JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1970, 14, 201-211 NUMBER 2 (SEPTEMBER)

THE EFFECT OF PUNISHMENT SHOCK INTENSITY UPON RESPONDING UNDER MULTIPLE SCHEDULES[1]

ROBERT W. POWELL

UNIVERSITY OF SOUTH FLORIDA

In the first of two experiments, responses of two pigeons were maintained by multiple variable-interval, variable-ratio schedules of food reinforcement. Concurrent punishment was introduced, which consisted of a brief electric shock after each tenth response. The initial punishment intensities had no lasting effect upon responding. Then, as shock intensity increased, variable-ratio response rates were suppressed more quickly than variable-interval response rates. When shock intensity decreased, variable-interval responding recovered more quickly, but the rates under both schedules eventually returned to their pre-punishment levels. In the second experiment, the following conditions were studied in three additional pigeons: (1) With each shock intensity in effect for a number of sessions, punishment shock intensity was gradually increased and decreased and responding was maintained by multiple variable-ratio, fixed-ratio schedules of food reinforcement; (2) Changes in punishment shock intensity as described above with responding maintained by either a variable-ratio or a fixed-ratio schedule, which were presented on alternate days; (3) Session-to-session changes in shock intensity with responding maintained by multiple variable-ratio, fixed-ratio schedules. Responding under the two schedules was suppressed to approximately the same extent by a particular shock intensity. Also, post-reinforcement pauses under the fixed-ratio schedule increased as response suppression increased.

Studies of punishment have 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; Powell and Morris, 1969). It has also been found that the effects of a punishing stimulus are influenced by the schedule of reinforcement maintaining the response. When responding is maintained by a variable-interval (VI) schedule, response rate decreases, as punishment shock intensity increases, but the pattern of responding remains relatively stable (Azrin, 1960). Responding under fixed-interval (FI) schedules is characterized as a discrete two-state process, that is, as an extended pause after reinforcement, followed by a rapid transition to a high and constant response rate (Schneider, 1969). Under this schedule, punishment reduces overall responding in proportion to the punishment intensity, but the pattern of responding is not altered substantially (Azrin and Holz, 1961). When punishment is delivered for every response under fixed-ratio (FR) schedules, the major effect is an increase in the duration of post-reinforcement pauses. The ratio response rate, which is typically high, is reduced only slightly (Azrin, 1959*b*). Punishing the first response in the ratio has essentially the same effect (Dardano and Sauerbrunn, 1964). The effect of punishment upon responding under variable-ratio (VR) schedules has not been studied, but Lyon and Felton (1966) did study the effects of imposing a conditioned suppression paradigm upon a baseline of responding maintained by several VR schedules. Conditioned suppression is a decrease in response rate during a relatively short duration stimulus that terminates independently of the animal's behavior and coincidentally with a brief unavoidable shock. The authors found that generally the VR schedules studied were quite insensitive to the conditioned suppression procedure, although almost total suppression was obtained on a few occasions. Also, the response rate during the pre-shock stimulus often decreased abruptly, independent of the presentation of a reinforcement.

While the available studies point to characteristic differences in the effects of punishment upon responding under the different

[1]The author wishes to thank Richard Prewitt for his help in collecting the data and Max Dertke for his thoughtful reading of the manuscript. Reprints may be obtained from the author, Department of Behavioral Science, University of South Florida, Tampa, Florida 33620.

schedules of reinforcement, they do not provide a sound basis for camparing punishment effects under different schedules. This is true because of differences in subjects, punishment techniques, punishment shock intensities, deprivation, and other relevant variables.

Multiple schedules involve two or more independent schedules of reinforcement, which are presented successively to the subject, with each schedule signalled by a different stimulus. Ferster and Skinner (1957) suggested that multiple schedules provide a technique for arranging control performances within a single subject and a single session. They showed that the basic schedules of reinforcement produce patterns of responding that are qualitatively similar to the performance generated by the same schedules presented alone.

The present experiments were undertaken to study the degree of response suppression produced by increasing punishment shock intensities under VR, VI, and FR schedules. Recovery of responding was studied as punishment shock was decreased and finally withdrawn. Multiple schedules were employed in order to maximize control.

EXPERIMENT I: MULTIPLE VARIABLE-RATIO AND VARIABLE-INTERVAL SCHEDULES

METHOD

Subjects

Two adult White Carneaux pigeons (16, 20) were maintained within 10 g of 80% of their free-feeding weight. Both pigeons were experimentally naive. Water and grit were available at all times in the home cages.

Apparatus

A Lehigh Valley pigeon test chamber, Model 1519C, was employed. Mixed grain was used for reinforcement. Reinforcement times were 2.5 sec (Bird 16) and 3.5 sec (Bird 20), throughout the experiment. During reinforcement, the key light was turned off. All scheduling was accomplished by standard relay circuitry. Electric shock was provided by a 110-v ac shock source and was delivered to the pigeons via internally implanted electrodes (Azrin, 1959*a*). The resistance of the electrodes *in situ* was approximately 3 K ohms for each bird, as measured by an ohmmeter. Shock intensities were measured with a 3 K ohms resistor substituting for the pigeon in the circuit. Changes in the shock current were accomplished by adjustments of a variable transformer. Data were recorded by digital counters and a Gerbrands cumulative recorder.

