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SOME EFFECTS OF PUNISHMENT SHOCK INTENSITY UPON DISCRIMINATIVE RESPONDING[1]

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Three pigeons received visual discrimination training under both multiple variable-ratio extinction and variable-interval extinction schedules. All birds developed nearly perfect discrimination. When punishment for every tenth response during food reinforcement was presented, responding decreased as shock intensity increased. At the same time, responding during extinction, which was not punished, increased at intermediate punishment intensities, but returned to low levels under severe punishment. A second procedure, in which punishment and no-punishment sessions alternated unsystematically, was employed with two of the birds. The results under this procedure essentially replicated the data obtained as punishment shock intensity increased gradually.

Multiple schedules of positive reinforcement involve two or more independent reinforcement schedules that are presented successively to the subject, with each schedule correlated with a different stimulus. When extinction is one of the components, the experimental situation is typically identified as a discrimination. Animals exposed to this procedure eventually respond at much higher rates during the stimulus correlated with positive reinforcement (S^D), than during the stimulus correlated with extinction (S^Δ).

Experiments in which aversive stimuli have been concurrently presented during operant discrimination have produced inconsistent findings. Hearst (1965) superimposed a conditioned suppression procedure upon an established baseline of discriminative responding, maintained by a multiple variable-interval (VI) extinction schedule. Discrimination was impaired markedly in conjunction with decreased responding during the pre-aversive stimulus. The predominant effects were a supernormal rate of responding during extinction, but little change in response rate under positive reinforcement. When response-independent shocks were presented without a warning stimulus, discrimination was impaired to an even greater extent than by the conditioned suppression procedure. The presentation of strong response-dependent shock (punishment) also impaired discrimination, but the effect was temporary and discriminative performance returned to baseline as responding recovered from its initial overall suppression. Weiss (1968), on the other hand, found that the conditioned suppression procedure reduced responding under both S^D and S^Δ conditions. He observed also that mild response-independent shocks, presented without a warning stimulus, increased responding during S^D and S^Δ, although the effect was not systematic.

The present experiment studied the effects of punishment shock upon an operant discrimination. Because the differences between Hearst's and Weiss's finding could result from differences in shock intensity, a range of shock values was employed in the present experiment. In addition, VI and variable-ratio (VR) schedules were used as components in the multiple schedules. Since suppression of responding increases as punishment shock intensity increases, reinforcement frequency would be differentially affected under the two schedules. Under VR schedules, reinforcement frequency decreases in direct relation to decreases in response rate, while suppression of VI responding reduces reinforcement frequency only slightly (Powell, 1970). Thus, any differential changes in reinforcement frequency could be related to changes in discriminative performance, if they occurred.

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METHOD

Subjects

Three adult White Carneaux pigeons were maintained within 10 g of 85% of their free-feeding body weights; one (25) was experimentally naive and the other two (27, 29) had previous training under fixed-ratio schedules.

Apparatus

A Lehigh Valley pigeon test chamber, Model 1519C, was employed. Mixed grain was used for reinforcement. A minimum force of 15 g (0.147 N) was required to operate a microswitch attached to the response key. Reinforcement times were 3.0 sec (Birds 25, 29) and 3.5 sec (Bird 27) throughout the experiment. During reinforcement, the keylight was turned off. Experimental procedures were scheduled by standard relay circuitry. Electric shock was provided by a 110-v ac shock source that included a 10 K ohms resistor in series with the output. Shock was delivered to the pigeons via internally implanted electrodes according to the technique developed by Azrin (1959). The resistance of the electrodes *in situ* was approximately 3 K ohms for each bird. Data were recorded by digital counters and a Gerbrands cumulative recorder.

Procedure

Baseline training. Following shaping with Bird 27, all pigeons were exposed to gradually extended VR and VI schedules that were presented during alternate sessions. The VR and VI schedules were associated with green and red keylights, respectively. Training was continued until consistent responding occurred under VR 75 and VI 45-sec, which were the terminal schedules employed. These sessions were usually 30 min in duration.

