THE EFFECTS OF PUNISHMENT INTENSITY ON SQUIRREL MONKEYS¹

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Responses of squirrel monkeys were maintained by a variable-interval schedule of food reinforcement. Concurrently, punishment consisting of a brief electric shock followed each response. As has been found for pigeons and rats, punishment did not produce extreme, all-or-none reactions. By gradually increasing the punishment intensity it was possible to produce response rates intermediate to no suppression and complete suppression. Similarly, the moment-to-moment response rate was free of extreme fluctuations. A "warm-up" effect occurred in which the punished responses were especially suppressed during the initial part of a session. The pre-punishment performance was negatively accelerated within a session, and punishment reduced the degree of negative acceleration. When punishment was discontinued, responding recovered immediately except when suppression had been complete or prolonged. When the punishment intensity was decreased gradually, more suppression resulted at a given intensity than when intensity was increased gradually. This suggests a "behavioral inertia" effect wherein behavior at a new punishment intensity is biased toward the behavior at the previous value. A corollary generalization is that the larger the change in intensity, the less the behavior at the new value will be biased toward the behavior at the previous value.

Studies using pigeons (Azrin, 1960) and rats (Appel and Peterson, 1965) have shown that the rate of a punished response decreases as a direct function of the intensity of the punishing stimulus. For individual subjects, gradual increases in punishment intensity resulted in progressively lower rates of responding. There are results, however, which suggest that punishment may produce more extreme effects in the monkey. For example, Appel (1961) found that squirrel monkeys stopped responding at the one punishment intensity (1 ma) used and did not begin again when 50 more 8-hr sessions were provided after punishment was removed. Masserman and Pechtel (1953) indicated that the presentation of a toy snake as a monkey reached for food could eliminate feeding behavior and produce behavior disorders resembling those observed in human subjects. Aversive stimuli have been widely used with monkeys in the study of avoidance, *e.g.*, Sidman, Herrnstein, and Con-

rad (1957), Azrin, Holz, and Hake (1962), Morse and Kelleher (1966), and conditioned suppression (Brady, 1959), but there has been little parametric experimentation on the effects of punishment. The present study investigated the effects of punishment intensity on the squirrel monkey in order to provide a more definitive basis for comparative statements. If punishment does result in more extreme effects with the squirrel monkey, this might be revealed in an all-or-none reaction, *i.e.*, responding at the pre-punishment rate or not responding at all. An all-or-none reaction would be expected (1) to different punishment intensities, (2) in the moment-to-moment rate of the punished response, and (3) after the removal of punishment. Special care was taken to eliminate variability in administering the punishing stimulus, thereby assuring that behavioral variability or all-or-none reactions could not be an artifact of variations in the punishing stimulus.

METHOD

Subjects

Seven male squirrel monkeys were maintained at about 80% of free-feeding body weight. After each daily session the monkeys

¹This investigation was supported by grants from the Mental Health Fund of the Illinois Department of Mental Health, NSF Grant 1987, and NIMH Grant 4925. The valuable advice of Drs. R. R. Hutchinson and L. K. Miller is greatly appreciated. Reprints may be obtained from D. F. Hake, Behavior Research Lab., Anna State Hospital, Anna, Illinois 62906.

were returned to individual home cages and given enough food to maintain experimental weight. The food in the home cage and in the experimental chamber was a complete liquid diet (Ellison and Riddle, 1961).