Procedure

Training. Following shaping in the presence of a white key light, the pigeons were exposed to gradually extended VR and VI schedules presented during alternate sessions. The VR and VI schedules were signalled by green and red keylights, respectively. Training was continued until stable performance was achieved under both VR 100 and VI 1-min schedules, which required 47 and 53 sessions for Birds 16 and 20, respectively. These sessions were generally 30 min in duration. The birds were next trained under a multiple VR 100, VI 1-min schedule that had 6-min components. Throughout the experiment, the initial component presented in a session alternated from day to day. Sessions were 36 min in duration. Training to stable performance required 36 sessions for each bird. The stability criterion was a variation in response rates of $\pm 10\%$ or less of the mean rate under each schedule over 10 consecutive sessions.

Punishment. Electric shock, 0.20 sec in duration, was delivered for every tenth response under each schedule. The punishment schedule and the reinforcement schedules were independent, so it was possible for a single response to produce both food and electric shock. The FR schedule of punishment did not reset when the components in the multiple schedule changed. Both birds were initially exposed to a shock intensity of 1.30 mA, which was maintained until stable performance was achieved. The stability criterion during punishment was a variation in response rates of $\pm 10\%$ or less of the mean rate under each schedule over four consecutive sessions. Shock intensity was then gradually increased as stable performance was achieved at succeeding shock intensities. In addition, each shock intensity remained in effect for a minimum of five and a maximum of 12 sessions. Each bird was exposed to increasing punishment shock until it met the following suppression criteria: no responses over two consecutive sessions (Bird 16), or fewer than 100 responses per session over four consecutive sessions (Bird 20).

Recovery. When the suppression criterion was achieved, punishment shock intensity was gradually reduced to zero for each bird. Decreases in punishment shock were scheduled according to the same stability criterion that applied when punishment shock was increasing. For Bird 16, whose responding was suppressed completely, it was necessary to increase deprivation markedly in order to reinstate responding. This bird's body weight decreased approximately 12% as a result of reduced feeding over 10 days, before any responding occurred. Body weight was then gradually returned to the 80% level by supplemental feeding over 30 days, as the experiment continued.

Results

The data for the entire experiment, which are summarized in Table 1, show that both birds had higher pre-punishment response rates under the VR schedule. The initial punishment shock intensities had no lasting suppressive effect upon responding under either schedule, and the VR response rate remained higher. However, as shock intensity increased further, VR responding was suppressed more fully than VI responding. This difference in response suppression continued until shock intensity decreased. Variable-interval responding then showed greater initial recovery, but the VR response rates eventually became higher

Table 1

Response rates under each schedule and number of sessions at successive shock intensities. Mean response rates for the first four and last four sessions are presented, where eight or more sessions were conducted at a particular intensity.

	Pigeon 16				*Pigeon 20*			
			Resp. Rate (min)				*Resp. Rate (min)*	
Reinf. Sched.	*Shock Int. (mA)*	*No. of Sess.*	*First 4 Sess.*	*Last 4 Sess.*	*Shock Int. (mA)*	*No. of Sess.*	*First 4 Sess.*	*Last 4 Sess.*
VR	0.00	47		100	0.00	53		152
VI	0.00			74	0.00			112
VR	1.30	11	97	74	1.30	10	157	140
VI	1.30		74	67	1.30		121	120
VR	2.50	12	79	80	3.30	12	139	133
VI	2.50		77	79	3.30		109	103
VR	4.25	12	101	100	6.70	12	158	151
VI	4.25		91	89	6.70		112	134
VR	6.70	5		93	12.00	7		81
VI	6.70			81	12.00			65
VR	12.00	12	35	37	16.00	12	30	4
VI	12.00		56	43	16.00		31	17
VR	16.00	6		0.1	20.00	11	0.4	0.1
VI	16.00			0.5	20.00		17	5
VR	20.00	10	0.1	0.0	12.00	12	1.0	0.3
VI	20.00		1.0	0.1	12.00		5	4
VR	12.00	12	0.0	0.0	6.70	11	1.0	1
VI	12.00		0.0	3	6.70		16	107
VR	4.25	11	19	12	2.50	12	2	113
VI	4.25		38	17	2.50		129	111
VR	1.60	12	81	127	0.00	6		132
VI	1.60		63	119	0.00			123
VR	0.00	5		160				
VI	0.00			118				