Discrimination training. The birds were next trained under multiple VR 75-extinction, and VI 45-sec-extinction schedules that had six components (6 min each), with three each of reinforcement and extinction. Extinction was associated with a white keylight. The VR and VI schedules were present during successive sessions. The reinforcement and extinction components alternated within a session, with a reinforcement component presented first each day. The accuracy of discrimination was assessed through calculation of a discrimination ratio based on the formula:

$$\frac{\text{responses during } S^D}{\text{total session responses}}.$$

Perfect discrimination would be reflected in a ratio of 1:00; failure to discriminate would result in a ratio of 0.50. Training continued until discriminative performance stabilized. The stability criterion was a range of 0.10 or less in the discrimination ratio over six consecutive sessions under each schedule. Baseline and discrimination training required 49, 51, and 64 sessions for Birds 25, 27, and 29, respectively.

Procedure 1: increasing punishment shock intensity and shock removal. Punishment shock, 0.20 sec in duration, was delivered for every tenth response (FR 10) during food reinforcement, and responses under extinction were not punished. Each bird was initially exposed to a shock intensity of 2.50 mA.

All shock intensities remained in effect for a minimum of six sessions; and if response suppression was observed under either schedule, the same intensity was scheduled for six additional sessions. Each bird was exposed to increasing punishment shock until the animal emitted up to 100 responses in each of six consecutive sessions. After this criterion was attained, punishment shock was withdrawn entirely, and sessions continued until responding recovered substantially.

In order to maintain stable weight levels, the birds were given supplemental feeding after sessions in which few reinforcements were obtained during Procedures 1 and 2.

Procedure 2: session-to-session changes in punishment shock intensity. Birds 25 and 27 were studied as punishment and no-punishment sessions alternated unsystematically. Bird 29 died from unknown causes prior to this procedure. Bird 25 was studied with a shock intensity of 7.50 mA, while shock intensities of 7.50 mA and then 10.50 mA were employed with Bird 27. In general, one reinforcement schedule was in effect for four consecutive sessions, with punishment present in two of these sessions, and absent in the other two. The following sequences of sessions were employed equally with each schedule of reinforcement: (1) Punishment during first two sessions, or (2) punishment during first and third sessions, or (3) punishment during first and fourth sessions, or (4) punishment during third and fourth sessions; with no punishment during the other two sessions in each of the above.

RESULTS

Increasing Punishment Procedure

Each bird achieved a high level of discrimination under both schedules before punishment. Table 1 shows that discrimination became progressively poorer, in most cases, as punishment shock intensity increased, and then recovered to the pre-punishment level when punishment was removed. In some cases, the discrimination ratios are based on only a small number of responses, and thus are not particularly informative.

Figure 1 presents response rates and reinforcement rates at each punishment shock intensity for each bird. The data show that all birds had higher response rates under the VR schedule before punishment. Two of the birds (25, 27) increased responding at the initial shock intensity (2.50 mA), but aside from this, all of the curves show decreases in rates under both VR and VI schedules, as punishment intensity increased.

Each bird showed increases in responding during extinction at the intermediate punishment shock intensities, with greater increases appearing during the VR sessions for Bird 25 and 29, while Bird 27 had equivalent response rates under S^Δ during VR and VI sessions.

Table 1

Response rates during S^D and S^Δ and discrimination ratios under the two schedules at each punishment shock intensity. The discrimination ratio represents the proportion of responses during S^D in relation to the total number of responses in the season. Each figure below represents the mean performance over three sessions.

