STRESS-INDUCED BREAKDOWN OF AN APPETITIVE DISCRIMINATION¹

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Rats trained to discriminate between S^D and S^A for food reinforcement showed marked impairments in this discrimination when strong, unavoidable shocks occurred at the termination of a third stimulus. The predominant feature of this impairment was a supernormal rate of unreinforced (S^A) behavior. Shocks delivered without exteroceptive warning also led to a discriminative breakdown. The effect was a direct function of shock intensity. When behavior was strongly suppressed in the third stimulus by response-correlated shock ("punishment"), instead of unavoidable shock, breakdowns were only temporary; as soon as responding recovered from its overall suppression, discriminative performance returned to normal. The discriminative deterioration may be interpreted as an emotional by-product of frequent aversive stimulation, but accidental contingencies could also have played a role.

An incidental observation in some past work was a deterioration of appetitive discriminations when CER periods were added to the procedure. The discriminative breakdown was apparently dependent on the presence of shocks and thus was reminiscent of observations of Pavlov and others (see Broadhurst, 1961) that easy, well-established discriminations suffer during periods of conflict, fear or general stress. The effect appeared also to be related to findings in the field of stimulus generalization, which have shown that highly anxious subjects usually exhibit greater than normal stimulus generalization (Mednick and Freedman, 1960).

The present experiments were specifically designed to explore and amplify those earlier incidental observations. Does unreinforced (S^A) responding increase whenever reinforced responding is suppressed in some way? Is shock alone, without the exteroceptive warning that characterizes the CER procedure, sufficient to produce the discriminative impairment? Is the impairment reversible? Is it a function of shock intensity? Does response-

correlated shock have the same effects as unavoidable (CER) shock?

METHOD

Subjects

Six naive male albino rats of the Osborne-Mendel strain, approximately 6 mo old at the start of training, were maintained at 75% of their free-feeding weights. Condensed milk reinforcements were used during experimental sessions and supplementary Purina rat pellets provided after sessions and on weekends. Water was continuously available in all home cages.

Apparatus

A standard rat chamber (Foringer) served as the experimental enclosure. The response lever was a modified telegraph key. Reinforcement consisted of access for 3 sec to a motor-driven dipper, which contained approximately 0.1 ml of a solution of equal volumes of sweetened condensed milk and tap water. A small lamp above the lever provided a flickering light stimulus. A clicking sound and a tone were available as auditory stimuli. Electric shocks were delivered through the walls and grid floor of the chamber by means of a shock scrambler. A dim house light in the rear of the chamber remained on throughout experimental sessions. In another room, a system of timers, counters, relays, and cumulative re-

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corders automatically controlled experimental events and recorded response data. With few exceptions, experimental sessions occurred every weekday.

Preliminary Procedure

After conventional periods of (a) dipper training, and (b) the continuous reinforcement of lever pressing, subjects were reinforced on a 1-min VI schedule for six 90-min sessions. During this phase, the exteroceptive stimuli which later served as S^A or CER stimuli were not present.

Subjects next received training in either an auditory or a visual discrimination for milk reward. For three subjects (No. 60, 63, and 65) the tone was the negative stimulus (S^A), whereas for the other three (No. 62, 64, and 66) the flickering light was S^A . The positive stimulus (S^D) for all the subjects was the absence of S^A .

Either S^D or S^A was in effect during successive 1-min periods, according to a nonsystematic order derived from Gellerman tables. This sequence produced single S^D and S^A durations that were either 1-, 2-, or 3-min long. The 96-min experimental session was equally divided between S^D and S^A . A 1-min VI schedule was in effect in S^D . No reinforcements were possible in S^A .

Subjects remained on this procedure for 30-35 sessions, by which time their discriminative performances had become quite stable from day to day. Subjects with the auditory S^A displayed somewhat better S^A/S^D response ratios (range of individual medians over the last five days on this procedure: 0.12 to 0.22) than those with the visual S^A (range: 0.08 to 0.57).

After this preliminary discrimination procedure was completed, all subjects were used in a series of interrelated experiments. Since later experiments were motivated in part by earlier findings, it seems best to describe both the "procedure" and "results" of each experiment before going on to subsequent experiments.

EXPERIMENT I

Addition of CER Component

Procedure. In the first experiment, a CER component was introduced to the two-compo-

nent discrimination procedure. The effects of the presence or the absence of shocks at the end of this CER stimulus were then investigated.

