VARIABLE-INTERVAL PUNISHMENT DURING VARIABLE-INTERVAL REINFORCEMENT¹

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Variable-interval punishment was superimposed on a variable-interval food reinforcement baseline for three groups of rats. The value for the variable-interval punishment schedule was the same as that for the variable-interval food reinforcement schedule, although the two schedules were programmed independently. The three groups were Variable Intervals 0.5, 1, and 3 min. Little or no suppression occurred in the three groups at mild (0.2 and 0.4 ma) intensities of punishment, but at 0.6 ma, complete suppression occurred almost uniformly. During continued punishment, there was no consistent recovery toward the pre-punishment baseline at suppressing intensities of punishment. After punishment was discontinued, recovery from suppression was more rapid the lower the punishment intensity, and the lower the value of the variable-interval schedules of reinforcement and punishment.

When punishment follows a response which is concurrently positively reinforced, a temporary or permanent reduction ("suppression") in the rate of responding is usually seen. This temporary reduction is followed by recovery during, and after, a punishment period either to, below, or even above, the pre-punishment level. Previous studies, using a continuous (Azrin, 1959, 1960b; Appel, 1963; Boroczi, Storms, and Broen, 1964), periodic (Estes, 1944, Experiments E and K), or fixed-ratio punishment schedule (Azrin, Holz, and Hake, 1963; Hendry and Van-Toller, 1964), have related both the suppression and recovery phenomena of punishment to characteristics of the punishing stimulus (shock level, shock duration), the concurrent schedule of positive reinforcement which maintains responding, and the state of the punished organism (deprivation level).

Studies of the effect of the punishment schedule suggest that it is an important variable. For example, intermittent punishment causes less suppression than continuous punishment. But intermittent punishment resulted in a more "persistent inhibitory effect" during subsequent extinction or reconditioning

(Estes, 1944, Experiments E and K; Azrin *et al.*, 1963).

There has been little work on variable-interval punishment. In Azrin's (1956) study of punishment, a modified variable-interval punishment schedule was used, the punishment period (signaled by a change in key color) alternating with a "safe" period. A fairly high shock level was used, and behavior was rapidly and completely suppressed, with subsequent slow recovery. It is not certain whether these results are characteristic of variable-interval punishment at lower shock levels.

The present study extends Azrin's (1956) work. Primary interest was on the effect of frequency of punishment (number of punishments delivered to each animal per session was approximately constant) and punishment intensity (shock level was systematically varied from low to high) on behavior. In studies of punishment using a continuous punishment schedule, number of punishments is an uncontrolled variable. That is, when punishment follows each and every response, a higher rate of responding results in a greater number of punishments. This correlation may enhance the effect of the punishment itself. In a variable-interval punishment schedule, the two are independent, as long as the animal maintains a minimal level of responding. Thus, variable-interval punishment may have different effects on behavior than other schedules of punishment.

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METHOD

Subjects

Twelve experimentally naive, male Sprague-Dawley rats (obtained from Charles River Co), 120 days old at the beginning of the experiment, were randomly assigned to one of three groups. The groups were designated by the variable-interval schedules which programmed punishment and reinforcement, *viz.*, the Variable-Interval 0.5 group, Variable-Interval 1 group, and Variable-Interval 3 group. One animal (in the Variable-Interval 3 group) died of unknown cause(s) midway through the experiment; data obtained from this animal were included in the group data. All subjects were on a 22-hr food deprivation schedule, and were fed after the daily experimental session.

Apparatus

Each of two light-shielded and sound-insulated boxes had a grid floor (R. Gerbrands Model C), was dimly illuminated, and contained a single lever, a reinforcement well, and a dipper. The reinforcer was 0.05 ml of sweetened milk and vitamins. Approximately 15 g of force was required to activate the lever. Electric shock was delivered to the lever and the grid floor by a Grason-Stadler model E1064GS shock generator and scrambler. The dial values of the shock generator were accepted without independent monitoring of intensity since interest was on the effect of changes (*i.e.*, increases) in the shock level, and not on the absolute value of the shock. To control for possible differences between the two boxes, half of each group was run in each box. The grids and adjacent walls of the boxes were thoroughly cleaned daily to maintain constant resistance from day to day. All programming and recording equipment was housed in an adjacent room.