Shock Intensity (mA)	*Schedule*	*Bird 25*			*Bird 27*			*Bird 29*		
		Resp/Min		*Discr. Ratio*	*Resp/Min*		*Discr. Ratio*	*Resp/Min*		*Discr. Ratio*
		S^D	S^Δ		S^D	S^Δ		S^D	S^Δ	
0.0	VI	103	5	0.95	118	0.2	1.00	119	10	0.91
0.0	VR	120	6	0.95	134	3	0.98	149	4	0.97
0.0	VI	129	3	0.98	106	3	0.97	155	5	0.97
0.0	VR	145	2	0.99	145	1	0.99	163	0.5	1.00
2.5	VI	145	5	0.97	101	2	0.98	41	10	0.80
2.5	VR	165	6	0.96	136	0.2	1.00	64	5	0.93
2.5	VI							80	1	0.99
2.5	VR							92	1	0.99
5.0	VI	109	10	0.92	74	30	0.71	10	14	0.42
5.0	VR	109	11	0.91	136	22	0.86	4	36	0.10
5.0	VI	123	10	0.93	71	30	0.70	67	8	0.89
5.0	VR	124	6	0.95	133	34	0.80	37	22	0.63
7.5	VI	58	8	0.88	47	7	0.87	40	4	0.91
7.5	VR	63	36	0.64	125	15	0.89	1	9	0.10
7.5	VI	35	18	0.66	73	15	0.83	45	4	0.92
7.5	VR	43	28	0.61	97	9	0.92	0.5	10	0.05
10.5	VI	28	26	0.52	5	13	0.28			
10.5	VR	2	27	0.07	1	16	0.06			
10.5	VI	48	16	0.75	2	0.5	0.80			
10.5	VR	22	29	0.44	0.2	3	0.06			
12.0	VI							2	0.2	0.91
12.0	VR							0.0	0.6	0.00
15.0	VI	1	1	0.50						
15.0	VR	0.3	7	0.04						
15.0	VI	0.3	0.0	1.00						
15.0	VR	0.0	0.0	0.00						
0.0	VI	49	13	0.79	58	0.2	1.00	6	3	0.67
0.0	VR	0.02	0.43	0.08	104	1	0.99	2	6	0.25
0.0	VI	80	13	0.86	85	2	0.98	64	1	0.98
0.0	VR	88	14	0.86	133	0.1	1.00	107	1	0.99
0.0	VI	106	6	0.94						
0.0	VR	113	12	0.91						