Apparatus

The monkeys were seated in a restraining chair that imposed a minimum of restraint on peripheral body movement (Hake and Azrin, 1963). The horizontal plate that served as a waistlock left the monkey free from the waist up. The punishing stimulus was a brief electric shock delivered through two electrodes resting on a shaved portion of the tail. To assure electrical contact, the electrodes were coated with electrode paste (EKG Sol) and the tail was immobilized by a tail-stock and a tail-trough. In addition, the waistlock extended to the walls of the chamber, thereby preventing the monkey from reaching its tail. The ac shock was delivered through the secondary of a step-up transformer that was in series with a variable transformer. Constant current regulation was obtained by placing a 50 k resistor in series with the monkey. Since the resistance of the monkeys was about 6000 ohms across the range of voltages employed, a fluctuation as large as 100% in the monkey's resistance would result in only a 10% change in current flow. Oscilloscopic tests showed no peak transients. Each shock was 0.1 sec; this brief duration reduced the duration of elicited skeletal reactions. Since the prime objective was to determine the effects of various punishment intensities, it was essential that the methodology for delivering shock be free of any variability. One source of variability in grid shock procedures is the ability of a subject to change the current flow by any body movement that changes the degree of contact with the electrified grid (see Dinsmoor and Campbell, 1956). The present use of surface electrodes on the motionless tail of the monkey was intended to eliminate these uncontrolled variations.

Two experimental compartments with the tail-electrode type restraining chairs were used. In one of these, used with monkeys 1, 2, 3, and 4, the response bar was located on the front wall 3 in. above the horizontal waistlock and about 5 in. from the monkey. The response bar was 1 in. wide and protruded only $\frac{1}{2}$ in. from the front wall, thereby minimizing

contact by incidental movements. A buzzer sounded briefly after each bar-press, providing response feedback. A dipper presented .15 ml of the liquid food reinforcer through a hole in the top of a metal box located to the right of the response bar. During dipper presentation, the overhead lights were extinguished and simultaneously a light above the dipper was activated. The dipper was presented about 1.5 sec after the dipper lights were activated and was available for 3 sec. Water was continuously available from a bottle mounted within the chamber. The experimental compartment was within a sound-attenuating and light-proof enclosure. Continuous white noise masked extraneous sounds.

The second experimental compartment was used with monkeys 5, 6, and 7. There were several differences in the response and reinforcement mechanisms. First, the dipper used to deliver liquid reinforcer was larger (0.25 ml) because the monkeys run in this chamber received fewer presentations. Second, in addition to the buzzer, the overhead lights served as response-feedback. The overhead lights blinked on briefly after each response. The start of the session was signaled by the illumination of a stimulus light above the response bar instead of the illumination of the overhead lights. Third, the response bar protruded further into the experimental chamber. The response bar was located about 3 in. above the horizontal waistlock and was mounted in a box attached to the front wall of the compartment. The bar protruded 1 in. from the box, making it about 2 in. from the monkey. This more accessible bar may have been partly responsible for the higher rates of responding of monkeys 5, 6, and 7.

Procedure

Bar-press responses were reinforced with food according to a variable-interval (VI) schedule, that is, at irregular intervals of time. Table 1 shows the average time interval between the scheduled food reinforcements and the maximum session duration for each monkey. For three of the monkeys (1, 2, and 3), sessions lasted until a maximum number of food reinforcements was obtained or until a maximum time limit was reached. For these three, the maximum time limit exceeded the time normally needed to obtain the reinforce-

ment limit. Hence, if the response rate were reduced to the extent that the monkey had not received the reinforcement limit in the usual time, there was additional time to obtain reinforcements.

After the monkey was put in the chamber, a timer automatically provided a 5-min session delay during which all chamber lights were extinguished and responding was not followed by feedback, reinforcement, or punishment. Following this 5-min session delay, the start of the session was signaled by illumination of the overhead lights (monkeys 1, 2, 3, and 4: chamber #1) or the stimulus light (monkeys 5, 6, and 7: chamber #2).