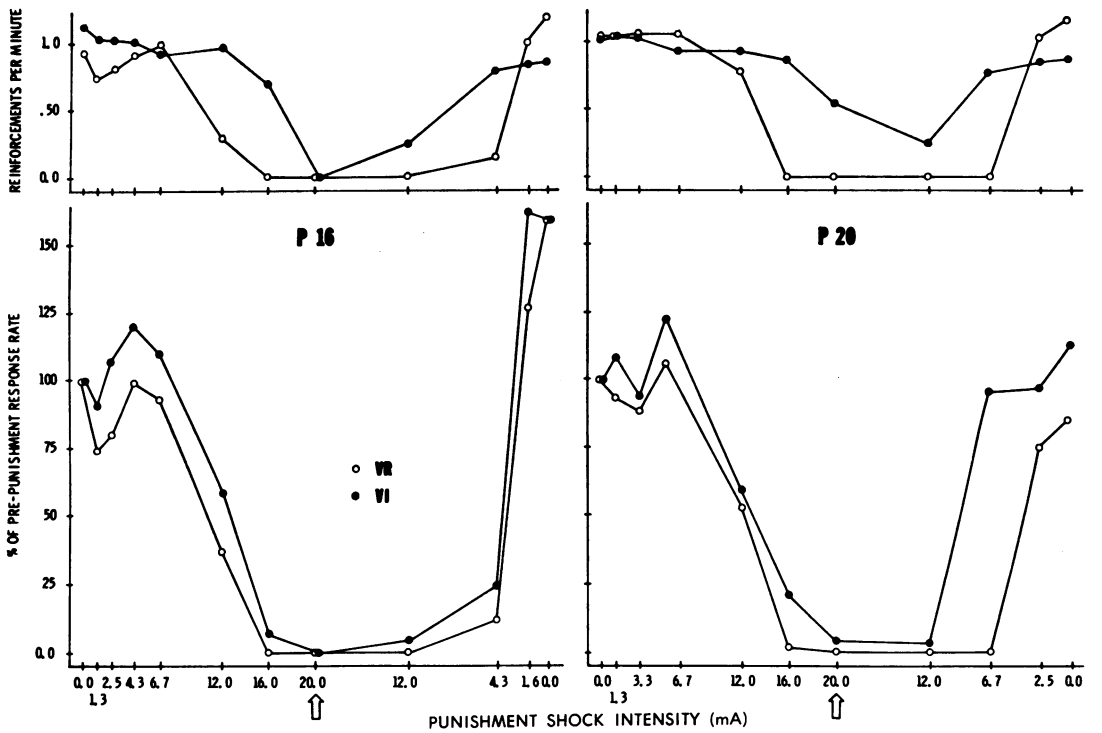

Fig. 1. Response rates and reinforcement rates for the two birds under multiple VR and VI schedules with successive increases and decreases in punishment shock intensity. The response rate at each shock intensity has been calculated as a percentage of the pre-punishment response rate under the same schedule. The arrow beneath the abscissa indicates the highest shock intensity presented. To the right of the arrow, shock intensities decrease.

for both birds. Figure 1 shows more clearly the greater suppression of VR responding by punishment. In this figure, response rates during punishment under each schedule have been calculated as percentages of pre-punishment response rates under the same schedule.

Before punishment, reinforcement frequency was approximately equal under the two schedules for Bird 20, while the responding of Bird 16 was reinforced at a higher rate under the VI schedule, as shown in.Fig. 1. The rate remained higher under the VI schedule for both birds, at punishment intensities that produced significant response suppression.

A comparison of the response rates under each schedule at high shock intensities (6.70 to 20.00 mA) shows that responding was more suppressed at a particular shock intensity during the decreasing series than it was at the same intensity when punishment shock was increasing. Table 1 shows also that response rates generally decreased with exposure to an intensity during the increasing series, but changes in rate were inconsistent at a particular shock intensity, as shock decreased.

Cumulative records of responding at different punishment shock intensities are presented for each bird in Fig. 2. Both birds showed considerable within-session recovery of responding at certain shock intensities. For both birds, suppression of responding was most pronounced during the initial components of a session and tended to recover gradually with each succeeding component. Variable-interval responding was generally more stable than responding under the VR schedule, as well as being more resistant to the suppressive effects of punishment.

EXPERIMENT II: MULTIPLE AND SINGLE VARIABLE-RATIO AND FIXED-RATIO SCHEDULES

Method

Subjects

Three adult White Carneaux pigeons (33, 44, 50) were maintained within 10 g of 75%