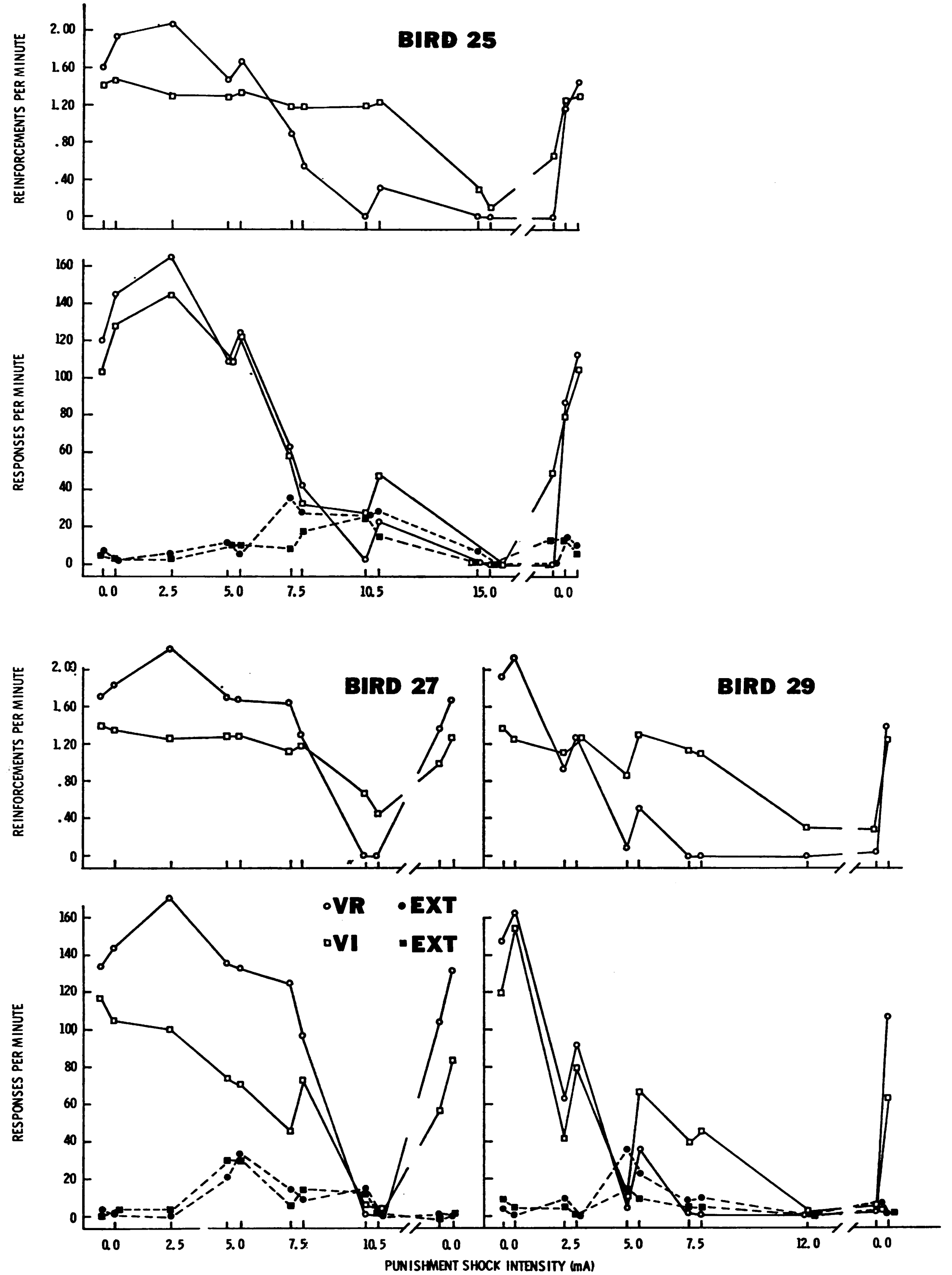

Fig. 1. Response rates during S^D and S^Δ and reinforcement rates under the VI and VR schedules at each punishment shock intensity. Each data point represents the mean performance over three sessions.

However, when responding under S^D was suppressed to a high degree by severe punishment, all birds showed a decrease in responding under S^Δ to near the zero level. Kruskal-Wallis analyses of variance were performed which compared baseline (pre-punishment) extinction responding under each schedule with extinction responding under each schedule at the two punishment intensities where extinction responding was highest. The probabilities that the difference obtained could have arisen from chance were less than the following values: Bird 25, (VI) 0.01, (VR) 0.01, (VI + VR) 0.001; Bird 27, (VI) 0.01, (VR) 0.02, (VI + VR) 0.002; Bird 29, (VI) 0.95, (VR) 0.01, (VI + VR) 0.05.

When punishment shock was withdrawn, responding under the VR and VI schedules recovered substantially, and the VR rates were again higher for all birds when this procedure terminated. Recovery of responding under S^D was gradual in all cases, and did not attain the pre-punishment rates in either two (Birds 27, 29) or three (Bird 25) six session blocks after punishment was removed.

Reinforcement rates under the two schedules were differentially affected by decreases in responding. Variable-ratio reinforcement frequency decreased in direct proportion to decreases in VR responding, but reinforcement frequency was relatively unaffected by decreases in responding under the VI schedule, until almost total suppression was achieved. Although VR responding was higher for each bird before punishment, VI responding eventually became higher in every case, as responding under both schedules was suppressed by punishment.