Table 1

Schedule of Food Reinforcement and Session Duration

Monkey	Schedule of Reinforcement	Session Duration
1	1 min VI	75 reinf. or 240 min
2	2 min VI	65 reinf. or 175 min
3	30 sec VI	160 reinf. or 175 min
4	30 sec VI	85 min
5	1 min VI	60 min
6	1 min VI	60 min
7	1 min VI	60 min

A variable-interval schedule of food reinforcement was used because it is known to produce a fairly constant response rate (Ferster and Skinner, 1957). This constancy could be expected to simplify evaluation of intra-session effects of punishment. The monkeys were exposed to the variable-interval schedule until the response rate was fairly constant, then punishment was arranged to follow each response. The intensity of the punishing stimulus was progressively increased until the rate of responding reached the zero level (monkeys 1, 2, 3, and 4) or near-zero level (monkeys 5, 6, and 7). A minimum of three sessions was given at each punishment intensity. The intensity generally was changed only when there was less than 15% change in total responses for three sessions, or no consistent direction of change. For monkeys 1, 2, 3, and 4 as many as 15 to 20 sessions were provided at the highest punishment intensity. Punishment was discontinued after the highest intensity. For some monkeys (1, 2, 5, 7) punishment was again introduced and additional intensity functions were obtained.

RESULTS AND DISCUSSION

Punishment produced both short- and long-term changes. The results will be presented and discussed separately for these changes and for the different methods of varying the punishment intensity.

Punishment Intensity and Average Response Rate

Figure 1 shows the relationship between response rate and punishment intensity for each of the seven monkeys. The response rate is expressed as a percentage of the pre-punishment (zero volts) response rate. The first functions for monkeys 1 and 2 (solid line) were obtained before testing the other subjects. In these first functions of monkeys 1 and 2, the lower punishment intensities had little (M-1) or no effect (M-2), whereas in the subsequent higher intensities responding ceased.

It appeared that punishment did indeed have an all-or-none effect. Responding was either suppressed completely or not at all. On the other hand, it was possible that the absence of intermediate degrees of suppression simply reflected the absence of intermediate punishment intensities. This possibility was evaluated by repeating the functions using more intermediate punishment intensities. Monkeys 1 and 2 were exposed to various punishment intensities again after the response rate had been allowed to recover by removing the punishment contingency. The second function of M-1 is indicated by the broken lines. For M-2 the second function (not shown) using 10 to 20 v increments was similar to the first function. The third function of M-2 using 5 to 10 v increments is indicated by the dotted lines. In addition, five new monkeys (3, 4, 5, 6, and 7) were studied using many intermediate intensities.

The results for all seven monkeys were now similar in that (1) the response rate was an inverse function of punishment intensity, (2) there was little or no suppression at the initial lower intensities suggesting a "threshold value", (3) responding was either completely eliminated (monkeys 2, 3, and 4) at the highest punishment intensity or reduced to less than 1% of the pre-punishment rate (monkeys 5, 6, and 7; monkey 1 died before completion of the function), and (4) intermediate levels of suppression were obtained at the punishment

Fig. 1. The relationship between response rate and punishment intensity. Response rate is expressed as a percentage of the pre-punishment rate. Each point is the average of the last three sessions. Monkey 1 died before completion of the second function.

intensities that were intermediate to the threshold values and the values that eliminated or nearly eliminated responding. It appears that gradual increases in punishment intensity can result in intensity functions with intermediate levels of suppression for the squirrel monkey as well as for the pigeon and the rat.

Punishment Intensity and Moment-to-Moment Response Rate

The intermediate levels of suppression seen in Fig. 1 were based upon the average re-

sponse rate. However, observation of the moment-to-moment responding within sessions might still reveal an all-or-none effect. For example, an average response rate could be based on a series of alternations between periods of no responding and periods of responding at the pre-punishment rate instead of responding at an intermediate rate. Observation of the moment-to-moment responding was possible by continuous response records which were obtained concurrently with the counter readings of overall responses. Figures 2 and 3 show samples of these continuous rec-

ords for each monkey. Records at several punishment intensities were selected to illustrate the various degrees of suppression. For any monkey and for any intensity, alternations between periods of no responding and periods of responding at the pre-punishment level were not evident. The continuous response records of Fig. 2 and 3 reveal that punishment did result in more gradual changes over the course of the session. An initial period of low response rate followed by a gradual acceleration in responding was consistently observed for monkeys 1 and 5 and inconsistently for others. This "warm-up" period of initial suppression and subsequent recovery has been observed and studied in punishment (Azrin, 1960) and avoidance (Hoffman, Fleshler, and Chorny, 1961) procedures.