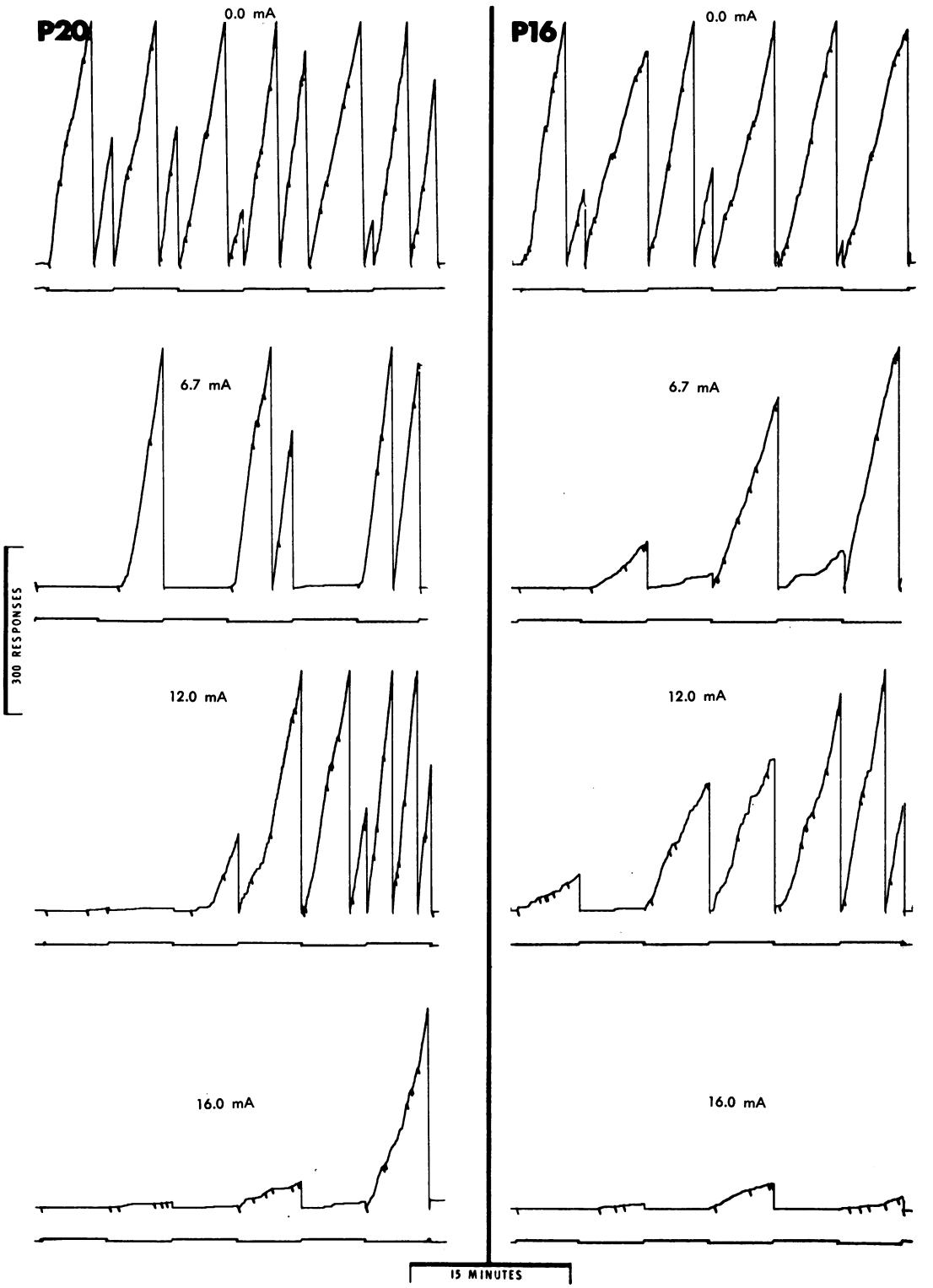

Fig. 2. Representative cumulative records for each pigeon with zero, intermediate, and high punishment intensities. The VR schedule was in effect when the event pen was in the "up" position.

of their free-feeding weight. All pigeons had previous FR training. Water and grit were available at all times in the home cages.

Apparatus

The apparatus was the same as Exp. I, except for the following: the FR schedule was arranged by a Grason-Stadler ratio counter. The elapsed time from the end of the reinforcement period to the first response in the ratio run, *i.e.,* the post-reinforcement pause, was measured under the FR schedule. Pause durations were recorded individually by a Grason-Stadler print-out counter, as well as cumulatively over each daily session. Internal resistance of the pigeons was approximately 3 K ohms, as measured by the same technique employed in Exp. I.

Procedure 1 (multiple schedules). The terminal schedules were VR 100 and FR 100, with the VR and FR schedules signalled by green and white keylights, respectively. The birds were trained under a multiple VR 100, FR 100 schedule, with 6-min components, until stable performance was achieved. Stability was defined according to the criterion of a variation in response rates of $\pm 10\%$ or less of the mean under each schedule over 10 consecutive sessions. Training sessions were 36 min in duration. Stable performance was achieved in 37, 40, and 35 sessions for Birds 33, 44, and 50, respectively.

Punishment shock, 0.20 sec in duration, was then introduced for every tenth response. Shock intensity was gradually increased according to the same four-day stability criterion observed in Exp. I. When each bird met a suppression criterion of 100 responses or less per session over four consecutive sessions, punishment shock was gradually decreased. This continued until response rates recovered to the pre-punishment level.

Procedure 2 (single schedules). The three pigeons were next studied with the VR 100 and FR 100 schedules presented singly during alternate sessions. The schedules were signalled by the same keylights as before. All sessions were 36 min in duration. Following baseline training with no shock, punishment shock 0.20 sec in duration was introduced for every tenth response at 3.30 mA for Birds 44 and 50, and 4.25 mA for Bird 33. Shock intensity was increased for each bird according to the same four-day stability criterion observed under the multiple schedule procedure, so there were two sessions under each schedule. Recovery of responding was studied as shock intensity gradually decreased for Bird 50 and was withdrawn completely following suppression for Bird 33.

Procedure 3 (session-to-session changes in punishment shock intensity under multiple schedules). Birds 33 and 50 were studied as punishment shock intensity changed in each succeeding session. The same schedule and punishment parameters were in effect as under Procedure 1. Each bird was re-trained for five sessions under the multiple schedule before punishment shock was reintroduced. Generally, punishment shock of a different intensity was present in every other session, with no shock present during the intervening sessions. The entire experimental sequence during this procedure is shown in Fig. 4.

Results

The mean response rate under FR was determined by dividing the total number of FR responses by the total time in the FR component less the post-reinforcement pause time and the reinforcement time. Variable-ratio response rates were calculated in the same way, except that reinforcement time only was deducted from the total time in the VR component.

