JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1969, 12, 149-157 NUMBER 1 (JANUARY)

CONTINUOUS PUNISHMENT OF FREE-OPERANT AVOIDANCE IN THE RAT[1]

ROBERT W. POWELL AND GRANT MORRIS

UNIVERSITY OF SOUTH FLORIDA

Three groups of albino rats were trained under a free-operant avoidance (Sidman) procedure with equal shock-shock and response-shock intervals. After stable performance was achieved, the animals were concurrently exposed to a brief electric shock after each response. The procedures were as follows: Punishment Schedule I: punishment shock was introduced at an intensity approximately one quarter that of avoidance shock; increments of nearly this same size were made as stable performance was achieved at succeeding punishment shock intensities. Punishment Schedule II: punishment shock was introduced at approximately one-half the intensity of avoidance shock; after stable performance, punishment shock was increased to the same intensity as avoidance shock. Punishment Schedule III: punishment shock was introduced and maintained at the same intensity as avoidance shock. Punishment was continued for all groups until one of two suppression criteria was attained. All animals made fewer responses and received more avoidance shocks as a function of increasing punishment shock. Half of the animals under Punishment Schedule I required punishment shock higher than avoidance shock to meet their assigned suppression criterion. A comparison of all procedures showed that suppression was greater when punishment shock was initially at high intensity.

Azrin and Holz define punishment as "a reduction of the future probability of a specific response as a result of the immediate delivery of a stimulus for that response" (1966, p. 381). This definition emphasizes function. Definitions of punishment which relate only to procedure have proven to be unsatisfactory. A number of experiments have shown that under certain conditions, aversive stimuli will increase the frequency of the response which produces them. For example, McKearney (1968) reported that a fixed-interval schedule of shock presentation maintained a pattern of positively accelerated responding in monkeys.

Most studies of punishment have focused on responses developed and maintained on a schedule of positive reinforcement. These studies have generally shown that the rate of a punished response decreases as the intensity of the punishing stimulus increases (Azrin, 1960; Appel and Peterson, 1965; Hake, Azrin, and Oxford, 1967).

In the present experiment, a punishment contingency was applied to a response being maintained under negative reinforcement. Lever-press responses produced an immediate electric shock, while failure to make the same response within a prescribed interval, also produced a shock. Thus, an aversive stimulus, electric shock, was concurrently employed to maintain and to suppress responding.

It has generally been found that the concurrent presentation of aversive stimuli during avoidance conditioning increases responding. Sidman, Herrnstein, and Conrad (1957) found that delivery of non-contingent shocks during free-operant avoidance training increased response rates. Appel (1960) alternated periods of free-operant avoidance and punished extinction, with discriminative stimuli in effect. The punished extinction procedure initially increased response rate, but this was eventually replaced by a low rate under extinction. Subsequently, the discriminative stimuli were withdrawn and the two contingencies produced equally high response rates.

[1]This work was supported in part by a grant from the University of South Florida Research Council. A report of this study was presented at the 1968 Southeastern Psychological Association Convention, Roanoke, Virginia. Reprints may be obtained from Robert W. Powell, Department of Behavioral Science, University of South Florida, Tampa, Florida 33620.

Kelleher, Riddle, and Cook (1963) employed a multiple schedule consisting of positive reinforcement and avoidance. When a conditioned suppression procedure was superimposed on the multiple schedule, response rate increased under both components. This is opposite to the conditioned suppression effect originally demonstrated by Estes and Skinner (1941) and subsequently replicated many times. Kelleher *et al.* (1963) demonstrated that the increased responding they found in their subjects was due to the unavoidable shock.

Recently, several studies have applied punishment to a response being maintained under negative reinforcement. Sandler, Davidson, Greene, and Holzschuh (1966), for example employed a discriminated avoidance procedure and found that bar-press behavior increased and avoidance efficiency decreased as a function of increases in punishment-shock intensity. A second experiment by Sandler, Davidson, and Holzschuh (1966) employed a free-operant avoidance procedure with punishment scheduled according to a fixed ratio which decreased gradually from FR 12 to FR 2. Punishment shock was one-half the intensity of avoidance shock. Under these conditions, response rates increased initially but were quickly replaced by reduced rates. The number of avoidance shocks received did not change appreciably even when every other response was punished. Both of the above experiments employed marmoset monkeys as subjects.