As before, each session lasted 96 min and the stimulus-sequence stepper was operated every minute. One-sixth of the stimulus presentations were S^A periods and one-sixth were CER periods; the rest were S^D periods. The subjects (No. 60, 63, and 65) which had the tone as S^A were assigned the flickering light as the CER stimulus, whereas those (No. 62, 64, and 66) which had the flickering light as S^A were then assigned the tone as their CER stimulus.

The S^A and CER stimuli occurred in a non-systematic order and never immediately followed each other; one to three S^D periods intervened between every S^A or CER period. In the calculation of the *Discrimination Index* (S^A response rate/ S^D response rate) and the *CER Index* (response rate in the CER stimulus/ S^D response rate), total cumulated daily responses in the 1-min S^A and CER components were compared to total cumulated daily responses in the immediately preceding 1 min of S^D ("pre- S^A " or "pre-CER"). Reinforcement with milk on the 1-min VI schedule was possible during the CER period, just as it was during S^D .

For the first six sessions of exposure to the three-component schedule, the CER stimulus was not followed by shock. This initial period without shock was included (a) to check on any unconditioned effects of the CER stimulus, and (b) to make sure that the decreased amount of S^A time (now $\frac{1}{6}$ of the total session time, as compared to $\frac{1}{2}$ of the total session time in the preliminary discrimination phase) did not itself adversely affect the discrimination between S^D and S^A . The results showed that (a) the CER stimulus had negligible and inconsistent effects on lever pressing, and (b) S^A/S^D performance was slightly poorer under the new three-component procedure; discrimination indices ranged from 0.15 to 0.39 for the tone- S^A subjects and from 0.15 to 0.41 for the light- S^A subjects. These values may be compared to those given above at the end of discrimination training.

During subsequent sessions, the procedure was exactly the same as above except that an unavoidable shock (approximately 0.9 ma, 0.35 sec) occurred at the end of every CER

Table 1

Effects of the shock-off ("OFF") and shock-on ("ON") procedures on several behavioral measures when preshock (CER) periods were accompanied by an exteroceptive stimulus.

Subject	Discrim. Index		CER Index		Rate in S ^A (rpm)		Rate in S ^D (rpm)		Total Reinforcements	
	"OFF"	"ON"	"OFF"	"ON"	"OFF"	"ON"	"OFF"	"ON"	"OFF"	"ON"
No. 60	0.36	0.74	1.20	0.02	4.5	9.2	11.6	10.9	58.5	51.7
No. 62	0.41	0.68	1.22	0.34	10.4	20.3	26.5	29.3	67.3	64.3
No. 63	0.12	0.32	0.89	0.37	6.8	8.1	52.6	23.1	67.8	65.7
No. 64	0.69	0.94	1.06	0.11	7.2	15.3	11.1	15.8	61.8	53.7
No. 65	0.38	0.56	1.04	0.32	15.7	19.5	44.9	32.7	65.0	66.0
No. 66	0.14	0.86	1.36	0.24	2.9	34.5	20.0	38.0	59.3	63.0
Group Mean	0.35	0.68	1.13	0.23	7.9	17.8	27.9	25.0	63.3	60.7

period.³ Since 16 CER periods were presented in the 96-min sessions, subjects received a total of 16 shocks per session. They remained on this procedure until inspection of their experimental records indicated that their behavior had stabilized. Then they were once again placed on the procedure without shock.

Stable behavior with and without shock was determined at least three times each for every subject. Subjects remained on a given procedure for a minimum of five experimental sessions—until inspection of the records indicated that stability had been attained. The modal amount of time required for stability was 10 days.

Results. The values in Table 1 are means of three or four separate "determinations" of stable behavior with and without shock. Medians of measures from the last three sessions under a particular procedure were used as the measure of final performance. Each such median represents a single "determination".

All subjects showed a deterioration in discrimination index when shocks occurred at the end of CER periods. Rat No. 66 displayed the largest per cent change in discrimination index as a result of the procedure with shocks. Rat No. 64 exhibited the smallest per cent change, but it had produced the poorest, and

most variable, discriminative performance of all subjects when no shocks were delivered.

Besides this impairment in relative measures of discrimination, Table 1 shows that the delivery of shocks also produced an increase in the absolute rate of S^A responding in every subject. In four of the six subjects, response rate in S^A increased by more than 90%.