Punishment Intensity and Intra-session Response Rate

To evaluate these changes in response rate over the course of the entire session, an index

Fig. 2. Continuous response records at several of the punishment intensities illustrating the various degrees of suppression for monkeys 1, 2, 3, and 4. The records were taken from the last three sessions at a given intensity. The records show the start of sessions and the first 1500 responses or the entire session duration, whichever occurred first. Food reinforcements were indicated by the downward deflection of the response pen.

of curvature (Fry, Kelleher, and Cook, 1960) was calculated for sessions at the various punishment intensities. The indices of curvature in Fig. 4 show the direction and extent of acceleration in response rate within sessions as a function of punishment intensity. Each point in Fig. 4 represents the average of the indices for the last three sessions at a given punishment intensity. The punishment intensities at which the number of food reinforcements dropped below 80% of the pre-punishment number are indicated by the open circles. These points also include all the punishment intensities at which the index of curvature was based upon less than 100 responses/session. Before punishment was introduced (zero volts) the indices of curvature reveal a negatively accelerated response rate for all monkeys. This negative acceleration may reflect a gradual lessening of food deprivation as a function of the increasing number of food reinforcements. Little or no change resulted from the introduction of the lower punishment intensities. As the punishment intensity was increased, however, there was a tendency toward positive acceleration. When punishment was discon-

Fig. 3. Continuous response records at several of the punishment intensities illustrating the various degrees of suppression for monkeys 5, 6, and 7. The records were taken from the last three sessions at a given intensity. The records show the start of sessions and the first 1500 responses or the entire session duration, whichever occurred first. Food reinforcements were indicated by the downward deflection of the response pen.

Fig. 4. The index of curvature as a function of punishment intensity. Each point from zero volts to the highest intensity represents the average of the indices for the last three sessions. For monkeys 3 and 4 considerable responding remained for several sessions at the highest intensity before responding ceased. These sessions were used in the calculations at the highest intensity. The return to zero volts (arrow) is based upon sessions 11-15 after responding resumed or the last four sessions if fewer than 15 sessions were run. The open points indicate intensities at which the number of reinforcements dropped to less than 80% of the number received before punishment. The open points also include all intensities at which the index was based upon less than 100 responses per session. For each session the index was calculated from the number of responses in consecutive 5-min cells. For monkeys 5, 6, and 7, the number of 5-min cells was always 11. For monkeys 1, 2, and 3, the number of 5-min cells varied slightly depending on when the session timed out. These variations occurred only at the higher punishment intensities and did not appreciably change the index.

tinued, the response rate was again negatively accelerated. (The severe negative acceleration seen for monkeys 2, 3, and 4 when punishment was discontinued will be discussed in a later section.)

At some of the highest punishment intensities the severe suppression of responding resulted in a reduced number of food reinforcements (open circles). This factor may have reduced the possibility of satiation and negative acceleration but it does not explain positive acceleration. Also, for most of the monkeys, reduced negative acceleration was evident when there was little or no reduction in the number of food reinforcements. Some other factors involved in the reduction of negative acceleration are illustrated with two monkeys in Fig. 5 which shows the absolute

Fig. 5. Intra-session changes in response rate as a function of punishment intensity. Each point represents the average rate of responding for consecutive 5-min periods averaged over the last three sessions.