The present investigation was undertaken to study the effects of increasing punishment-shock intensity upon the free-operant avoidance responding of albino rats. A functional definition of punishment was adhered to throughout.

METHOD

Subjects

Ten male albino rats of the Wistar strain were used; seven were experimentally naive and three (A, B, C) had received previous avoidance training. All of the animals were six to nine months old at the start of the experiment. They were housed in individual cages in the department colony and had free access to food and water throughout the experiment.

A Gerbrands rat test chamber, 8 by 9 by 7.5 in., with a single lever at the center of one end, 3 in. from the floor, was enclosed in a sound-attenuated chamber. The experimental program was provided by a series of Grason Stadler electromechanical circuits. Electric shock was provided by a 110 v ac shock source which included 200,000 ohms in series with the output. To provide for the delivery of two different shock intensities within a session, a special module was constructed. This consisted essentially of a relay operated rheostat. A lever press initiated the shock duration timer which simultaneously opened the relay so that the shock current was routed through the rheostat. When the relay was closed the shock current was not affected by the rheostat. The module also contained a milliammeter and a control knob which permitted adjustment of the shock intensity. The shock was scrambled to the grid floor of the test chamber. Data were recorded by electromechanical counters and a Gerbrands cumulative recorder.

Procedure

A free-operant avoidance procedure (Sidman, 1953) was used. Under this procedure, there is a fixed time interval between the presentation of brief electric shocks in the absence of a lever press (shock-shock interval), and each lever press postpones the next shock for a fixed period of time (response-shock interval). In the present case, the shock-shock and response-shock intervals were each 20 sec. The shock duration was 0.5 sec. Responses in the presence of shock did not terminate it. Experimental sessions were 45 min per day.

All animals were trained with an avoidance-shock intensity of 1.25 ma. Training was continued until a stable level of performance was achieved. Stability was defined throughout the experiment as a range of 25 or fewer shock occurrences over five consecutive sessions. When this criterion had been met the punishment contingency was introduced. Under this condition each lever press immediately produced a 0.50-sec electric shock. Three schedules of punishment were employed, with the animals grouped accordingly.

Punishment Schedule I. Six rats (A, B, C, D, E, F) were initially exposed to a punishment-shock intensity of 0.35 ma, which was maintained until stable performance was again achieved. Punishment-shock intensity was then increased in increments of 0.30 ma, as stable performance was achieved at succeeding shock levels. The animal was exposed to increasing punishment shock until it met either of two arbitrarily assigned suppression criteria: (a) 20 or fewer responses over two consecutive sessions (Rats B, C, D); (b) Avoidance of less than 10% of the scheduled shocks over two consecutive sessions (Rats A, E, F). Avoidance parameters remained unchanged throughout the punishment procedure.

When the suppression criterion had been met, Rats A, B, and E had the punishment shock reduced to 0.65 ma. It remained at this level until stable performance was achieved, at which point it was reduced to zero. Rats C, D, and F had punishment shock reduced to zero after suppression. Assignment to the two groups was again arbitrary. All animals were exposed to the avoidance contingency for a minimum of 10 sessions after the punishment shock was withdrawn. If some recovery of responding occurred during this period, experimental sessions were continued until performance stabilized.

Punishment Schedule II. Two rats which had been exposed to Schedule I (C, F) and two previously naive animals (K, M) were employed under this schedule. The previously punished animals were given additional avoidance training. After stable performance was achieved all animals were exposed to punishment shock of 0.65 ma. This contingency was maintained until stable performance was again achieved, at which point punishment shock was increased to 1.25 ma. Punishment was continued at this intensity until animals met the suppression criterion of avoidance of less than 10% of the scheduled shocks over two consecutive sessions. Punishment was also terminated if the animal failed to reach this criterion in 20 sessions.

The two previously naive rats (K, M) were exposed to reduced punishment shock after suppression. Albino M had punishment shock immediately reduced to zero, while Albino K was exposed to 0.65-ma punishment before punishment shock was withdrawn. These contingencies were again maintained until stable performance was achieved at the respective intensities.