Table 1 indicates that the delivery of shocks did not have consistent effects on either (a) response rate in S^D (calculated by combining data for the 1-min pre-S^A and pre-CER periods) or (b) total number of reinforcements. Apparently the deterioration in the S^D *vs* S^A discrimination was more or less independent of changes in the overall response level or in the frequency of reinforcement.

As would be expected from many prior experiments (see Sidman, 1960), responding in the CER stimulus was suppressed under the procedure with shocks. When no shocks occurred there was some tendency for the CER index to rise above 1.00 (particularly pronounced and reliable in the daily records of No. 62 and 66—see Fig. 3—but not consistent for the other four subjects).

The sample cumulative response curves in Fig. 1 for Rat No. 66 under the shock and no-shock conditions were selected from final performance (*i.e.*, one of the last three days) on a particular procedure, and were chosen so that the total amount of responding on each record would be approximately equal. Only the final 60 min of sessions (10 S^A and 10 CER periods) are shown, but the discrimination and CER indices noted on each record were calculated from the entire 96-min session.

When shocks were not delivered, Fig. 1 shows that the subject pressed the lever at a comparatively high rate during the CER stim-

³Once the procedure with shocks began, the flickering light was found to be a poor CER stimulus. Even after extended training, all subjects that had this CER stimulus still showed response suppression throughout the session rather than in the specific presence of the CER stimulus. Therefore, a clicking noise was presented simultaneously with the light to constitute a compound CER stimulus; soon after the clicker was added, the behavior of these subjects became specifically suppressed during the CER period and eventually approximated that of the other subjects which had the tone-alone as the CER stimulus.

Fig. 1. Sample cumulative response curves for rat No. 66 on the procedure without shock (left) and the procedure with shock (right). Pen deflections indicate S^A or CER periods. S^A periods are denoted by Δ , CER periods by $\bullet$.

ulus; but, when shocks did occur, the subject pressed the lever very infrequently during the same stimulus. On the other hand, S^A responding occurred at a very low rate during the no-shock condition and at a relatively high rate during the shock condition.

EXPERIMENT II

Elimination of Exteroceptive Shock Warning

Procedure. The above results showed that as responding in the CER stimulus decreased or increased due to the presence or absence of shocks, S^A responding was affected in the opposite direction. Thus, the effect might be considered an example of "behavioral contrast," since contrast is defined (Reynolds, 1961a) as a change in rate of responding during one stimulus in a direction opposite to a change in rate during another stimulus. An interesting question was whether the declines in rate in CER were essential for the increases in rate in S^A . Would shocks alone disrupt the S^D vs S^A discrimination, even if responding in the pre-shock periods were not selectively suppressed?

To answer this question, the exteroceptive stimulus that served as the shock warning signal was eliminated, but shocks were administered at exactly the same times as before. Under these conditions, subjects would have no warning that shock was about to be delivered. Response rate in the 1-min periods before shock should thus be approximately

equal to response rates throughout S^D . If a discriminative impairment of the magnitude exhibited in Table 1 were to occur even under these new conditions, it would suggest that the impairment was brought about by the shocks themselves and was not dependent upon some reciprocal, "compensatory" relationship between responding in the S^A and CER components of the schedule.

Three subjects (No. 60, 63, and 65) were first exposed to the procedure without shock for 16 sessions (this procedure was thus the same as the no-shock condition in Exp. I except that the former CER stimulus was never presented). The procedure with shocks was then in force for 18 sessions. Later, the no-shock procedure was reinstated for 10 sessions.

The other three subjects were first exposed to the procedure with shocks for 10 sessions and then to the procedure without shocks for 12 sessions.

Results. Table 2 summarizes the results of these procedures without an exteroceptive CER stimulus. Rats No. 60 and 63 showed a virtually complete suppression of responding in all components of the multiple schedule even after 18 sessions of exposure to the procedure with shocks. Each emitted fewer than 30 total responses on almost every one of the last 11 sessions. The various response measures for these subjects were therefore extremely unreliable and are omitted from Table 2. The entries for the other four subjects were derived

Table 2

Effects of the shock-off ("OFF") and shock on ("ON") procedures on several behavioral measures when pre-shock periods were not accompanied by an exteroceptive stimulus.