rate of response throughout sessions at selected punishment intensities. The number of food reinforcements was not reduced at the punishment intensities shown in Fig. 5. Before punishment was introduced (zero volts), the response rates of both monkeys were considerably higher at the start of the session than at the end, yielding negatively accelerated functions. When the suppressive effects of punishment are to be evaluated for different points within a session, the suppression at a given point in the session must be calculated relative to this same point in the pre-punishment session. Therefore, any tendency for punishment to produce more suppression at the start of the session than at subsequent points would be seen in a reduction of the negative acceleration existing before punishment. Figure 5 shows that this was one effect of punishment. For the lowest punishment intensity, however, this initial suppression was sometimes only slightly greater (M-3) and it always diminished quickly. The suppression over the remaining portion of the session was fairly constant (no suppression, M-5; slight suppression, M-3) and the rate function for this larger portion of the session was of the same shape as the pre-punishment function. Consequently, the degree of negative acceleration calculated for the entire session was reduced only slightly. Conversely, if the initial suppression had been severe for both monkeys and diminished gradually over a larger portion of the session, only a smaller proportion of the rate function could have paralleled the pre-punishment function. Therefore, there would have been less negative acceleration for the entire session. Figure 5 reveals that this was the effect at higher punishment intensities.

Removal of Punishment: Short Term Effects

The major concern to this point has been whether or not punishment intensity could be varied to produce levels of responding intermediate between no suppression and the virtual elimination of responding. The question remains concerning the effects of punishment upon subsequent unpunished responding. For example, does punishment result in an all-or-none effect, *i.e.*, irreversible elimination of responding? To answer this question, the punishment contingency was removed after the highest punishment intensity for each monkey.

Punishment did leave residual effects. However, for most monkeys these residual effects were brief, the pre-punishment response rate being recovered within two to nine sessions. The continuous response records of Fig. 6 illustrate these short-term effects for one monkey following partial suppression (left side) and complete suppression (right side). The pre-punishment performance is shown at the top of the figure. The 5-min session delay is also indicated by the heavy line at the start of sessions. Responding during the session delay is indicated by the shaded area above the line. During the last session at 100-v punishment, responding was reduced to 0.6 responses per min. It may be seen that after removal of the 110-v punishment, responding returned to a high level but a warm-up persisted for several sessions. The warm-up disappeared by the sixth session after punishment was removed, and the responding throughout the session

Fig. 6. Continuous response records showing responding before punishment, during the highest punishment intensity, and after the removal of punishment. The records on the left show responding after 110-v punishment; those on the right show responding after 400-v punishment. The 5-min session delay is also indicated by the heavy line at the start of sessions. Responding during the session delay is indicated by the shaded area above the line.

was comparable to that seen before punishment. After responding was eliminated by 400-v punishment, responding did not return until reshaping was accomplished during the fifth session after punishment was removed. Again, a warm-up persisted for several sessions. By the ninth session, the warm-up disappeared and responding throughout the session was comparable to the pre-punishment performance. Pre-punishment performance may be recovered after complete as well as partial suppression, although reshaping may be necessary in the case of complete suppression.

A warm-up after punishment is removed has been noted with pigeons (Azrin, 1960; Azrin, Holz, and Hake, 1963). Azrin *et al.* (1963) found that even after responding within the session had recovered to the pre-punishment level, the warm-up could be reproduced within a session by stopping and restarting the session. This finding suggests that the warm-up is at least in part attributable to the onset of stimuli that have been paired with punishment (Azrin *et al.*, 1963). Since the warm-up gradually decreases within and over sessions, it follows that a period of adaptation to the session stimuli might reduce the effect of these stimuli within the session. Estes (1944) found such results. It is possible that in the present experiment the 5-min session delay functioned as a period of adaptation. Observation of M-7 revealed responses during the session delay. It will be recalled that responses during the session delay, hereafter called delay responses, were not followed by response feedback, food reinforcement, or punishment. Whatever the cause of delay responses, *e.g.*, a lack of stimulus control by the stimulus light indicating the start of the session, Fig. 6 shows that before punishment, M-7 emitted delay responses at a high rate. Responding in the delay decreased to a zero level at a punishment intensity of 100 v. Delay responses did not return until punishment was removed. It may be seen in Fig. 6 that even then delay responses did not return until the warm-up during the session had disappeared. These findings suggest that suppression during the 5-min session delay was simply a part of the warm-up. The inconsistency of the warm-up, particularly at the lower punishment (Fig. 2 and 3) intensities, may have been due in part to the fact that the warm-up had already occurred in the 5-min session delay.