Punishment Schedule III. Two rats which had been exposed to Schedule I (A, E) and two previously naive animals (J, L) were employed under this schedule. The previously punished animals were given additional avoidance training. After performance stabilized, all animals were exposed to a punishment shock of 1.25 ma. This contingency remained in effect until the animal met the criterion for suppression by avoiding less than 10% of the scheduled shocks over two consecutive sessions. Following suppression, Albino L had punishment shock withdrawn in accord with the two-step procedure (0.65, 0.0 ma). Albino J could not be run under the reduced punishment condition, having died in an accident unrelated to the conditioning procedure.

RESULTS

Punishment Schedule I

Five of the six animals showed increased responding during the first punishment session; the results for this session are shown in Table 1.

Table 1
Performance for the First Session under Punishment

Subject	*Responses*	*Change in Responses over Mean of Five Previous Sessions*	*Avoidance Shocks*	*Change in Avoidance Shocks over Mean of Five Previous Sessions*
Alb A	665	+316	21	+5
Alb B	192	−381	88	+72
Alb C	578	+261	15	−18
Alb D	287	+28	88	+7
Alb E	531	+188	28	−6
Alb F	783	+393	70	+42

This effect rapidly attenuated, however, so that all animals showed reduced response rates as a consequence of the 0.35-ma punishment shock, when the criterion for stable performance was achieved. Each subsequent increase in punishment shock produced consistent decreases in responding and increases in avoidance shocks for all animals. These data are presented in Fig. 1.

It can be seen that three of the rats (B, D, E) met their assigned suppression criterion at a punishment-shock intensity of 1.25 ma. Two others (A, F) met their criterion when punish-