Variable-ratio response rates were slightly higher than FR response rates under the multiple schedule before punishment. Figure 3 shows that asymptotic response rates under each schedule were not suppressed by the initial three or four punishment shock intensities. Both response rates then declined precipitously as shock intensity increased further, with the degree of suppression approximately equal under each schedule. Recovery of responding was similar under the two schedules for Birds 33 and 44, whereas VR responding recovered more rapidly for Bird 50. The response rates for each bird recovered to the pre-punishment level as punishment shock intensity was reduced.

The effects of punishment shock intensity upon responding under single VR and FR schedules were quite similar to that observed under multiple schedules. Generally, there was only slight suppression at the initial shock intensities and then a severe disruption of

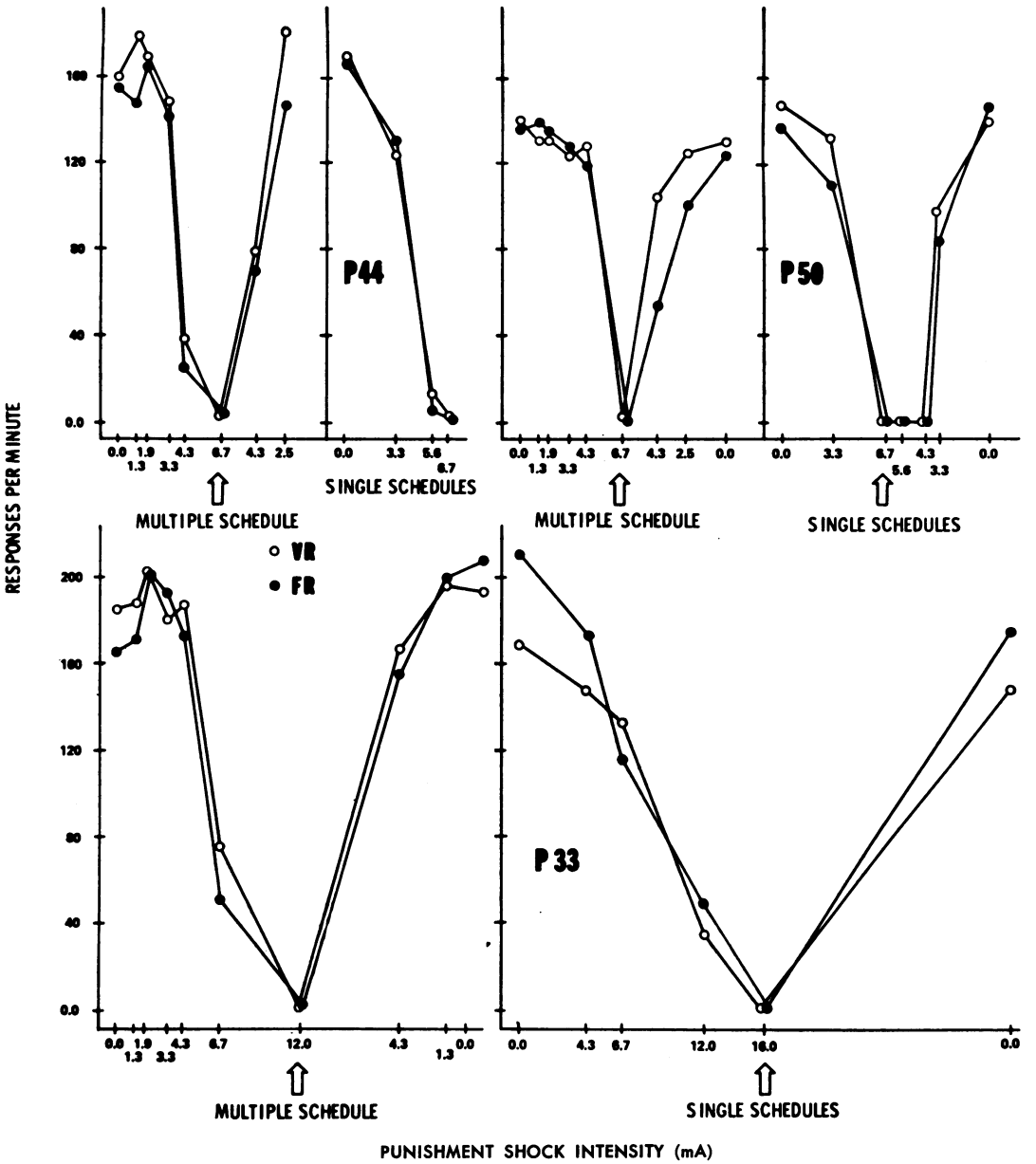

Fig. 3. Variable-ratio and FR response rates for each bird under the multiple schedule and single schedule procedures, with successive increases and decreases in punishment shock intensity. The arrow beneath the abscissa indicates the highest shock intensity presented. To the right of the arrow, shock intensities decrease. Each data point represents the mean performance over the final four sessions at that intensity.

responding occurred when punishment intensity increased again. Two of the birds (44, 50) met the suppression criterion at the same shock intensity under multiple and single schedules, while the third pigeon (33) showed a small difference (12.0 *vs* 16.0 mA). Post-punishment response rates were approximately equal to the pre-punishment rates under single VR and FR schedules in the two birds studied (33, 50).