Subject*	Discrim. Index		CER Index		Rate in S ^A		Rate in S ^D		Total Reinforcements	
	"OFF"	"ON"	"OFF"	"ON"	"OFF"	"ON"	"OFF"	"ON"	"OFF"	"ON"
No. 62	0.43	0.85	0.92	0.90	11.4	11.6	27.1	11.8	63.0	36.0
No. 64	0.64	0.92	0.83	1.01	4.9	30.3	8.3	33.0	54.0	65.0
No. 65	0.31	0.95	0.99	1.01	18.0	11.1	60.4	13.3	67.5	61.0
No. 66	0.30	1.21	1.06	0.99	4.0	12.9	12.8	13.5	59.0	47.0
Group Mean	0.42	0.98	0.95	0.98	9.6	16.5	27.2	17.9	60.9	52.3

*Subjects No. 60 and 63 are not included in this table because under the shock-on procedure their responding continued to be almost completely suppressed throughout experimental sessions, even after 18 sessions of exposure to this procedure.

from medians over the last three days of exposure to each procedure.

Table 2 shows an even greater impairment of the S^D vs S^A discrimination than Table 1; when shocks occurred, the mean discrimination index of Table 2 approximated 1.00, which signifies no discrimination whatever between S^D and S^A. However, with regard to absolute response rate in S^A, rats No. 64 and 66 exhibited a pronounced facilitation under the procedure with shocks, whereas No. 62 and 65 showed either very little change or a decrease. The absence of S^A facilitation in these latter subjects, which does not match the results of Table 1, may well be due to the extremely strong opposing influence of the suppressive factors in the situation. This is suggested by the fact that response rates in S^D for No. 62 and 65 were markedly suppressed by the delivery of shocks. In Table 1 the S^D rates of these subjects had been much less affected by the shock procedure than they were here.

Since no exteroceptive stimulus accompanied pre-shock periods, CER ("dummy") indices were, as expected, close to 1.00 under both experimental conditions. Therefore, the results shown in Table 2 indicate that a discriminative impairment will occur even when there is no specific suppression of response in another component of the multiple schedule.

Figures 2 and 3 present daily discrimination and CER indices over most of Exp. I and II for rats No. 65 and 66 respectively. The only sessions omitted from the records were (a) a few sessions on which apparatus failures occurred, and (b) some early training sessions, including those for No. 65 before the change to a compound (auditory-visual) CER stim-

ulus.³ There was very little overlap in discrimination indices between the procedure with shock and the procedure without shock. A virtually complete and immediate recovery of discriminative performance occurred whenever shock was eliminated.

EXPERIMENT III

Comparison of CER and Punishment

Procedure. Exp. I and II showed that delivery of unavoidable shocks, with or without warning, produced a breakdown of the discrimination between S^D and S^A. Next, a comparison was made between response-correlated shock and unavoidable shock. Is it likely that another method of response suppression in the CER stimulus would also be accompanied by a discriminative impairment?

The former CER stimulus was restored to the procedure but, instead of signalling unavoidable shock, it now served as a signal that all responses in its presence would be punished. The procedure was essentially the same as in Exp. I except that each lever press during the former CER stimulus produced a brief electric shock of approximately 0.3 ma for 0.11 sec. To obtain a degree of stimulus-specific suppression approximating that on the unavoidable-shock procedure, and to minimize the possibility of a permanent overall suppression of lever-pressing rate, it was necessary to use a lower intensity and duration of shock than on the CER procedure (by inference from the results of Azrin, 1956, and Appel, 1963). Experiments with a punishment procedure that employed the same high shock intensity and duration as on the CER pro-

Fig. 2. Day-to-day records of the discrimination and CER indices for rat No. 65 during Experiments I and II.

cedure of Exp. I were deferred until the final stages of work with these subjects, where a permanent overall suppression would not have been so critical (See Exp. V).

The procedure was in force without shock for at least 10 sessions to reaccustom subjects to presentations of the former CER stimulus and to restabilize performance on the procedure without shocks. Then the punishment procedure was introduced for 15 sessions. Later, in successive 10- to 16-day periods, performance with and without shocks was determined again.

In the final stages of this experiment, all subjects were returned to the CER procedure of Exp. I (same warning signal, shock level, etc.) to determine if the intervening training in Exp. II and III, or the increasing age and experience of the subjects, had brought about any lessening of the discriminative effects observed previously in Exp. I. Subjects remained on the CER procedure with shocks for 11-13 sessions. Then, behavior without shocks was redetermined for 10 days.