Figure 7 shows that responding during the session delay was an inverse function of punishment intensity. The incomplete recovery after the removal of 110 v was probably due to the introduction of 80-v punishment after only six sessions without punishment (see Fig. 6). These data suggest that the suppressive effect of the onset of session stimuli will be more severe the higher the intensity of the punishment paired with these stimuli.

Removal of Punishment: Long-Term Effects

For some monkeys the residual effects of punishment endured long after its removal. Table 2 summarizes the effects of removing punishment for all monkeys. The long-term residual effects were of two types. Column 3 of Table 2 indicates that without reshaping, monkeys 3 and 4 may have never resumed responding. Irreversibilities of that type have been reported for squirrel monkeys (Appel, 1961) and rats (Storms, Boroczi, and Broen, 1963). In the present study, whenever responses were at a zero level during the last punishment session (Column 2), reshaping or several sessions without punishment were required before responding resumed (see Column 3). The third function of M-2 was the only exception. The cessation of responding appeared to prevent a discrimination that punishment was no longer in effect. When responding was not eliminated in the last punishment session (monkeys 5, 6, and 7), responding always occurred during the first session after punish-

Fig. 7. Response rate during the 5-min session delay as a function of punishment intensity. Each point is the average of three sessions; the last two sessions at the indicated intensity plus the first session at the next intensity. The first session at the next intensity was included since there was no basis for discriminating a change in intensity.

ment was removed. Spontaneous recovery was delayed or absent after complete suppression; immediate recovery occurred after partial suppression.

A second long-term effect is indicated in Column 4. Monkeys 2, 3, and 4 did not reach the pre-punishment rate until 2 to 3 months after responding resumed. Figure 8 illustrates the intra-session performance before punishment (top) and after punishment was removed for one of these monkeys. It may be seen that the pre-punishment response rate was fairly constant with only slight negative acceleration. For this monkey, punishment was severe enough to eliminate responding and responding did not return for 20 sessions after the removal of punishment when reshaping (not shown) was accomplished. Session 21 is the first session after reshaping. After reshaping, responses were not emitted until near the end of session 22 (arrow). Even though punishment had not occurred in the last 21 sessions, a warm-up continued for several sessions. As responding began to occur sooner in the sessions, severe negative acceleration became evident. Some negative acceleration was evident 100 sessions after punishment was removed. It will be recalled that the index of curvature (Fig. 4) for these three monkeys indicated considerable negative acceleration after punishment had been removed, much more than had been evident before punishment. However, the index of curvature of Fig. 4 also indicated that responding had not been negatively accelerated at the punishment intensities before responding was eliminated. In fact, there had been positive acceleration. For two of the monkeys (3 and 4) at least 80% of the scheduled food reinforcements had been obtained at those punishment intensities. This suggests that the factors responsible for the negative acceleration occurred at or after the punishment intensity that resulted in the cessation of responding. During that period these monkeys had two factors in common. First, the intensity of the punishing stimulus was severe enough to eliminate responding. However, responding was also eliminated in the initial functions of monkeys 1 and 2 and in a later function for monkey 7. These monkeys reached the pre-punishment level within 2 to 9 sessions after responding resumed. Also, the intra-session performance did not reveal increased negative acceleration. It appears that severity of the

punishment *per se* was not responsible. The number of sessions in which responding was eliminated or severely reduced, the second common factor, does appear relevant. For monkeys 3 and 4 responding had been eliminated for 35 to 40 sessions. Although responding was eliminated for only 10 sessions at the highest punishment intensity for M-2, responding had been severely reduced for many sessions at prior punishment intensities. Because of the reduction in responding, these monkeys had been receiving few, if any, reinforcements within the allotted session time.

Fig. 8. Continuous response records showing responding before punishment and after removal of 200-v punishment.