Figure 4 shows that session-to-session changes in punishment shock intensity produced suppression under the multiple VR-FR schedules, which was generally greater the higher the shock intensity employed. Marked recovery of both VR and FR responding oc-

curred during sessions in which punishment was omitted. During the last eight sessions for each bird, responding decreased as shock intensity increased, and then increased as shock intensity was reduced. These data replicate to a fair degree the curves for the same birds shown in Fig. 3. The present results are based on single-session exposures to the different shock intensities, whereas the earlier procedure continued the same shock intensity for five to 12 sessions.

Changes in post-reinforcement pause duration were assessed as a function of response suppression under the FR schedule. The per cent of response suppression was calculated by dividing the FR response rate in each punishment session by the mean FR response rate before punishment. The difference between the unpunished response rate (100%) and the punished response rate was expressed as the per cent of response suppression. The data for individual sessions were then divided into three class intervals on the basis of response suppression, plus a class interval of 0.0 which corresponded to sessions in which punishment was not presented. The data were then averaged to yield the mean suppression percentage and the corresponding mean post-reinforcement pause for sessions falling within each class interval. Figure 5 shows that pause duration generally increased as response suppression increased, although there was inconsistency in the data of Bird 33. Pause duration was not compared directly to punishment shock intensity, because when a high degree of response suppression occurred, few reinforcements were obtained; and, therefore, few post-reinforcement pauses could be studied. By summarizing the data across several shock intensities, a sufficient number of pauses was obtained to permit meaningful comparisons.

Cumulative records that show intermediate levels of response suppression under single FR and VR schedules are presented for each

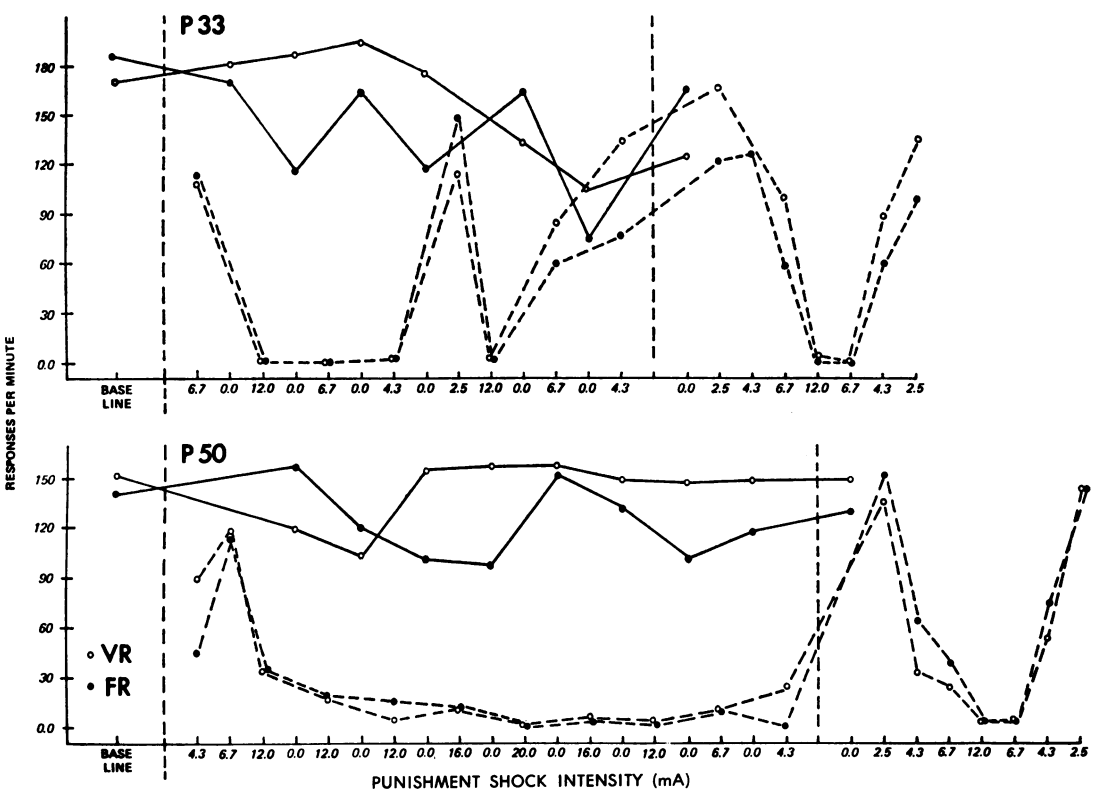

Fig. 4. Variable ratio and FR response rates for the two birds studied with session-to-session changes in punishment shock intensity. Each data point represents the mean performance for one session except for the baseline points, which represent four sessions. The dashed vertical lines correspond to transitions in procedure. The solid curves connect sessions in which punishment was absent. The dashed curves connect sessions in which punishment was present.