Session-to-Session Changes in Punishment Procedure

Figure 2 compares the results for Birds 25 and 27 at the same shock intensities with increasing punishment shock intensity (Procedure 1), and with session-to-session changes in punishment shock intensity (Procedure 2). The responding of both birds during S^D was suppressed more at 7.5 mA during Procedure 2. Also, response rates during S^D were lower in the post-punishment sessions under both

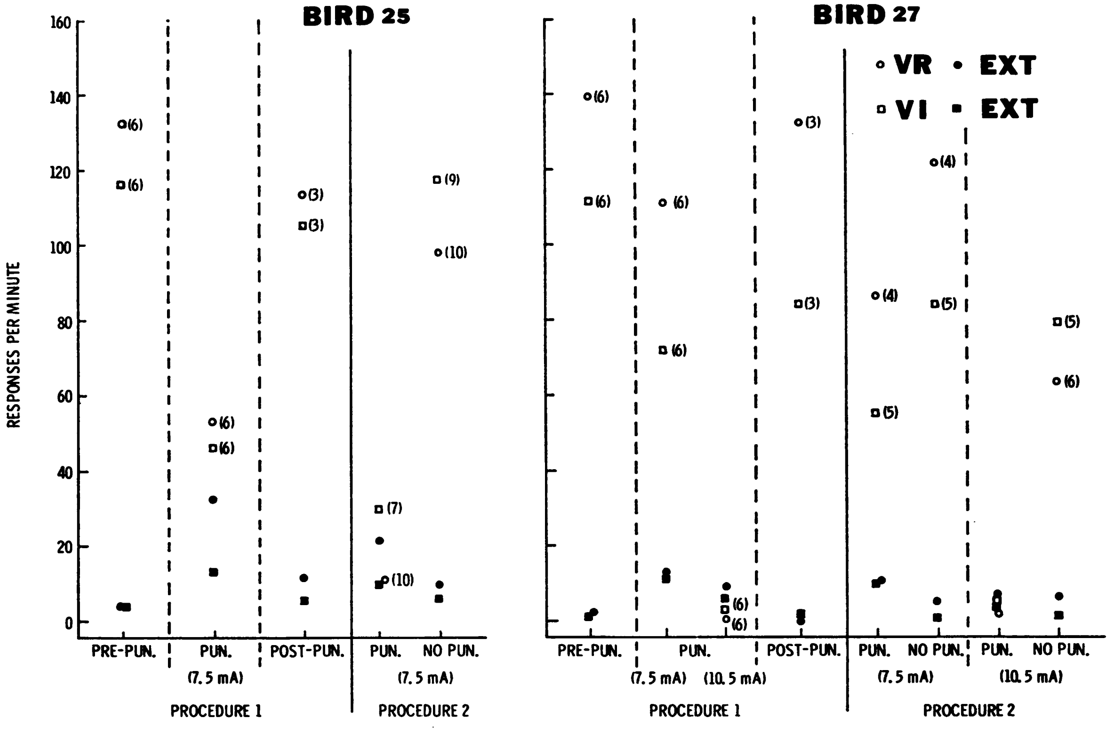

Fig. 2. A comparison of S^D and S^Δ response rates under the VR and VI schedules between Procedures 1 and 2 at the same punishment shock intensity. The numbers in parentheses indicate the number of sessions that the corresponding data points are based upon.

procedures, as compared to response rates under S^D during the pre-punishment sessions of Procedure 1. The most significant decrease occurred during the no-punishment sessions for Bird 27 that alternated with sessions in which 10.5-mA punishment occurred (Procedure 2). These results seem attributable to the residual effects of punishment, and can also be observed in the gradual recovery of responding by each bird when punishment was withdrawn during Procedure 1.

During Procedure 2, both birds had higher response rates under S^{Δ} at 7.5-mA punishment shock during the punishment sessions as compared to the no-punishment sessions. The differences were not as great in this respect, as occurred during Procedure 1. The differences in performance between the two procedures could be attributed to residual punishment effects or behavioral inertia (Hake, Azrin, and Oxford, 1967), which should be most pronounced when shock intensity changes substantially from session to session (Procedure 2). As examples of this, Fig. 3 presents cumulative records of three no-punishment sessions that followed punishment sessions. In each case, responding under S^D was suppressed markedly at first, and there was considerable responding under S^{Δ}. However, as responding under S^D recovered, responding under S^{Δ} decreased to a low level.