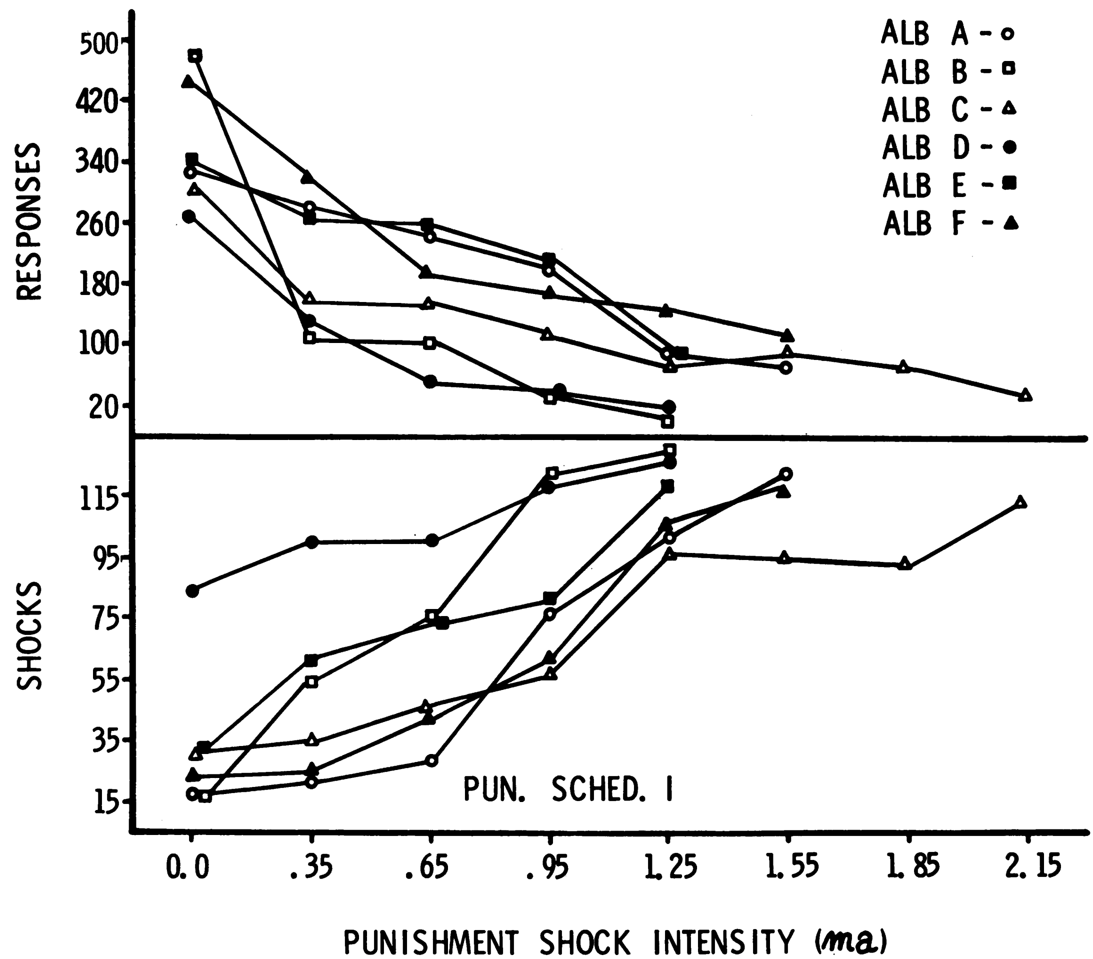

Fig. 1. The mean number of responses and avoidance shocks for each animal over the final three sessions at each punishment-shock intensity. The data points for Albino A at 1.55 ma represent the mean over two sessions.

ment shock was increased to 1.55 ma, while the final animal (C) did not display criterion performance until punishment shock was increased to 2.15 ma. As it turned out, the criterion of 20 or fewer responses over two consecutive sessions was the more difficult to achieve. All of the animals except Albino C avoided less than 10% of the scheduled shocks while still making more than 20 responses per session.

The cumulative records for one animal (A) at each final session during increasing punishment shock are presented in Fig. 2. The record for the first day of punishment shock at 0.35 ma is also presented. These records, which are typical, show that the punishment procedure gradually suppressed responding. The distribution of responding within a session was not significantly altered. The initial presentation of punishment shock produced bursts of responding, but this effect attenuated over the course of the session.

When punishment was withdrawn, the animals showed varying degrees of recovery in relation to their pre-punishment performance. These data are shown in Fig. 3 with the points at the extreme right representing asymptotic pre-punishment performance.

These data show that the animals subjected to the more stringent suppression criterion (B, C, D), *i.e.*, making 20 or fewer responses over two consecutive sessions, made the smallest degree of recovery. Rats B and D, in fact, showed no recovery at all over the period studied. On the other hand, the animals exposed to the suppression criterion of less than 10% avoidance effectiveness (A, E, F) showed a much higher degree of recovery in terms of