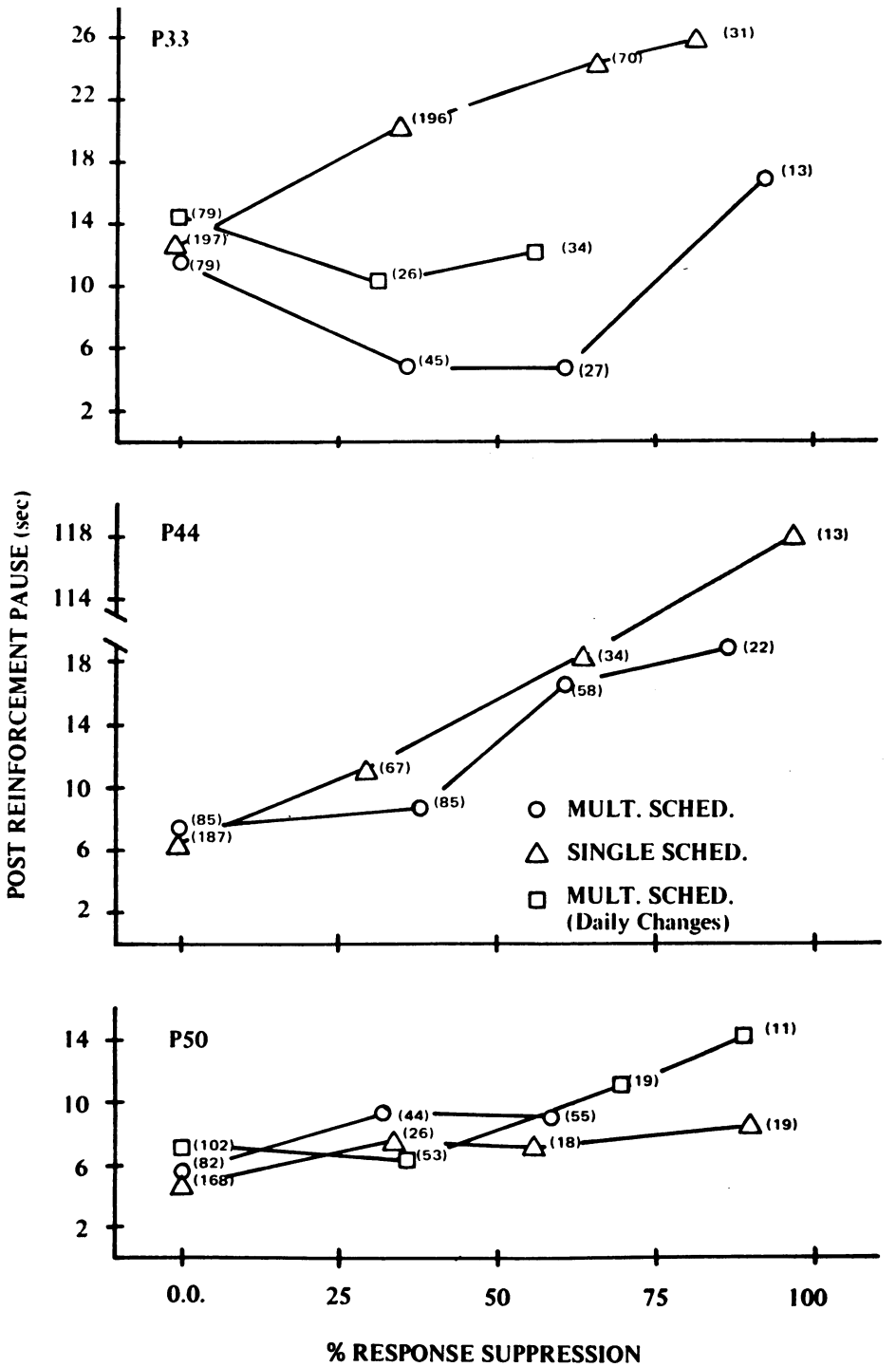

Fig. 5. Duration of post-reinforcement pausing under the FR schedule as related to the per cent of FR response suppression. Sessions were separated into three class intervals on the basis of per cent of FR response suppression as compared to the no-punishment condition (0.0). The limits of the class intervals were 25 to 49%, 50 to 74%, and more than 75% suppression. The numbers in parentheses are the number of post-reinforcement pauses upon which the corresponding data points are based.

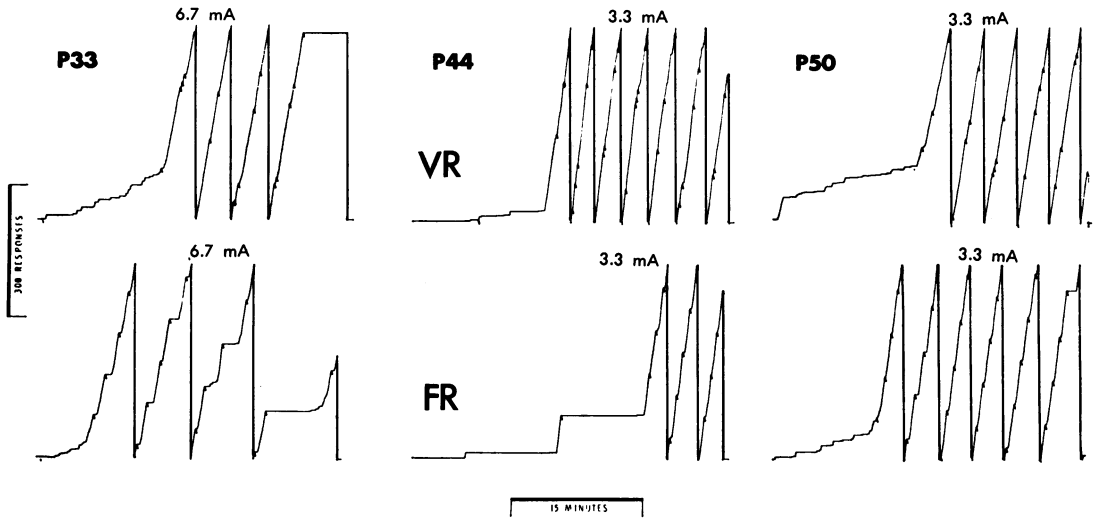

Fig. 6. Representative cumulative records for each pigeon under single VR and FR schedules at punishment shock intensities that produced an intermediate level of response suppression.