Results. On the first few days of the initial exposure to the punishment procedure there

was some temporary disruption of discriminative performance. However, by the time behavior had stabilized (See Table 3) discrimination ratios under punishment were generally as good as in the absence of punishment. On the second exposure to the punishment procedure (after a 10-day period without punishment) there was no evidence of even an initial, temporary effect of punishment on the S^D vs S^A discrimination. Worth reiterating is the fact that the impairments observed earlier in Exp. I and II with unavoidable shock were not merely temporary, initial effects, but ones which lasted as long as shocks were delivered (see Fig. 2 and 3).

Table 3 indicates the level of final performance achieved on the punishment and no-punishment procedures for all subjects. The values in the table are means of three determinations of stable behavior on the "OFF" procedure and two determinations on the "ON" procedure. Medians of measures from the last five sessions under a particular procedure served as the measure of final performance. Each such median represents a single "determination".

Fig. 3. Day-to-day records of the discrimination and CER indices for rat No. 66 during Experiments I and II.

Table 3 indicates very little, if any, effect of response-correlated shock on the discrimination between S^D and S^A , even though suppression during the former CER stimulus (see the punishment index) was generally greater than on the CER procedure of Experiment I. There was no consistent change in either the absolute or relative discrimination measures. Effects of the punishment procedure upon response rate in S^D were inconsistent from subject to subject, but there was a small decline for all subjects in the total number of reinforcements, presumably because of missed reinforcements occurring during marked suppression in the punishment-correlated stimulus. The number of punishments accepted by individual subjects did not bear any ob-

vious relationship to discrimination indices or to response rates in S^D and S^A .

The results of Exp. I and III suggested that the suppression produced by a stimulus that signals unavoidable shock is much more likely to be accompanied by a marked discriminative impairment than is the suppression produced by response-correlated shock, even though the degree of suppression on the latter may be greater. As a further check on the reliability of this finding, subjects were returned to exactly the same CER procedure as had been tested in Exp. I. The degree of discriminative impairment proved to be at least as great as in Exp. I. In all subjects, absolute rates of S^A responding increased markedly (group mean without shock was 7.3 rpm and with

Table 3

Effects of the response-correlated punishment procedure on several behavioral measures. During the "OFF" procedure no punishments were possible, whereas during the "ON" procedure punishments were delivered after every response in the former CER stimulus. The mean number of shocks per session is given in parentheses in the Punish. Index ("ON") column.

Subject	Discrim. Index		Punish. Index		Rate in S ^A (rpm)		Rate in S ^D (rpm)		Total Reinforcements	
	"OFF"	"ON"	"OFF"	"ON"	"OFF"	"ON"	"OFF"	"ON"	"OFF"	"ON"
No. 60	0.46	0.48	0.82	0.00 (0.5)	5.7	5.7	12.9	10.1	56.7	50.5
No. 62	0.75	0.45	1.28	0.02 (3.5)	9.9	8.8	13.3	19.1	57.0	55.5
No. 63	0.18	0.31	0.89	0.04 (22.0)	11.1	15.3	60.5	39.6	64.3	58.5
No. 64	0.26	0.28	0.67	0.36 (44.5)	2.5	2.4	9.5	10.2	56.0	54.0
No. 65	0.28	0.35	0.99	0.24 (153.5)	14.7	13.3	49.8	43.1	60.7	58.5
No. 66	0.24	0.18	1.19	0.21 (63.5)	5.5	7.1	21.9	29.9	60.3	59.5
Group Mean	0.36	0.34	0.97	0.15 (47.9)	8.2	8.8	28.0	25.3	59.2	56.1

shock 18.6 rpm) and discrimination indices deteriorated (group mean was 0.34 without shocks, and 0.80 with shocks).

EXPERIMENT IV

Variation of the Intensity of Unavoidable Shock

Procedure. Variations in the intensity of CER shock were investigated. The unavoidable-shock procedure of Exp. I was in effect throughout this new experiment, but shock intensity was shifted every few days in each subject. Shock duration was constant at 0.11 sec, but shock intensity ranged from 0.3 ma (its value during the punishment procedures of Exp. III) up to 0.8 ma.