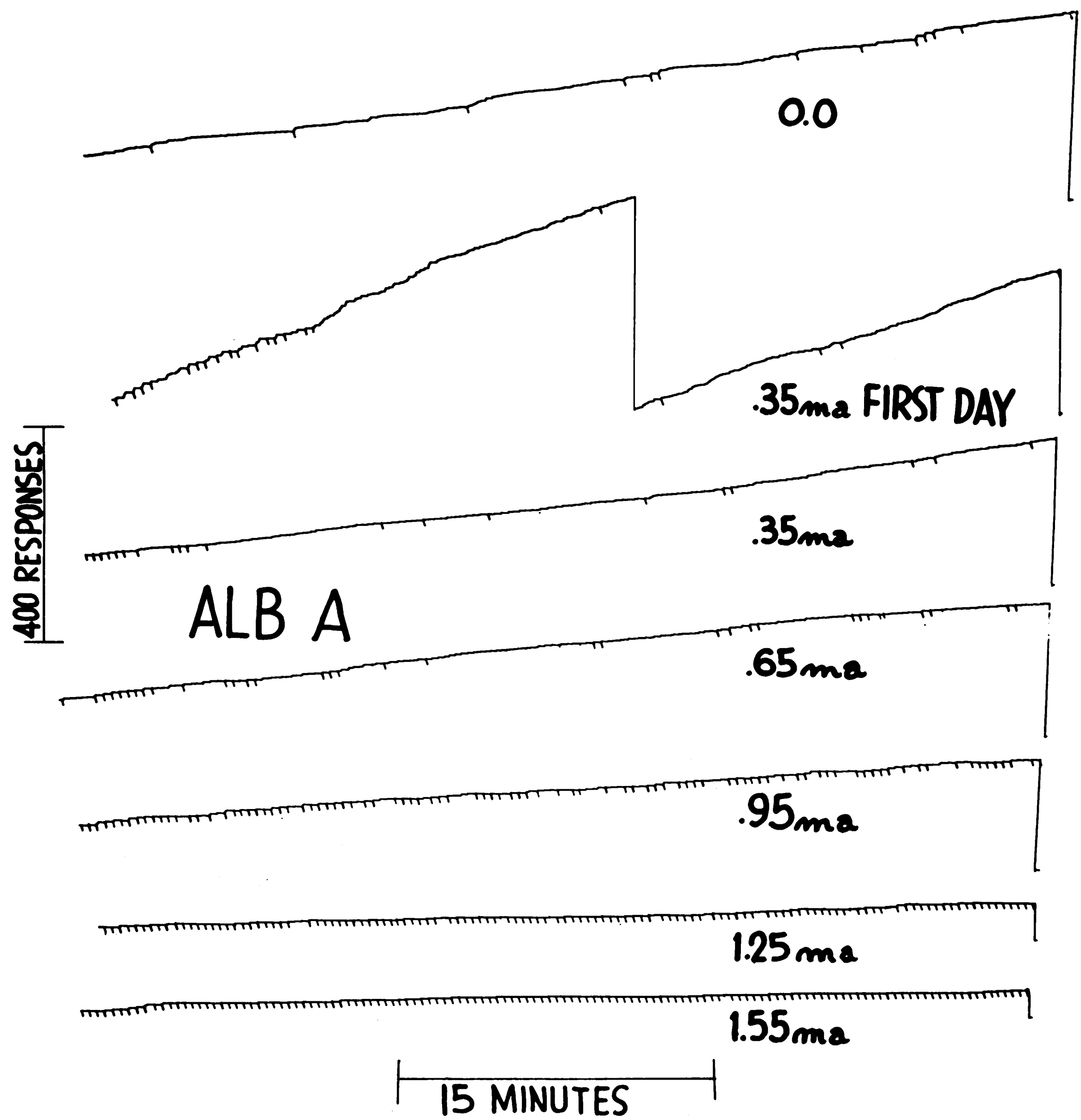

Fig. 2. Cumulative records of the last session at each shock intensity during increasing punishment shock for Albino A. The record for the first day of punishment shock at 0.35 ma is also presented. Avoidance shocks are indicated by the downward displacements of the response pen.

both number of responses and avoidance shocks. Whether the animal had punishment shock reduced in one or two steps seemed to exert no differential effect in terms of the degree of recovery eventually achieved.

The number of sessions at each punishment-shock intensity is given for each subject in Table 2. It can be readily seen that the stability criterion was generally achieved more quickly as the punishment-shock intensity was increased.

Table 2

The number of sessions at each punishment shock intensity.

Subjects	*0.0*	*0.35*	*0.65*	*0.95*	*1.25*	*1.55*	*1.85*	*2.15*	*0.65*	*0.0*
Punishment Schedule I										
Alb A Sessions	20	6	9	12	2				7	11
Alb B Sessions	14	12	8	3					14	11
Alb C Sessions	19	5	9	14	5	6	6			23
Alb D Sessions	12	11	5	13						13
Alb E Sessions	16	11	10	5					9	7
Alb F Sessions	14	14	9	5	5					7

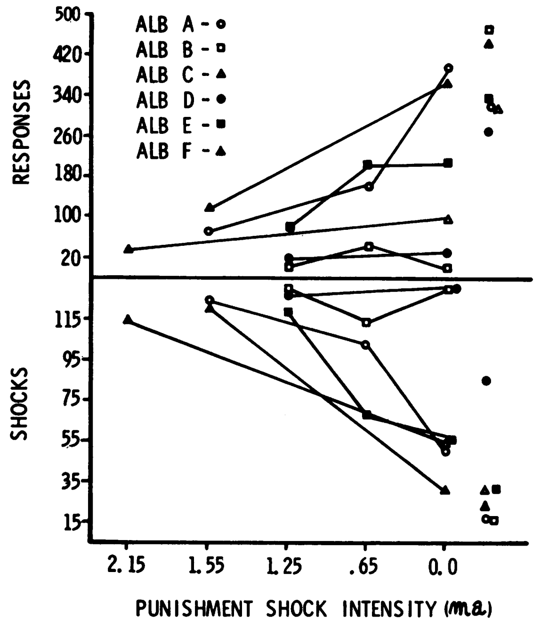

Fig. 3. The mean number of responses and avoidance shocks for each animal over the final three sessions with decreasing punishment shock. The points plotted at 2.15, 1.55, and 1.25 ma represent the mean over the final three sessions before punishment shock reduction. The data points at the extreme right represent the asymptotic pre-punishment performance for each animal.

