*A CHOICE TECHNIQUE TO ASSESS THE
EFFECTS OF SELECTIVE PUNISHMENT
ON FIXED-RATIO PERFORMANCE¹*

M. C. DAVISON

UNIVERSITY OF AUCKLAND, NEW ZEALAND

The emission of a fixed number of responses by rats was followed by food reinforcement. This fixed number could be accumulated in any way from two continuously available but mutually incompatible response classes, bar pressing, and not bar pressing for a fixed time period. A preference for one response class was arranged by specifying different maximum reinforcement rates for the two classes. Under selective punishment conditions, the preferred response occasionally led to both food and electric shock, while the non-preferred response led only to food. Selective punishment effects were measured through changes in the preference to the two responses in the sequence. The actions of shock intensity, deprivation, the specification of the non-preferred response, and three drugs were investigated. The results were broadly similar to the work reported by Dardano and Sauerbrunn (1964), who found localized increases in interresponse times before punished responses in fixed-ratio schedules. Performance under this procedure was found to be stable and sensitive to each of the experimental variables examined.

In a fixed-ratio (FR) schedule, the emission of a fixed number of responses is followed by reinforcement. A number of experiments have investigated the effect of punishing one ordinal response in the FR sequence (Dardano and Sauerbrunn, 1964; DeArmond-Edwards, 1966; Donahoe and Schulte, 1967; Richardson and Donahoe, 1967; Davison, 1968). These workers reported that when punishment (electric shock) was contingent upon the terminal response of the ratio (the reinforced response), increases in interresponse times occurred just before the punished response.

Selective punishment techniques are not generally satisfactory for parametric investigations of the variables controlling punishment effects. If animals are trained at a number of shock intensities and deprivation levels (without causing responding to cease), difficulties occur in replicating quantitative measures of responding within each animal (Davison, 1968). If the shock intensity is raised so that responding ceases, food reinforcement is no longer obtained and the effects of punishment must be measured in extinction. Many problems arise in analyzing data from such rapidly changing behavioral baselines (Sidman, 1960).

The present experiment investigated a method of stabilizing behavior under selective punishment procedures. The method used was a variant of the alternative response technique described by Herman and Azrin (1964) and Azrin and Holz (1966). An alternative and incompatible response was made available to rats bar pressing on a short FR schedule in which the terminal response was punished. The alternative response (not bar pressing for a fixed time period) counted towards the same FR schedule as the bar-press response. If the alternative response was emitted as the final response of the ratio, reinforcement was delivered without punishment. It was arranged that the maximum reinforcement rate for the alternative response was lower than for the bar-press response, leading to a preference for the bar-press response (Herrnstein, 1964). The present study was a preliminary investigation of the effects of deprivation, shock intensity, changes in the specification of the alternative response, and three drugs on performance under these conditions.

METHOD

Subjects

Thirteen naive albino rats served. Nine were female and, except where explicitly stated, were maintained at 80% of their free-feeding body weights. They were numbered

¹This study was carried out at the University of Otago, New Zealand. The author thanks Beverly Barron for her assistance. Reprints may be obtained from the author, Department of Psychology, University of Auckland, Private Bag, Auckland, New Zealand.

12, 17, 19, 20, 21, 22, 23, 24, and 25. Males (numbered 1, 2, 3, and 4) were maintained at 70% of their normal body weights following some difficulties in magazine training at an 80% deprivation level. All were 3 to 4 months old at the beginning of the experiment.

Apparatus

Grason-Stadler relay circuitry, which controlled the experimental contingencies, was situated remote from the soundproofed and ventilated chamber. The chamber (Grason-Stadler E3125D) contained two response levers (only one was operative) and a light to illuminate the chamber. A relay inside the soundproofed box could be used to provide feedback for response completion.

Data from experimental sessions, which were conducted six days per week, were collected on cumulative and event recorders and on a battery of impulse counters.

Reinforcement consisted of 3-sec access to a dipper containing 0.1 ml of a 50% mixture of sweetened condensed milk and water, and each session was terminated after 100 reinforcements. When necessary, subsidiary feeding was given immediately after training sessions. Punishment, when scheduled, was 0.1-sec exposure to scrambled footshock supplied by a Grason-Stadler E1064GS shock generator. Shock intensities are reported as nominal settings on the shock generator.

