated. This irreversibility of the effects of punishment occurs at high intensities of punishment. At lower intensities, as seen previously, the effects of punishment are quite reversible. In our continuing studies of punishment, the shock stimulator setting has occasionally been placed at a high level (say, 20 ma) for a subject that has never before received shock-punishment. In every such instance, the responses have ceased completely after one or two punishments have been received and have not recovered even though the punishment was immediately discontinued. Under these circumstances, the effect of punishment was so great as to generalize to the behavior of eating from the food reinforcement magazine. It has been necessary to recondition the response by manual shaping. Because of the suppression of the behavior of eating from the food magazine, this reshaping has required more time and a higher food deprivation level than the initial shaping. Because of this continuing possibility of complete suppression, great care is taken customarily to introduce punishment at a low intensity and to increase its intensity in gradual stages as was done in the present study.

Punishment appears to be capable of reducing responses to an extent, and with a speed and degree of irreversibility, that is unmatched by either stimulus change, satiation, or extinction. Of course, these four procedures do not exhaust the methods available for eliminating responses. The simplest method of all is a fifth procedure: physically preventing the occurrence of the response. In the present study, this physical restraint existed between each session when the subject was removed from the experimental chamber. Clearly, this procedure was as effective as punishment in the immediacy, degree, and duration of response reduction. However, the response reduction did not persist when the subject was returned to the chamber for the next session. Even after extremely long periods of physical removal (4 yr) the rate resumed unabated (Skinner, 1950, Fig. 2).

In the present experiment the various reductive procedures were based upon the use of a DRL schedule of reinforcement for maintaining the responses. However, the overall conclusions reached about the relative effectiveness of each of the reductive procedures appear to be generally applicable to responses maintained by other reinforcement schedules as well.

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