Punishment Schedules II and III

The data for these two groups are presented together to facilitate comparison. The number of responses and shocks emitted by and delivered to each animal in the two experimental groups over the last three sessions at each punishment shock intensity is shown in Fig. 4.

These data show a marked suppression of responding for all animals with punishment shock introduced at 0.65 ma. The rats not previously punished (K, M) also received many more avoidance shocks. On the other hand, the previously punished rats (C, F) showed essentially no change in avoidance shocks received. All rats, except Albino C, showed marked decreases in responding during the initial punishment session. Albino C showed a slight increase. These results contrast with those of Punishment Schedule I, where four of the six animals showed significant increases in responding during the initial punishment session.

When punishment shock was increased to 1.25 ma, three of the four animals met the criterion for suppression by avoiding less than 10% of the scheduled shocks over two consecutive sessions. It is interesting to note that Albino F failed to meet this same criterion under Schedule I until punishment was increased to 1.55 ma. Albino C did not meet the suppression criterion with punishment shock at 1.25 ma, even though it was exposed to this contingency for 20 sessions. This animal required punishment shock of 2.15 ma before meeting the criterion for suppression under Schedule I.

All animals in the group that had punishment shock introduced at 1.25 ma showed an immediate reduction of responding to almost the zero level. This effect can be seen clearly in the cumulative records of the final unpunished session, and the initial punishment session for Albino L, which are presented in Fig. 5. All animals met the suppression criterion in the minimum number of sessions. This group also included one animal (A) that required punishment shock higher than avoidance shock to meet the suppression criterion under Schedule I.

In the three animals studied under conditions of reduced punishment shock, two (K, L) had shock withdrawn in two steps (0.65, 0.0 ma), while the third (M) had punishment shock reduced to zero immediately after suppression. This latter animal showed complete recovery of avoidance responding to the prepunishment level. On the other hand, of the animals exposed to a two-step reduction in punishment shock, Albino K showed only partial recovery avoidance responding and Albino L showed no recovery at all over the period studied.

Table 3 shows the number of sessions at each punishment-shock intensity for each animal.

Table 3

The number of sessions at each punishment shock intensity.

Subjects	0.0	0.65	1.25	0.65	0.0
	Punishment-Shock Intensity (ma)				
Punishment Schedule II					
Alb C		8	20		
Alb F		14	7		
Alb K		6	2	10	10
Alb M		7	2		6
Punishment Schedule III					
Alb A,E,J			2		
Alb L			2	10	15