Procedure

After dipper training and shaping to bar press, the animals were given one training session in which every response was followed by food reinforcement. They were then trained on an FR 10 bar-pressing schedule until total session times were roughly constant. An alternative response class was then introduced. In this, the no bar press for a period of 5 sec counted as a response towards the same FR requirement. Completion of this contingency, which constitutes a DRO requirement (differential reinforcement of other behavior: Reynolds, 1961), was signalled by a click of the relay in the experimental chamber. This alternative response class, which was incompatible with bar pressing, was available at all times. The clock controlling the DRO requirement did not run during food reinforcement. Thus, the animal could complete the ratio requirement either by emitting 10 bar presses, or by

not bar pressing for 50 sec, or by any sequence of bar presses and DRO responses totalling 10.

This procedure presents the animal with a sequence of 10 options (Findley, 1962) between emitting bar presses and DRO responses. With the parameters given above, the maximum overall rate of reinforcement if the DRO response is exclusively chosen is 72 per hr. If the bar press is exclusively chosen, the maximum rate of reinforcement, while unspecified in advance, should be considerably higher. Since preference is, in part, a function of reinforcement rate (Herrnstein, 1964), the bar press would be expected to be chosen under these conditions.

Punishment Procedure

Selective punishment was introduced into the bar-press sequence by allowing the tenth option to produce both food and shock if it was completed by a bar press, and food only if it was completed by a DRO response. Responses emitted in options before the tenth had no effect on the production of punishment.

Punishment was introduced at a low intensity and gradually increased over sessions until the number of bar presses made in a session was greatly decreased. The shock intensity was maintained at this level until a stable performance had developed in which the overall bar-pressing rate was quite high but few shocks were delivered.

When the performance was stable, the probability of emission of the DRO response in each successive option was increased. In the present experiments, the effects of a number of independent variables were investigated: shock intensity (animals 17, 19, 20, 22); deprivation (18, 21, 23); length of time necessary to complete the DRO contingency (12); and subcutaneous injection of *d*-amphetamine sulfate (2,3), sodium amobarbital (25), and sodium pentobarbital (1, 4, 24). Experimental contingencies were changed, and drug injections administered, only when performance appeared stable to the eye. For most changes in procedure, stability was achieved in 15 to 35 sessions.

Drug injections were given subcutaneously (intrascapularly) 30 min before the experimental session commenced. Amounts of drug injected are reported as the weight of the drug proportional to the animal's deprived body

weight. In control sessions, 0.1 ml of isotonic saline per 100-g body weight was injected, and this volume was not exceeded in drug sessions. At least six sessions of normal training intervened between each drug or saline session.

RESULTS

Shock Intensity

Four animals were used to investigate the effects of shock intensity in the selective pun-

Fig. 1. Effects of various shock intensities on choice between DRO 5-sec and FR 1 bar-press responses in 10 successive options. Shock and food reinforcement were delivered in the tenth option if this was completed by a bar press. Food reinforcement only was delivered if the tenth option was completed by a DRO response. The graphs should be read from left to right, top to bottom, and results from each animal are shown in the order they were obtained. The data are median values from the final five sessions under each shock intensity.

ishment of FR performance. In the absence of shock (0 ma, Fig. 1) the probability of emission of the DRO response was normally zero in all options except the first and, occasionally, the second. These differentially high probabilities of DRO choice are clearly associated with the usual pause-after-reinforcement in FR performance. Beyond options 1 and 2, the expectation that the different maximum reinforcement rates for the two responses would lead to a preference for the bar press is borne out.

In all four animals studied under varying shock intensities, the effects of selectively punishing the bar response in the terminal option was to produce increased probabilities of DRO response choice toward the end of the sequence of options (Fig. 1). Higher shock intensities reliably produced greater probabilities of completing the DRO requirement in the terminal option and also led to increased DRO response preference in preceding options. For two animals (19, 20), increasing shock intensities also produced increases in the preference for the DRO response in the initial two options.

Figure 1 shows also that performance under low shock intensities (and in the absence of shock) could be recovered after exposure to higher shock intensities. There were, however, some "behavioral inertia" effects (Hake, Azrin, and Oxford, 1967) in which performance lagged behind small shock-intensity changes. This is illustrated in the comparison of the performance of animal 22 at 0.5-ma shock intensity after exposure to 0.4 ma and to 0.6 ma (Fig. 1).

When shock was no longer contingent upon a bar press in the tenth option, performance returned to the baseline no-shock values in 6 to 10 sessions. Figure 2 presents typical data from the first five sessions in the absence of shock for one of the three animals studied under these conditions.