Each of the six subjects was first exposed to the mildest shock level (0.3 ma) for 10-17 sessions. Then, they were tested on shock intensities of 0.5 and 0.8 ma, in a different order for different subjects. Each of these shock levels was in effect for five successive sessions. Finally, the whole procedure was repeated in a different irregular order for each of five subjects (No. 62-66), to obtain a second set of five-session data at the three shock levels. Only one set of data at the different shock levels was obtained for rat No. 60.

Results. The data in Fig. 4 are means of all determinations in every subject (final three-day medians for the standard five-day test

periods, and final five-day medians for the initial exposure of 10-17 sessions at the mildest shock level). Individual subjects displayed effects similar to those exhibited in the group functions.

As shock intensity increased, discrimination ratios deteriorated and absolute rate of S^A responding increased. Despite these changes, response rate in S^D remained fairly constant. CER indices declined with increases in shock intensity.

EXPERIMENT V

Punishment at High Shock Intensity

Procedure. In the comparison (Exp. III) of response-correlated shock with unavoidable shock, shock level was not the same on the two procedures. This difference in shock levels may have been important in producing the behavioral differences between CER and punishment observed in that experiment. Therefore, in a final experiment the response-correlated procedure of Exp. III was reinstated. The intensity and duration of shock were set at the same high values as had been employed on the unavoidable-shock procedures of Exp. I through III.

First, subjects were exposed to the procedure without shock for six to nine sessions. Then, the effects of response-correlated shock were studied as in Exp. III, but with a shock

Fig. 4. The effect of unavoidable-shock intensity on several measures of performance.

intensity of 0.9 ma and duration of 0.35 sec. There was a great deal of overall suppression during initial days on this new procedure and exposure to it was therefore continued for 40 sessions.

Results. The effects of a high intensity of response-correlated shock are summarized in Table 4. For each of the three measures of behavior (Discrimination Index, S^A Rate, and S^D Rate) terminal performance in the pre-punishment stage (*i.e.*, no shock was possible) is indicated along with terminal performance

over each successive block of 10 punishment sessions. Medians of measures from the last five sessions on pre-punishment, or from the last five sessions of each block of 10 punishment sessions, served as the measure of terminal performance.

It is clear from the table that discrimination indices were generally impaired over the first 20 sessions of the punishment procedure and that this impairment was associated with a marked overall suppression of responding. The two subjects (No. 62 and 65) that showed

Table 4

Effects of the response-correlated procedure with a high shock intensity. Pre-punishment levels are given for each measure, as well as terminal performance on successive blocks of 10 sessions under punishment.

Subject	Discrimination Index					Rate in S ^A (rpm)					Rate in S ^D (rpm)				
	Pre-Pun.	Sess. 1-10	Sess. 11-20	Sess. 21-30	Sess. 31-40	Pre-Pun.	Sess. 1-10	Sess. 11-20	Sess. 21-30	Sess. 31-40	Pre-Pun.	Sess. 1-10	Sess. 11-20	Sess. 21-30	Sess. 31-40
No. 60	0.63	1.04	1.25	0.52	0.73	6.1	9.6	4.9	3.4	3.8	9.5	7.2	4.0	6.4	5.5
No. 62	0.35	2.14	0.35	0.42	0.39	7.0	1.9	3.7	2.3	2.9	18.2	1.8	9.5	8.7	5.3
No. 63	0.32	— ^a	1.24	0.33	0.12	9.6	0.9	5.2	4.5	1.1	33.9	0.0	4.3	9.1	8.9
No. 64	0.43	1.18	1.02	0.57	0.28	7.1	3.9	5.6	6.6	1.8	17.1	2.9	7.6	14.0	5.7
No. 65	0.25	0.72	0.24	0.39	0.38	8.2	13.1	5.1	7.3	5.6	32.6	20.9	20.3	19.6	14.2
No. 66	0.16	— ^a	— ^a	2.13	2.11	4.9	0.3	0.1	0.3	3.4	31.3	0.0	0.0	0.1	2.5
Group Mean	0.30	0.91	0.54	0.42	0.44	7.2	5.0	4.1	4.1	3.1	23.8	5.5	7.6	9.7	7.0

^aFor these entries, the rate in S^D was 0.0 rpm—which made the discrimination index infinitely large. Rate in S^A was greater than zero in all these cases.