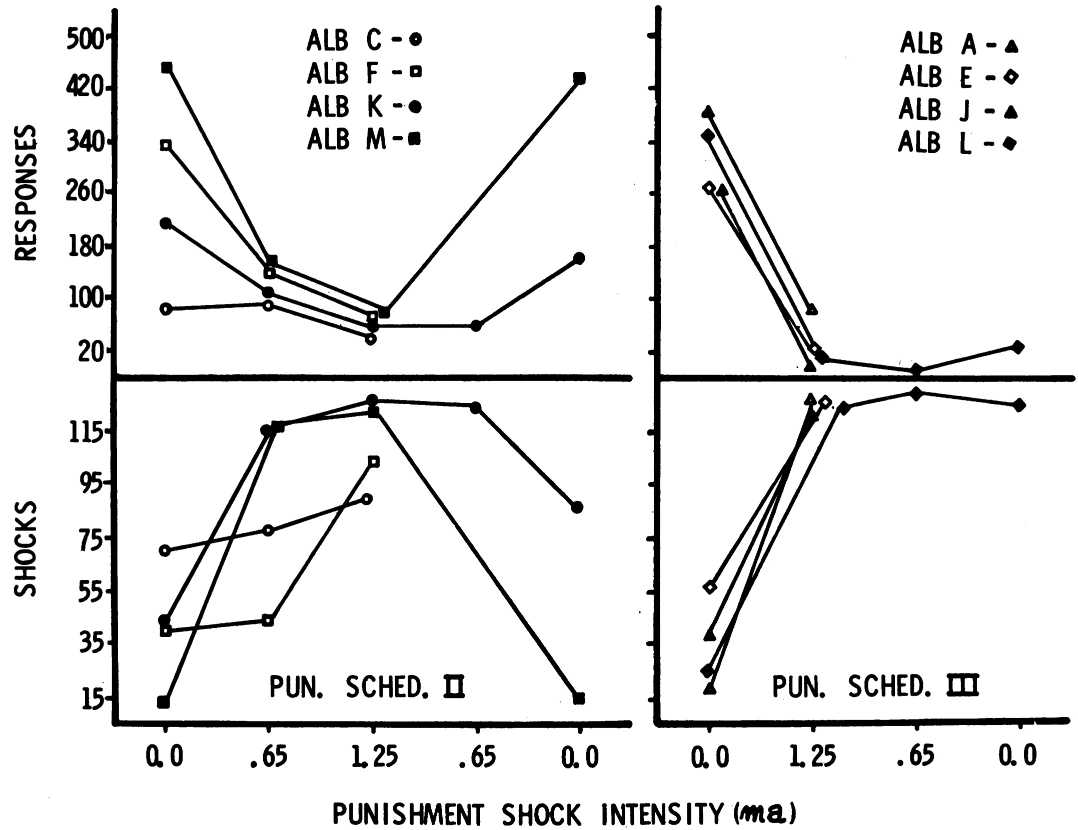

Fig. 4. The mean number of responses and avoidance shocks for each animal in the two groups over the final three sessions at each punishment-shock intensity. The data points for Albinos A, E, J, K, L, and M at 1.25 ma represent the mean over two sessions.

These data show clearly that the suppression criterion was achieved much more quickly when punishment shock was presented initially at 1.25 ma, as compared to presentation at this intensity after punishment with lower shock intensities.

DISCUSSION

The present results show a functional relationship between response suppression and punishment-shock intensity with responding being maintained by a negative reinforcement

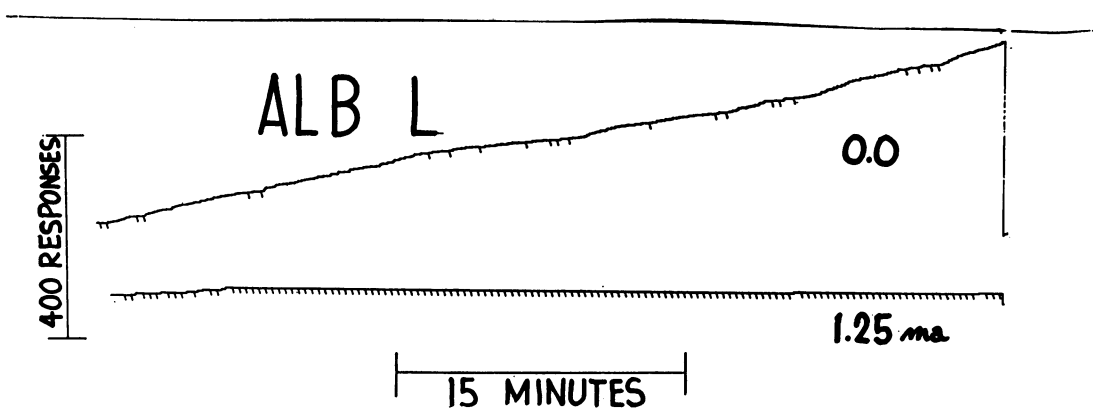

Fig. 5. Cumulative records of the last unpunished session and the first punishment session for Albino L. Avoidance shocks are indicated by the downward displacements of the response pen.

contingency. All of the animals showed systematic decreases in response rate and increases in avoidance shocks received as a function of increasing punishment-shock intensity. These findings are in essential agreement with the results of experiments in which the effects of punishment shock upon positively reinforced responding were studied (Azrin, 1960; Appel and Peterson, 1965; Hake *et al.*, 1967). They contrast with the results of experiments in which "free" or unavoidable shocks were concurrently presented during avoidance training. This procedure resulted in increased responding (Sidman *et al.*, 1957; Kelleher *et al.*, 1963). This difference in effect would seem to relate to the contingency between response and shock which existed in the punishment experiments, as opposed to the non-contingent presentation of shock in the other experiments cited. McKearney's (1968) recent finding, that a fixed-interval schedule of electric shock presentation maintained a pattern of positively accelerated responding in monkeys, further illustrates the importance of the contingency between stimulus and response. McKearney originally trained his animals under a free-operant avoidance procedure. A 10-min fixed-interval schedule of electric shock presentation was then added concurrently, and had little effect on the pattern of responding. When the avoidance schedule was eliminated, the fixed-interval schedule of shock presentation produced a pattern of positively accelerated responding quite similar to that seen under fixed-interval schedules of reinforcement. McKearney pointed out that two of the most important determinants of the effects of a stimulus are the manner in which its presentation is related to responses, and the reinforcement history of the subject.