The performance of the four animals serving under the varying shock-intensity conditions was further analyzed to demonstrate the fine grain of the behavior maintained by the present procedure. Two measures were derived from event recordings. The first was the probability of occurrence, at each successive option, of the final bar press before reinforcement. The second was the probability in each option of the final bar press of an unbroken

Fig. 2. Effects of removal of shock contingent upon a bar press in the tenth option. The initial graph shows median values from the final five sessions under 0.8-ma shock. The subsequent graphs show performance in the first five sessions after shock was removed.

run of bar presses initiated in options 1 or 2. These measures co-varied very closely (Fig. 3), indicating that the performance normally consisted of an unbroken run of bar presses followed by an unbroken run of DRO responses.

Deprivation

The study of deprivation effects was initially carried out using pre-feeding techniques,

Fig. 3. The conditional probability, for each successive option, of the emission of the final bar press in the FR 10 sequence of options (circles) compared with the conditional probability of emission of the final bar press of an unbroken run of bar presses initiated in options 1 or 2 (triangles). The data shown for each animal are from a single session of stable performance. For the various animals, between 2% and 10% of the FR runs showed no bar presses in options 1 or 2, and these data have been disregarded.

but this gave extremely variable results that were not easily replicated. Since stable behavior under selective punishment was a goal of the present research, the procedure was changed to one using different maintained body weights. The three animals serving in this part of the experiment were trained under a fixed shock intensity and DRO requirement at various percentages of their normal body weights until performance at each level was stable. Session lengths remained the same (100 reinforcements) and body-weight increases were maintained through supplementary feeding. The results (Fig. 4) show that small body-weight increases produce a selectively greater probability of DRO responses both close to the punished option and in the initial two options. Further increases make

Fig. 4. Probabilities of choosing the DRO response in successive options at various percentages of the free-feeding body weights determined before experimentation began. The data are medians from the final five sessions of stable performance. The graphs should be read from left to right, top to bottom, and results for each animal are shown in the order that they were obtained.

DRO response choice more likely in all options, but the selective effects at the beginning and end of the sequence appear to remain until bar pressing is eliminated.

DRO Requirement

One animal was used to examine the effects on differing DRO requirements on performance under selective punishment. The DRO values used were 3, 5, and 7.5 sec, and the sequence of exposure to these intervals was different for each of the three shock intensities used (0.25, 0.3, and 0.4 ma in that order of exposure). Data from this animal are shown in Fig. 5. The performance is apparently sensitive to changes in the DRO requirement in much the same way as it is sensitive to shock: both higher shock intensities and lower DRO requirements increase the probability of DRO responses in both the initial and terminal options. However, in the absence of certain controls, it is not clear whether the effect was due to differences in measurement criteria or to actual changes in behavior. The performance at 0.4 ma DRO 7.5-sec appears inconsistent in comparison with that at 0.4 ma DRO 5-sec, and may suggest some limitations on the use of the DRO requirement variable. The apparent loss of control at this shock intensity under DRO 7.5-sec was probably due to a particularly low reinforcement rate. Median ses-

Fig. 5. Probabilities of choosing the DRO response in successive options under three DRO requirements and three intensities of selective punishment. The data are median values from the final five sessions of stable performance under each combination of parameters.

sion time under DRO 5-sec was 34 min. Under DRO 7.5-sec, this increased to 52 min.

Removal of DRO Option

After exposure to a variety of experimental procedures, the performance of four animals (1, 2, 4, and 18) was studied when the DRO response choice was removed. Under these conditions, 10 bar presses produced both reinforcement and punishment; the procedure thus becomes the selective punishment of FR performance (Dardano and Sauerbrunn, 1964). Pauses longer than 5 sec (the previous DRO value in all cases) were measured before each successive bar press in the performance.

The elimination of the DRO choice led to two different results. For three of the animals (1, 0.6 ma; 2, 1.0 ma; 4, 0.6 ma) this led to a high rate of bar pressing with little or no pausing before any response in the ratio except the first. Overall response rates were, however, lower than in the absence of shock. For one of the animals (18, 0.6 ma) bar pressing was eliminated and the performance extinguished.

Drug Effects

Six animals were used to study the effects of various dosages of sodium amobarbital, sodium pentobarbital, and *d*-amphetamine sulfate on performance under selective punishment. The order of dosages was randomized in each animal. The results shown (Fig. 6) are typical, except in the case of amobarbital for which only one animal was used. Performance after saline injection was, in all cases, similar to baseline performance in the absence of any injection, and therefore only performances under saline are shown as controls.