Procedure

After bar-press training, subjects were placed on their respective variable-interval food-reinforcement schedules. A session was terminated after 40 food presentations. After 30 days of daily training (the last 15 days furnishing the baseline for comparison with later treatments), subjects were placed on a concurrent reinforcement-punishment schedule, with food and shock programmed independently by their respective independent variable-interval

schedules. In order to hold both the number of food reinforcements and number of shocks approximately constant for the three groups, it was necessary to co-vary frequency of food reinforcement with frequency of punishment; thus, the food reinforcement schedule which maintained responding was confounded with punishment schedule. Animals in the VI 0.5 group received food and punishment on a variable-interval 0.5 min schedule; those in the VI 1 group on a variable-interval 1 min schedule, and those in the VI 3 on a variable-interval 3 min schedule. Food and shock deliveries were programmed on two separate tapes having different sequences of intervals, but identical in range and mean value of the intervals. When a food or shock delivery was programmed, the tape was stopped until the next response occurred. The shock was 60 cycles per sec ac with a duration of 0.5 sec. Since food and shock deliveries were programmed on separate tapes, the two rarely occurred simultaneously unless response rate fell to a very low level. A session was terminated after 40 food presenta-

Fig. 1. Mean response rates of the three Variable-Interval groups ($n = 4$ in each) on successive blocks of 15 days. A no-shock (NS) block of 15 days was alternated with a 15-day block of punishment (shock). The data for the first NS block was taken from the last 15 days of the 30-day pre-punishment period.^a

^aThe VI 0.5 and 1 groups show response rates during the second and third no-shock periods which are above that of the first no-shock baseline, indicating a rising baseline. If the immediately preceding no-shock response rate is taken as the point of comparison, there is suppression at 0.4 ma for these groups.

tions or, if responding were completely suppressed, after 40 min for the VI 0.5 group, 80 min for the VI 1 group, and 4 hr for the VI 3 group (*i.e.*, twice the duration of a normal session).

The sequence of treatment for all groups was as follows. All subjects were initially given 30 days of variable-interval food reinforcement (no punishment). Then a block of 15 sessions of reinforcement and punishment at a given shock level was alternated with a block of 15 sessions of reinforcement alone (no punishment). In five successive blocks of 15 reinforcement and punishment sessions, shock level was increased in the ascending sequence, 0.2, 0.4, 0.6, 0.8, and 1.3 ma. Thus, habituation to shock was not controlled for, and the obtained results probably represent a smaller effect than would have been obtained with independent groups at each shock level.

RESULTS

The summary of the results in Fig. 1 shows that the mean response rate for all three groups dropped to zero, or near zero, at 0.6 ma intensity, and remained at zero at subsequent shock intensities. At intensities below 0.6 ma, the effect of punishment (at 0.2 and 0.4 ma) was variable, *i.e.*, two groups, VIs 0.5 and 1, showed an increase at 0.2 ma, and little or no suppression (relative to the first no-shock baseline) at 0.4 ma; a third group, VI 3, showed a slightly increasing suppression at 0.2 and 0.4 ma shock intensities. During intervening no-shock blocks of 15 days, response rate recovered. The degree of recovery differed between groups, and also depending on the shock level during the preceding punishment period.

The data were replotted to examine (1) suppression during punishment, (2) recovery dur-

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Fig. 2. Mean response rates of each animal during each 15-day punishment period plotted as a percent of its (15-day) mean pre-punishment response rate. A "punishment ratio" above one indicates an increase in responding during punishment over the pre-punishment rate, while a "punishment ratio" below one indicates a decrease, or suppression, of responding below the pre-punishment rate. The heavy lines are the average punishment ratios for each group. Most punishment ratios fall to zero at 0.6 ma.

ing punishment, and (3) recovery after punishment.

Suppression. In Fig. 2, the response rate for each animal during each punishment intensity was plotted as a ratio of its pre-punishment response rate (*i.e.*, mean response rate during the last 15 days before the first punishment period). As in Fig. 1, the "punishment ratio" dropped to zero almost uniformly across the groups at 0.6 ma shock level. At lower intensities, there was considerable variability within groups, and no clear difference in punishment ratios between the three groups.

Recovery during punishment. At 0.6 ma and above, there was little or no recovery during punishment. At lower intensities there was no consistent picture; some animals showed recovery either to, or above, the pre-punishment level, some showed an increasing suppression, and some remained completely suppressed throughout the punishment sessions (see Fig. 3).