Kruskal-Wallis analyses of variance were performed that compared responding under S^{Δ} between punishment and no-punishment sessions. Within Procedure 2, the probabilities that the differences in extinction responding could have resulted from chance, were less than the following: Bird 25, (VI) 0.30, (VR) 0.05, (VI + VR) 0.02; Bird 27, (VI) 0.50, (VR) 0.20, (VI + VR) 0.20. Comparison of extinction responding between pre-punishment sessions under Procedure 1 and punishment sessions under Procedure 2 yielded the following values: Bird 25, (VI) 0.20, (VR) 0.01, (VI + VR) 0.001; Bird 27 (VI) 0.20, (VR) 0.20, (VI + VR) 0.05.

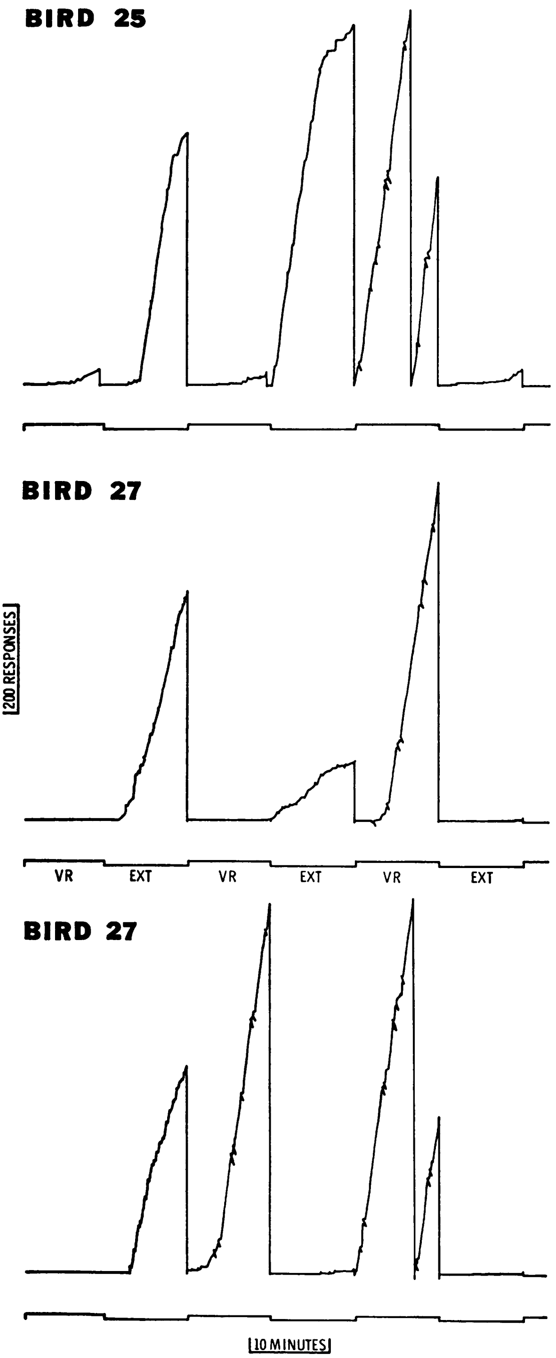

Fig. 3. Cumulative records of three no-punishment sessions that followed punishment sessions during Procedure 2. During these sessions, responding under the VR schedule was markedly suppressed or absent during the first component. Response rates were high during the first extinction components. Then, as responding under the VR schedule recovered, there were concomitant decreases in responding during the extinction components.

DISCUSSION

The present findings have areas of agreement with the results of both Hearst (1965) and Weiss (1968). Discriminative responding was greatly impaired by shock, as Hearst reported. The present procedure (punishment) produced concurrent increases in responding under S^{Δ} and decreases in responding under S^{D} at intermediate shock intensities, whereas the conditioned suppression procedure used by Hearst increased extinction responding, but did not change rates under S^{D}. Another area of agreement with Hearst was the finding that discriminative performance returned to baseline as responding recovered from the suppressive effects of punishment. When responding was suppressed to near the zero level during S^{D}, there was little or no responding during S^{Δ} in the present experiment. Weiss (1968) also reported decreased responding in the presence of both stimulus conditions when a conditioned suppression procedure was introduced. The facilitative effects of mild shocks upon responding, which Weiss observed, also occurred in two of the birds in the present study. It is possible that the third animal would have responded similarly, had a less-intense punishment shock been presented initially. Increased responding at low punishment shock intensities was observed in several animals in another recent experiment (Powell, 1970). In summary, it would appear that aversive stimuli may differentially affect discriminative performance, depending upon the intensity of the stimuli and the manner in which they are scheduled relative to the response.