Amobarbital and pentobarbital appeared to have similar effects on performance, although the amobarbital effects were not as clear. High dosages of both drugs non-specifically disrupted performance. Moderate dosages (11 mg/kg for amobarbital; 5 mg/kg for pentobarbital) decreased the probability of completing the DRO requirement in the initial and terminal options. Smaller dosages had no effect on performance. High dosages of amphetamine produced consistent choice of the DRO response in all options, but lower doses selectively increased the high probabilities of DRO choice before the punished option with no effects on the initial options. The magni-

tude of the drug effects was clearly dose-related.

Following these experimental determinations of amphetamine effects, performance under this drug at these and higher dosages was investigated with the animals being observed by the experimenter. It was found that under 1.0 mg/kg amphetamine, the animals were taking food reinforcement when it was pre-

Fig. 6. Probability of choosing the DRO response in successive options for three animals after various dosages of sodium amobarbital, sodium pentobarbital, and *d*-amphetamine sulfate. The data are from single experimental sessions. Each animal was exposed to a randomized order of dosages.

sented. Between reinforcements they would show a great deal of activity near the bar, even touching the bar without depressing it. At dosages around 1.5 mg/kg, food-taking ceased and the animals showed stereotyped behaviors in various parts of the experimental chamber. These informal observations indicate that the cessation of bar pressing found under 0.8 and 1.0 mg/kg amphetamine was not due to amphetamine's known depressant effect on food consumption (Cole, 1967).

None of the three drugs investigated produced irreversible effects on behavior and typical no-drug performance was found in the first and subsequent sessions after each drug session.

DISCUSSION

Under a selective punishment procedure, provision of an alternative response that is not punished, but which leads to a lower rate of reinforcement, gives a stable baseline performance that is sensitive to the action of a variety of experimental variables. The present study showed that shock-intensity effects under this procedure were replicable within individual animals. The results were broadly similar to previous studies of the effects of selective punishment of FR performance (Dardano and Sauerbrunn, 1964; DeArmond-Edwards, 1966; Donahoe and Schulte, 1967; Richardson and Donahoe, 1967; Davison, 1968). The present procedure, by providing reinforcement when the punished response was not emitted, amplified the punishment effects and greatly facilitated the measurement of these effects.

Previous studies by Herman and Azrin (1964) and Azrin and Holz (1966), concerned with the effects of punishment in FR performance with an alternative response available, showed that once a certain punishment intensity was reached, choice very rapidly switched to the previously non-preferred response. These investigators used continuous (FR 1) punishment, and the potential reinforcement rates for the two responses were identical. The present technique, in which a lower reinforcement rate was available for the alternative response, led to graded rather than all-or-none punishment effects.

Behavior under the present procedure was well-controlled by the two response contingencies involved. The performance normally was

composed of an unbroken series of bar presses followed by an unbroken series of DRO responses (Fig. 3). This analysis shows that the localized high probabilities of DRO responses in the terminal options under punishment are not merely the result of selective decreases in the local rate of bar pressing. If this were the case, few unbroken runs of both bar presses and DRO responses would be expected. The term *choice*, implying some control by both appetitive alternatives, is thus justified. The degree of DRO choice in the terminal options is due to the modification of appetitive preference by punishment. Appropriate control by the DRO contingency under selective punishment is also demonstrated by performance changing markedly when this contingency is removed.

Amobarbital and pentobarbital had similar effects on performance under selective punishment, decreasing (at moderate dosages) the effects of shock on choice in the sequence of options. This result is consistent with previous work showing that barbiturates increase the rate of punished behavior (Morse, 1964; Hanson, Witoslawski, and Campbell, 1967). Amphetamines, which in the present experiment enhanced the effects of shock on choice, have been found to decrease the rate of punished behavior (Geller and Siefert, 1960; Hanson *et al.*, 1967) and to increase the rate of avoidance behavior (Cole, 1967).

The present experiment had similarities, both in procedure and in results, with experiments on approach-avoidance conflict described by Miller (1944; 1959). The effects of shock intensity and deprivation on conflict in the straight runway are very similar to the effects of these variables in the selective punishment procedure reported here. Investigations of drug effects on conflict using variants of the straight runway procedure ("telescope alley", "automated conflict test") by Miller (1961), Barry and Miller (1962), and Barry, Wagner, and Miller (1963) showed that animals performing under amobarbital consistently took higher shock intensities than under saline control conditions. The latter two studies also examined the action of methamphetamine, but no clear effects of this drug were found.