Recovery following punishment. Figure 4 shows average response rates for each rat during the 15 days of post-punishment (in blocks of three days) following the five punishment periods (0.2, 0.4, 0.6, 0.8, and 1.3 ma). Recovery was a function of the variable-interval schedule and shock intensity during the preceding punishment period. That is, the VI 0.5 group showed the most recovery, VI 3 the least. Recovery was also most rapid and most complete as shock level decreased. This differential recovery as a function of shock level has not been noted in previous studies using continuous punishment (*e.g.*, Azrin, 1960b). In any case, where partial punishment is used, recovery appears to be a more sensitive index of the effects of shock intensity than suppression.

A short period of suppression at the beginning of each post-punishment session, which has previously been observed (Azrin *et al.*, 1963), was also observed in the present experiment. That is, a brief period of no responding occurred at the beginning of a session, followed by a gradual return of responding. This temporary suppression ("warm-up") reappeared at the start of each daily session, and became briefer with succeeding sessions of no-punishment.

DISCUSSION

Since both punishment and food reinforcement schedules co-varied, it is not known

whether the apparent lack of difference in suppression between the three groups was due to the punishment schedule or the co-varying reinforcement schedule. That is, a less frequently punished group may have shown less suppression than a more frequently punished group, if the frequency of food reinforcement were held constant in the two groups. Figure 5 compares the performance of the VI 1 group with the performance of a continuous punishment group run in a previous experiment in the same laboratory (Appel and Peterson, 1965). Except for the punishment schedule, the procedure and apparatus was the same for both groups. Figure 5 shows that a continuous schedule of punishment resulted in considerably more suppression at the milder intensities of shock (0.2 and 0.4 ma) than did a variable-interval schedule of punishment.

To recapitulate the main findings, variable-interval punishment differed from other punishment schedules in several respects. First, suppression was considerably attenuated when compared to suppression under continuous punishment; this attenuation has also been noted with fixed-ratio punishment. Second, recovery after variable-interval punishment did not occur immediately after punishment was removed, as it does after continuous punishment. As seen in Fig. 4, recovery patterns were variable, in some cases gradual (*e.g.*, No. 120, after 0.6 ma shock), and more frequently, abrupt (*e.g.*, No. 135, after 0.8 ma shock, and No. 136, after 0.4 ma shock). "Compensation"—an overshooting of the baseline after punishment was removed—was not observed with these variable-interval punishment animals. With continuous punishment, this overshooting is temporary and occurs immediately after punishment is removed; responding returns to pre-punishment baselines quickly, usually within three or four days (Azrin, 1960a). However, after fixed-ratio punishment, this temporary increase in response rate above the pre-punishment baseline does not occur immediately, but 3 to 4 hr after punishment ceases (Azrin *et al.*, 1963). Thus, had a longer recovery period been used, this compensatory overshooting may have eventually appeared.

Some animals showed what seemed to be "facilitation" (increased rate of responding over pre-punishment rates due to a change in stimulus conditions, *e.g.*, in this case, mild shock) at lower intensities of shock; but the

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BLOCKS OF 3 DAYS

Fig. 3. Performances of individual rats in the three groups plotted over five blocks of three days each for each intensity of shock. (Animal 138 died after 0.4 ma punishment period.)

Fig. 4. Performances of individual rats in the three groups plotted over the five blocks of three days each for each post-punishment period. Note the slowness, or absence, of recovery after higher intensities of shock.

intervening no-punishment periods after the 0.2 and 0.4 ma punishment periods also showed a response rate above the original value. The increased rate of responding during mild punishment was probably not due to the punishment but rather to the upward trend in

response rate which persisted through both punishment and non-punishment periods.

The gradual increase in shock level undoubtedly attenuated the effects of shock intensity; presumably a greater effect of shock intensity would have been obtained with independent groups at each shock intensity. For example, Azrin *et al.* (1963) customarily start with low intensities and gradually increase

shock level to avoid complete, and usually irreversible, suppression. Miller (1960), in a runway situation, also found that strong shock suddenly introduced had a greater effect on behavior than shock which was gradually increased in intensity. Thus, habituation can be said to occur when shock intensity is gradually increased. On the other hand, sensitization seems to occur when the subject is initially exposed to strong shock. Walters and Rogers (1963) found that subjects pretreated with strong unavoidable shock, showed more suppression in a punishment situation a year later (where mild shock—0.2 ma was used) than did subjects not pretreated.

Fig. 5. The punishment ratio of the Variable-Interval 1 group from the present experiment compared with the punishment ratio of a continuously punished group ($n=3$) from a previous (Appel and Peterson, 1965) study. Both groups were concurrently food-reinforced on Variable-Interval 1. The punishment ratio here is based on the mean response rate during the 15 days of punishment taken as a percent of the mean response rate during the five days preceding the punishment period.

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