The present results also showed that a punishment shock introduced at a particular intensity will have a greater suppressive effect upon responding than the same intensity after exposure to lower shock intensities. These data similarly suggest that the more gradual the increase in punishment intensity, the less effective any particular intensity will be in suppressing responding. This is essentially what Miller (1960) found relative to the effect of increases in punishment shock upon positively reinforced responses.

Under Schedule I, which involved small increases in punishment shock intensity, three of the six animals required punishment shock higher than avoidance shock in order to meet the suppression criterion. When exposed to the schedules employing larger increments in punishment shock, two of these animals met the suppression criterion with punishment shock equal to avoidance shock. All of the animals initially exposed to the schedules employing larger increments in punishment shock, met the suppression criterion with punishment shock and avoidance shock equal. It would appear then, that gradual increases in punishment shock may sometimes generate behavior which could be described as self-aversive.

The degree of recovery after punishment was withdrawn was found to be a function of the degree of response suppression imposed by the punishment. The three animals (B, D, L) that displayed the highest degree of suppression showed essentially no recovery over the period studied. Hake *et al.* (1967) also found that spontaneous recovery was delayed or absent after complete suppression. They found it necessary to reinstate responding by shaping with four of their animals. All of the animals eventually recovered pre-punishment rates. The difference between the Hake *et al.* results and those of the present experiment may relate to either of the following points: (a) No procedure analogous to reshaping was employed in the present experiment. (b) The behavior was not studied over as long a period in the present experiment. The animals that retained the highest response rates (A,E,F,M) in the present experiment showed rapid recovery to levels which approximated their pre-punishment performance. This was true even though the punishment shock severely disrupted the effectiveness of their avoidance responding.

The present findings, relative to the permanence of response reduction, are therefore in general agreement with the results of earlier experiments which examined this effect after punishment of positively reinforced responding (Azrin, 1960; Appel, 1961).

In summary, it can be said that the effects of punishment examined in the present experiment, which involved negatively reinforced responding, conform very closely to the results of experiments which have studied the same punishment effects relative to positively reinforced responding.

REFERENCES

Appel, J. B. Some schedules involving aversive control. *Journal of the Experimental Analysis of Behavior*, 1960, **3**, 349-359.

Appel, J. B. Punishment in the squirrel monkey *Saimiri sciurea*. *Science*, 1961, **133**, 36.

Appel, J. B. and Peterson, N. J. Punishment: Effects of shock intensity on response suppression. *Psychological Reports*, 1965, **16**, 721-730.

Azrin, N. H. Effects of punishment intensity during variable-interval reinforcement. *Journal of the Experimental Analysis of Behavior*, 1960, **3**, 123-142.

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.

Estes, W. K. and Skinner, B. F. Some quantitative properties of anxiety. *Journal of Experimental Psychology*, 1941, **29**, 390-400.

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.

Kelleher, R. T., Riddle, W. C., and Cook, L. Persistent behavior maintained by unavoidable shocks. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 507-517.

McKearney, J. W. Maintenance of responding under a fixed-interval schedule of electric shock presentation. *Science*, 1968, **160**, 1249-1251.

Miller, N. E. Learning resistance to pain and fear effects over learning, exposure, and rewarded exposure in context. *Journal of Experimental Psychology*, 1960, **60**, 137-145.

Sandler, J., Davison, R. S., Greene, W. E., and Holzschuh, R. D. Effects of punishment intensity on instrumental avoidance behavior. *Journal of Comparative and Physiological Psychology*, 1966, **61**, 212-216.

Sandler, J., Davidson, R. S., and Holzschuh, R. D. Effects of increasing punishment frequency on Sidman avoidance behavior. *Psychonomic Science*, 1966, **5**, 103-104.

Sidman, M. Two temporal parameters of the maintenance of avoidance behavior by the white rat. *Journal of Comparative and Physiological Psychology*, 1953, **46**, 253-261.

Sidman, M., Herrnstein, R. J., and Conrad, D. G. Maintenance of avoidance behavior by unavoidable shock. *Journal of Comparative and Physiological Psychology*, 1957, **50**, 553-557.

Received 14 June 1968.