In the absence of shock, substantial DRO probabilities were found in the first, and occasionally the second, option. These values were increased by higher intensities of selective

punishment and by higher body weights. Both of these effects may be predicted from previous studies. Dardano and Sauerbrunn (1964) reported that higher intensities of terminal response selective punishment increased the mean FR pause-after-reinforcement. Similarly, Sidman and Stebbins (1954) showed that body weight increases also lengthened the pause-after-reinforcement in FR performance without affecting the rate of responding in the terminal run. This finding acts as a control for the effects of body weight increases on performance under the present procedure. It suggests that a decrease in deprivation level would not produce high probabilities of DRO choice in the terminal options in the absence of punishment. Shorter DRO requirements also gave higher DRO probabilities in the initial options, but no data are presently available to indicate whether any part of this increase was due to a lengthened pause-after-reinforcement. It would be a simple matter to eliminate the differential DRO probabilities in the initial options by removing the DRO choice in the first option.

REFERENCES

- Azrin, N. H. and Holz, W. C. Punishment. In W. K. Honig (Ed.), *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 380-447.
- Barry, H. III and Miller, N. E. Effects of drugs on approach-avoidance conflict tested repeatedly by means of a 'telescope alley'. *Journal of Comparative and Physiological Psychology*, 1962, 55, 201-210.
- Barry, H. III, Wagner, S. A., and Miller, N. E. Effects of several drugs on performance in an approach-avoidance conflict. *Psychological Reports*, 1963, 12, 215-221.
- Cole, S. O. Experimental effects of amphetamine: a review. *Psychological Bulletin*, 1967, 68, 81-90.
- Dardano, J. F. and Sauerbrunn, D. Selective punishment of fixed-ratio performance. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 255-260.
- Davison, M. C. *Some effects of selective punishment on sequential interresponse times in fixed-ratio performance*. Unpublished doctoral dissertation, Otago University, N.Z., 1968.
- DeArmond-Edwards, D. Concurrent schedules of reinforcement and punishment. *Psychonomic Science*, 1966, 6, 219-220.
- Donahoe, J. F. and Schulte, V. G. Effects of stimulus intensity on approach-avoidance conflict behavior. *Psychonomic Science*, 1967, 8, 355-356.
- Findley, J. D. An experimental outline for building and exploring multi-operant behavior repertoires. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 113-166.
- Geller, I. and Seifter, J. The effects of meprobamate, barbiturates, d-amphetamine and promazine on experimentally induced conflict in the rat. *Psychopharmacologia*, 1960, 1, 482-492.
- Hake, D. F., Azrin, N. H., and Oxford, R. The effects of punishment intensity on squirrel monkeys. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 95-107.
- Hanson, H. M., Witoslawski, J. J., and Campbell, E. H. Drug effects in squirrel monkeys trained on a multiple schedule with a punishment contingency. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 565-569.
- Herman, R. L. and Azrin, N. H. Punishment by noise in an alternative response situation. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 185-188.
- Herrnstein, R. J. Secondary reinforcement and rate of primary reinforcement. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 27-36.
- Miller, N. E. Experimental studies of conflict. In J. McV. Hunt (Ed.), *Personality and the behavior disorders*. Vol. 1. New York: Ronald Press, 1944. Pp. 431-465.
- Miller, N. E. Liberalization of basic S-R concepts: extensions to conflict behavior, motivation and serial learning. In S. Koch (Ed.), *Psychology: a study of a science*. Vol. 1. New York: McGraw-Hill, 1959. Pp. 196-292.
- Miller, N. E. Some recent studies on conflict behavior and drugs. *American Psychologist*, 1961, 16, 12-24.
- Morse, W. H. Effect of amobarbital and chlorpromazine on punished behavior in the pigeon. *Psychopharmacologia*, 1964, 6, 286-294.
- Reynolds, G. S. Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 57-71.
- Richardson, W. K. and Donahoe, J. F. A test of the independence of approach and avoidance gradients. *Psychonomic Science*, 1967, 9, 569-570.
- Sidman, M. *Tactics of scientific research*. New York: Basic Books, 1960.
- Sidman, M. and Stebbins, W. C. Satiation effects under fixed-ratio schedules of reinforcement. *Journal of Comparative and Physiological Psychology*, 1954, 47, 114-116.

Received 6 November 1968.