^bDue to the presence of infinite values and the very small number of responses involved in some of the individual median determinations, these group indices were calculated from the mean S^A and S^D rates in the adjacent columns rather than from the individual discrimination indices themselves.

recovery to their normal levels of discriminative performance during Sessions 11-20 also had the highest S^D rates during this block of sessions, that is, they exhibited more recovery of overall responding than did all of the other subjects.

Even though S^D and S^A rates never attained pre-punishment levels for any subject during Sessions 21-40, five of the six returned to efficient discriminative performance during these sessions. Only No. 66, whose responding remained almost completely suppressed throughout the punishment procedure, continued to show poor discriminative indices at the end of the 40 test sessions.

Not only was discriminative performance impaired on the first 10-20 sessions of exposure to punishment, but discrimination indices for most subjects were consistently greater than 1.00 during this period. This meant that responding was more likely to occur in S^A than in S^D . Such an effect was obtained on 44 of the 60 total sessions in Sessions 1-10 (six subjects, 10 sessions each), 27/60 in Sessions 11-20, 14/60 in Sessions 21-30, and only 10/60 in Sessions 31-40 (eight out of the 10 occurrences in the numerator of the last value were contributed by rat No. 66, which still displayed marked overall suppression during Sessions 31-40).

It was rare for any subject to receive more than two shocks per day, either during initial phases (Sessions 1-10) or terminal phases (Sessions 31-40) of the punishment procedure. Throughout the entire 40 sessions, punishment indices (response rate in the punishment stimulus/response rate in S^D) were almost always below 0.01, which evidences a much greater degree of stimulus-specific suppression than that occurring on the CER procedure of Exp. I and III at the same shock level.

Although impairments in relative measures of the S^A vs S^D discrimination were observed in the early stages of this punishment procedure, there was little or no indication of absolute increases in S^A behavior over this period, as had consistently occurred during discriminative breakdowns on the unavoidable-shock procedures of Exp. I and III. Table 4 includes only two cases in which S^A rate during punishment was greater than its pre-punishment level. It may be that the overall suppressive ("inductive") effects of response-

correlated shock oppose any tendency towards facilitation of S^A rate.

DISCUSSION

This experiment has shown that the occasional delivery of strong, unavoidable shocks—whether or not preceded by an exteroceptive warning—produces a marked impairment in well-established appetitive discriminations. This impairment can be easily reversed, however; the discrimination returns to its former levels of accuracy as soon as the shocks are withdrawn.

An interesting feature of this discriminative breakdown with unavoidable shock is the facilitation of unreinforced (S^A) behavior that usually occurs. This increase in S^A behavior seems unrelated to concurrent effects upon (a) response rate in S^D , or (b) absolute or relative frequencies of reinforcement within the multiple schedule. In addition, the effect does not appear to be merely another example of "behavioral contrast"—i.e., a "compensatory" increase brought about by the suppression of reinforced responding—because another method of suppression, that produced by response-correlated shock, did not lead to increases in S^A responding, nor to a long-lasting discriminative breakdown. Also, even when behavior in pre-shock periods was not selectively suppressed (due to the absence of exteroceptive shock warning), the discriminative impairment still occurred. In any case, the present facilitatory effects are different from the phenomena classified as "contrast" by Reynolds (1961a, 1961b) and Brethower and Reynolds (1962). The predominant feature here was the facilitation of unreinforced behavior, whereas Reynolds' experiments studied component manipulations that produced a facilitation of reinforced behavior.

Previous reports of an increased emission of unreinforced operant behavior do not appear to bear more than a superficial resemblance to the facilitative effects observed here. For example, Reynolds (1964) noted an increased rate of nonreinforced behavior in one stimulus after responding had been strengthened during another stimulus. This result, however, seems to be a rather clear example of "positive induction", whereby facilitation of responding under one set of experimental conditions is accompanied by a facilitation of responding

under another set of conditions. In the situation described here, on the other hand, S^A responding increased regardless of whether response rate in S^D increased or decreased.