Table 2
Removal of Punishment

1	2	3	4	5
Monkeys	Responses last punishment session	Sessions before resumption of responding	Sessions to prepunishment rate after resumption of responding	Sessions received less than $\frac{1}{4}$ scheduled reinforcements before resumption of responding
M-1	0	2, reshaped	7	11
M-2*	0	reshaped	2	10
M-2	0	4	4	21
M-2	0	0	83	38
M-3	0	30, reshaped	57	48
M-4	0	20, reshaped	88	39
M-5	3	0	2	5
M-6	18	0	3	11
M-7*	37	0	2	0
M-7	0	4, reshaped	3	8

*Punishment was removed following three functions for M-2 and two for M-7. These are given in chronological order for each monkey.

Column 5 of Table 2 shows that for these monkeys there had been many more sessions in which the number of reinforcements was reduced to less than one-fourth of the scheduled number. After reinstatement of responding, however, the rate and number of reinforcements increased abruptly. It is possible that after reinforcements during the session time were eliminated or reduced to less than one-fourth of the scheduled number for over a month, the monkeys could no longer take the maximum number of reinforcements in the allotted session time without satiation.

Gradually Increasing and Gradually Decreasing Intensity Functions

Thus far, the effects have been seen of gradually increasing the punishment intensity and abruptly removing it. For two monkeys, a high punishment intensity was again presented and then reduced gradually. The effects of these changes are shown sequentially in Fig. 9. The gradually increasing functions are the same as shown for these monkeys in Fig. 1. After the gradually increasing function and the removal of punishment, a punishment intensity (80 v for M-7; 200 v for M-5) that had reduced responding to less than 5% of the original pre-punishment rate was presented. For M-7, the punishment intensity was increased to 100 v. Then, for both monkeys the punishment intensity was decreased gradually, 6 to 15 sessions being provided at each intensity. Upon removing punishment after the

highest intensity of the gradually increasing function, responding increased to 124% (M-7) to 147% (M-5) of the original pre-punishment rate. This increase appeared to be an enduring effect, since responding remained at this level over 6 (M-7) to 15 (M-5) sessions with no indication of decline. The abrupt introduction of the high punishment intensities (80 v for M-7; 200 v for M-5) resulted in more suppression than previously found at these intensities. For M-7, the abrupt introduction of 80 v reduced responding from 124% of the pre-punishment rate to 0.7% (1.5 responses/min). Following a history of gradual increments, 80-v punishment had reduced the original 100% pre-punishment rate to 4% (nine responses/min). For M-5, the abrupt introduction of 200-v punishment reduced responding from 147% to 0.001% (0.05 responses/min). The introduction of 200-v punishment following gradual increments had reduced the original 100% pre-punishment rate to 3% (2.8 responses/min). The decreasing functions of both monkeys were similar in that (1) response rate was an inverse function of punishment intensity, (2) there was little or no suppression at the lower intensities suggesting a threshold value, and (3) the response rate at a given intensity did not reach the rate obtained in the increasing function until the threshold values (20 v for M-7; 100 v for M-5). The difference in suppression between the increasing and decreasing functions indicates that more suppression results at a given super-threshold

Fig. 9. The effects of changing punishment intensity by gradual increments and gradual decrements. Response rate is expressed as a percent of the initial pre-punishment rate. Each point is the average of the last three sessions.

punishment intensity when there is a history of higher intensities than when there is a history of lower intensities. In the increasing function each punishment intensity had an immediate history of lower intensities, whereas in the decreasing function each intensity had an immediate history of higher intensities. To what extent the response rate at a given intensity is a function of the immediate history and/or a complex integration of all histories is not clear.

GENERAL DISCUSSION

The present results revealed that punishment did not produce all-or-none effects in the squirrel monkey. It is possible that a given punishment intensity can produce more suppression in the monkey than in the pigeon or the rat. But the relationships between punishment intensity and the rate of responding were similar to those observed in the pigeon (Azrin, 1960) and the rat (Appel and Peterson, 1965). By gradually increasing the intensity of the punishing stimulus it was possible to produce rates of responding intermediate between no suppression and the virtual elimination of responding. Similarly, punishment did not produce all-or-none fluctuations in the moment-to-moment rate of responding at the various punishment intensities. And, upon removal of punishment, there were no all-or-none effects, *i.e.*, irreversible elimination of responding. There were long-term residual effects but these appeared to be the result of complete or prolonged suppression rather than the punishing stimulus *per se*.