As responding in the present experiment was suppressed by punishment under the VR and VI schedules, responding during extinction, which was not punished, increased significantly, except under VI for Bird 29. When punishment shock was sufficiently intense to produce complete or nearly complete suppression of S^{D} responding, there was little or no responding during extinction. The initial effect, then, appears to be an example of behavioral contrast, which consists of a change in the rate of responding during the second component of multiple component schedules that is opposite in direction to the rate that prevails in the first component and typically accompanies a change in procedure in the first component (Wilton and Gay, 1969; Brownstein and Newsom, 1970). The temporary increase in rates under S^{Δ} as responding during S^{D} decreased with increases in punishment intensity, appears to conform to this definition. Contrast effects disappeared, however, when responding during S^{D} was suppressed to very low levels.

Reliability of the contrast effect was substantiated through a procedure in which punishment and no-punishment sessions alternated in an unsystematic sequence. Again, responding during S^{Δ} was higher during punishment than no-punishment sessions at intermediate shock intensities (7.5 mA), but there was no difference in responding during S^{Δ} at high intensity shock (10.5 mA). While the results of the second procedure replicate to a fair degree the data obtained as shock intensity increased gradually, the differences in responding under S^{Δ} were not as great between punishment and no-punishment sessions. The smaller differences obtained during the second procedure seem attributable to residual shock effects, or behavioral inertia. This refers to an effect wherein behavior at a new punishment intensity is biased toward the behavior at a previous value (Hake *et al.*, 1967). This effect was clearly seen in several no-punishment sessions where responding during S^{D} was suppressed markedly at first, and rates during S^{Δ} were high, but as responding during S^{D} recovered, the rates during S^{Δ} decreased to a low level. Because of this apparent confounding effect, it seems more legitimate to compare extinction response rates during punishment under Procedure 2, with pre-punishment extinction responding (Procedure 1).

Research has shown that changes in the relative frequency of reinforcement during one component of a multiple schedule typically result in contrast effects during the second component (Reynolds, 1961*a, b;* Reynolds and Catania, 1961). A number of recent experiments have shown that contrast can also be produced during one component, when there is no change in reinforcement frequency during the second multiple schedule component (Terrace, 1968; Weisman, 1969; Brownstein and Newsom, 1970; Brownstein and Hughes, 1970). Reynolds and Limpo (1968) suggested that a reduction in response rate in one component of a multiple schedule may be an important generative factor in the production of behavioral contrast in the second component. In the present experiment, positive contrast occurred at several punishment intensities under the VI schedule, even though response suppression during S^{D} did not result in a lower rate of reinforcement (Bird 25, 7.5 and 10.5 mA; Bird 27, 5.0 and 7.5 mA; Bird 29, 5.0 mA). However, contrast effects were greater under the VR schedule, as judged by the increase in responding during S^{Δ}.

Responding under the VI schedule was generally more resistant to the suppressive effects of punishment than VR responding. Powell (1970) also observed this effect during multiple VR-VI schedules. This resistance to suppression appears to be related to the very slight decreases in reinforcement frequency that occur as VI responding decreases, while reinforcement frequency changes in direct proportion to changes in response rate under VR schedules.

In summary, the present results show that punishment of positively reinforced responding results in positive contrast effects during a second stimulus correlated with extinction, at intermediate shock intensities. When responding during S^{D} was suppressed to very low levels, little or no responding occurred during S^{Δ}. As a whole, these results suggest a curvilinear relationship between the degree of response suppression and amount of behavioral contrast.

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