bird in Fig. 6. All records show that marked recovery occurred over the course of a session, and usually there was a sharp transition from the initially suppressed rate to the terminal rate attained in the session.

DISCUSSION

Responding under the VI schedule was more resistant to suppression by punishment than either the VR or FR schedules. The smaller amount of suppression under the VI schedule seems attributable to the slight decrease in reinforcement rate that occurs as responding under this schedule decreases. Studies by Anger (1956) and Catania and Reynolds (1968) have shown that rate of reinforcement is an important determinant of response rate under VI schedules.

Variable-ratio and FR responding were suppressed to approximately the same extent by a given punishment shock. Reinforcement rate decreases in direct proportion to decreases in response rate under VR and FR schedules. This suggests that a critical factor in the suppression of responding by punishment is the reduction in reinforcement rate that occurs as responding decreases.

Post-reinforcement pauses under the FR schedule, which were calculated separately, became longer as FR responding was suppressed. This finding agrees with the results of Azrin (1959) and Dardano and Sauerbrunn (1964), who reported that punishment reduced FR respondingly only slightly, while the major effect was an increase in the duration of post-reinforcement pauses.

Responding was suppressed to approximately the same degree, by a given shock intensity, under the single VR and FR schedules, as it had been during the VR and FR components of the multiple schedule. These effects were observed with a particular shock intensity in effect from five to 12 sessions. Approximately the same degree of response suppression was then obtained with the same shock intensity used earlier, during a procedure involving session-to-session changes in punishment shock intensity. This finding provides further evidence of the importance of prior exposure to shock, as a determiner of the effect that punishment shock will exert upon responding. Previous studies by Miller (1960), Rachlin (1966), and Powell and Morris (1969) have shown the importance of this factor. In the present case, prolonged exposure to different shock intensities resulted in an immediate and consistent change in response rate that accompanied each change in punishment shock intensity. This finding appears to be another example of the discriminative properties a punishing stimulus acquires, in addition to its aversive properties (Holz and Azrin, 1961).

At certain punishment intensities, all birds showed marked within-session recovery of responding under each schedule. This effect was most pronounced at intermediate punishment

shock intensities, where responding was usually severely disrupted or absent for the first two multiple schedule components and then recovered to approximately the pre-punishment level during the last several components of the session. Similar "warm-up" effects during punishment of responding under single schedules (Hake *et al.*, 1967; Azrin, 1960) have been reported.

In summary, the present results show that suppression of VI, VR, and FR responding increases as punishment shock intensity increases. Also, responding recovers to the pre-punishment level, or higher, under each schedule when punishment shock intensity is significantly decreased. Variable-interval responding is more resistive to complete suppression by punishment than the other two schedules, apparently because rate of reinforcement decreases less under this schedule as response rate decreases. The effects of punishment upon response patterns under VI, VR, and FR schedules seem to be the same, whether the schedules are presented singly or as components in multiple schedules.

The results of the present experiments demonstrate the usefulness of multiple schedule procedures in comparing the effects of punishment upon responding under different reinforcement schedules. The effect of many other independent variables could also be studied through these procedures.

REFERENCES

Anger, D. The dependence of interresponse times upon the relative reinforcement of different interresponse times. *Journal of Experimental Psychology*, 1956, **52**, 145-161.

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

Azrin, N. H. A technique for delivering shock to pigeons. *Journal of the Experimental Analysis of Behavior*, 1959, **2**, 161-163. (*a*)

Azrin, N. H. Punishment and recovery during fixed-ratio performance. *Journal of the Experimental Analysis of Behavior*, 1959, **2**, 301-305. (*b*)

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 during fixed-interval reinforcement. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 343-347.

Catania, A. C. and Reynolds, G. S. A quantitative analysis of the responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 327-383.

Dardano, J. F. and Sauerbrunn, D. Selective punishment of fixed-ratio performance. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 255-260.

Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.

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.

Holz, W. C. and Azrin, N. H. Discriminative properties of punishment. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 225-232.

Lyon, D. O. Frequency of reinforcement as a parameter of conditioned suppression. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 95-98.

Lyon, D. O. and Felton, M. Conditioned suppression and variable-ratio reinforcement. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 245-248.

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.

Powell, R. W. and Morris, G. Continuous punishment of free-operant avoidance in the rat. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 149-157.

Rachlin, H. Recovery of responses during mild punishment. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 251-263.

Schneider, B. A. A two-state analysis of fixed-interval responding in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 677-687.

Received 17 November 1969.