Another similarity in the effects of punishment upon monkeys, pigeons (Azrin, 1960), and rats (Appel and Peterson, 1965) was the occurrence of the warm-up. The warm-up occurred with the squirrel monkey even though the responding before punishment and at some of the lower punishment intensities was negatively accelerated. The index of curvature (Fry *et al.*, 1960) revealed that punishment reduced the degree of negative acceleration. It appears that before the existence of a warm-up effect can be ruled out, because of a constant or even negatively accelerated response rate during a punishment session, the response rate during the punishment session must be compared with the rate during pre-punishment sessions. It should be noted that

several factors favored finding the greatest reduction in negative acceleration at the intermediate and higher punishment intensities. First, the 5-min session delay appeared to function as a period of adaptation. At the lower punishment intensities, where the warm-up is usually brief, the warm-up was probably reduced or eliminated by the 5-min session delay. Second, the index of curvature indicated the extent to which responding departed from constancy for an entire session. It did not necessarily reflect acceleration in terms of the magnitude of change in absolute response rate, especially if the change occurred early in the session and lasted for only a brief portion of the session. The largest changes in terms of absolute rate were frequently seen at the start of sessions at the lower intensities, but these effects were usually too brief to affect greatly the index of curvature for the entire session. At the intermediate and higher intensities, changes in absolute rate were not always as large, but they did last over the entire session.

The present results concerning the effects of punishment intensity suggest the possibility of a single quantitative statement to integrate a number of findings on the effects of punishment intensity. Although response rate has been found to decrease as a direct function of punishment intensity, the present results indicate that the absolute rate of responding at a given intensity may be modified by the preceding intensities. There was more suppression at a given punishment intensity when that intensity was preceded by higher intensities (decreasing intensity function) than when preceded by lower intensities (increasing intensity function). Azrin (1960) found that when punishment intensity was decreased gradually, the response rate eventually did adjust to the level obtained when that intensity was reached by gradual increments. However, as Azrin pointed out, the adjustment was extremely gradual, extending over many sessions. These findings describe a type of "behavioral inertia" in which the behavior at a new punishment intensity has changed but is biased in the direction of the behavior at the previous intensities. The present results also suggest that this inertia-type effect may not occur when the magnitude of the change in punishment intensity is larger. For example, the abrupt increases in punishment intensity for monkeys 5 and 7 seen in Fig. 9 resulted in more sup-

pression at a given intensity than when that intensity was reached by more gradual increments. In a systematic investigation using a runway procedure, Miller (1960) also found that a given punishment intensity resulted in more suppression when that intensity was introduced abruptly rather than gradually. Similar findings have been obtained when punishment intensity was decreased abruptly. Using abrupt decreases to a given punishment intensity, Azrin (1960) found a rapid adjustment of responding to the rate which had been obtained at that intensity in an increasing function. This differs from the extremely gradual adjustment which had been obtained when the intensity was reached by a smaller decrement. At the extreme is the compensation or contrast effect that has been observed upon the abrupt removal of punishment (Azrin, 1960; Azrin *et al.*, 1963). Brethower and Reynolds (1962) found that the rate of responding in the unpunished component of a multiple schedule increased as the intensity of the punishment in the second component increased. It is possible that these findings concerning the direction and magnitude of change may be integrated into a more general quantitative statement which will describe the conditions under which the two effects, behavioral inertia and behavioral contrast, will result. That is, the smaller the change in punishment intensity, the more the behavior at the new value will be biased in the direction of the previous value. Stated conversely, the greater the change in the value of punishment intensity, the less the behavior at the new value will be biased in the direction of the behavior at the previous value. The magnitude of change may reach a point where the behavior at the new value will shift away from the behavior prevailing at the previous value, as in the compensation or contrast effect.

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Received June 13, 1966