Explanations of the discriminative breakdown and the facilitation of S^A responding in terms of certain accidental contingencies of reinforcement are worthy of consideration. Ray and Stein (1959) observed their highest response rates in a VI-rewarded exteroceptive stimulus not followed by shock, as compared to responding in normal VI periods or to responding during a stimulus (CER) followed by unavoidable shock. These experimenters discussed the possibility that the higher-than-normal rates in the non-shocked stimulus might have been due to the fact that responding in this stimulus was never negatively reinforced by the accidental production of the CER stimulus; the sequence of experimental conditions was such that these two stimuli never immediately followed one another. On the other hand, CER stimuli did follow normal VI periods and, therefore, responding during these periods could have been negatively reinforced by the production of CER stimuli. An important point is that in the present procedure, responses were never reinforced in the S^A stimulus, whereas Ray and Stein reinforced responses in the facilitated component on a VI schedule. Although accidental contingencies of the type noted by Ray and Stein may have been involved here, it is hard to believe that the mere fact that S^A responding is "safe" (*i.e.*, it never produces the CER stimulus) would—in the complete absence of any other source of reinforcement—account for the large increases in S^A rate observed here.

The facilitation of S^A responding and the loss of discriminative control under conditions of strong, unavoidable shock may be regarded as some kind of emotional effect, akin to the breakdowns in performance, "disinhibitions", and maladaptive behavior observed by Pavlov and others during periods of powerful conflict or stress (see, for example, Dinsmoor, 1960). A pertinent discussion of "emotionality" is offered by Amsel and Maltzman (1950) who stress the perseverative, energizing effects of certain emotion-producing variables. They also point to results which show that consummatory behavior (drinking) occurs at a super-normal rate when it is measured in a situation

different from the one in which the subject was given strong shocks while drinking. In the present experiment, the direct relationship between shock intensity and extent of discriminative impairment (Exp. IV) could be used to support an "emotionality" interpretation.

The comparison of unavoidable and response-correlated shock revealed more reliable and persistent discriminative effects under the unavoidable-shock procedure; also, there was a facilitation of S^A behavior with unavoidable shock that did not occur with response-correlated shock. The persistence of the unavoidable-shock effect is shown by the fact that over the numerous exposures to this procedure (Exp. I-III) there was no diminution in its destructive effects on the S^D vs S^A appetitive discrimination. On the other hand, such impairments were very minor and transient when a low level of response-correlated shock was used (Exp. III) and did not continue indefinitely even with a high level of response-correlated shock (Exp. V). There are, however, several factors that forestall very strong conclusions about unavoidable vs response-correlated shock. For one thing, subjects accepted many fewer shocks on the punishment procedure of Exp. V than they received on CER procedures. Also, the Exp. V punishment procedure was continued for 40 consecutive sessions, whereas subjects had rarely been left on CER for more than 20 consecutive sessions. Studies examining the effects of frequency of unavoidable shock and length of exposure to the CER procedure would help to clarify some of the findings reported here.

Appropriate comparisons from the present experiments show that the amount of conditioned-stimulus suppression brought about by unavoidable shock was much smaller than that produced by response-correlated shock. This result corroborates that of Azrin (1956), who also found greater suppression of responding in a stimulus associated with response-contingent shock than in a stimulus associated with noncontingent shock.

Cook and Dinsmoor (reported in Dinsmoor, 1960) have presented evidence that, after establishment of an S^D vs S^A discrimination for food reward, subsequent punishment in S^D leads to a greater proportion of responding in S^A than in S^D . Dinsmoor viewed such findings as a reasonable analogue to the clinical-

Freudian concept of "displacement". When a high level of response-correlated shock was used here (Exp. V), the same effect was temporarily observed: discrimination indices were consistently above 1.00. With continued exposure to the punishment procedure, however, the effect eventually disappeared.

The experiments described here show that aversive stimulation in the form of unavoidable shocks may have strong side effects on well-learned and seemingly independently-maintained appetitive discriminations. Sidman (1960) summarized some other intriguing effects of unavoidable shocks and pointed out how the "pathological" behavior which developed from such aversive control could often be traced to the prior experimental history of the subjects. In his studies a history of previous avoidance conditioning was critical in accounting for many of the unexpected facilitations of behavior that occurred with unavoidable shock. Despite the fact that no subject in the present experiments had ever received any prior avoidance conditioning, some unusual facilitatory effects and examples of "maladaptive" behavior were still observed. The phenomena that Sidman studied were different in many respects from the ones described here, so that the relationship of his results to these is rather unclear. What is clear, however, is that unavoidable shocks may produce a variety of unusual facilitatory effects, which do not all require an avoidance-conditioning history.

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