CONDITIONED SUPPRESSION OF AN AVOIDANCE RESPONSE¹

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A signal followed by shock was presented at irregular intervals during a free-operant avoidance schedule. The effects of this procedure were studied in terms of the rate of unavoided shock in the presence and absence of the signal and the rate of response before and during the signal. Three shock intensities were employed. Response enhancement as well as response suppression were observed; irrespective of changes in responding, shock rates substantially increased during signalled periods compared to non-signalled periods. Shock rates in non-signalled periods were generally higher than during training.

When a signal is regularly followed by shock, the signal may control responses that previously functioned to avoid shock. Thus, several studies have demonstrated that the rate of a free-operant avoidance response (Sidman, 1953) is increased in the presence of such a signal (Sidman, Herrnstein, and Conrad, 1957; Belleville, Rohles, Grunzke, and Clark, 1963; Waller and Waller, 1963). Such an increased response rate during signalled periods may later decrease until it matches the baseline response rates (Sidman *et al.*, 1957) but many sessions may have to be given before this phenomenon is observed.

In the studies cited above the dependent variable was a change in the rate of response. This dependent variable was selected on the assumption that in the free-operant situation there is an inverse correlation between rate of response and effectiveness of avoidance. Hurwitz and Bounds (1968) challenged this assumption by demonstrating that a response rate may also increase when shocks are not avoided. Unavoided shocks elicit response bursts (Sidman, 1958) which contribute little to the postponement of additional shocks but which may nevertheless represent a large proportion of the total number of responses recorded during a session. Moreover, Roberts and Hurwitz (1970) reported the suppression

of an avoidance response during a pre-shock signal when the free-operant avoidance schedule was suspended during signal presentation. The effect on rate of response of the signal-shock sequence was clearly different from the effect of presenting a signal without shock; *i.e.*, a timeout from avoidance. It is, therefore, necessary to reexamine the relationship between response rate and shock avoidance during a pre-shock signal. In the present study, frequency of shocks during signalled and non-signalled periods was the primary measure of avoidance, rather than response rate.

METHOD

Subjects

Nine female hooded rats, purchased from Blue Spruce Farms, N.J., weighed between 140 and 160g at the beginning of experimentation. Subjects were housed three per cage with food and water always available.

Apparatus

Three 9 by 9.25 by 9.25 in. (23 by 24 by 24 cm) lever-pressing chambers were used, each having a 2-in. (5-cm) wide lever protruding 1 in. (2.5 cm) into the chamber and mounted 2 in. (5 cm) above the grid floor. A weight of 10 g was needed to depress the lever. The floor was composed of 0.25-cm brass rods spaced 1.3 cm apart parallel to the length of the lever. A constant power stimulator delivered shock via a scrambling device to the floor, lever and sides of the chamber. Shock intensity was determined by measuring the current flow

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through a fixed resistance. Two ceiling lights illuminated the chamber during the session. An exhaust fan was used to ventilate the chamber and provided a masking noise (80 db). The signal for shock was a relay (Guardian Elec. #905-2C-24D) attached to the outside rear wall of the chamber which could be pulsed at 10 per second and added 10 db to the resting noise level. Each lever-pressing chamber was placed in a larger sound insulated box housed inside a larger sound insulated cubicle. The automatic scheduling and recording equipment were placed outside of this cubicle.

General Procedure

A: Free-operant avoidance training. A 0.1-sec shock was delivered every 5 sec (the S-S interval) unless a level press occurred, in which case the shock would be postponed for 20 sec (the R-S interval). Each lever press also resulted in a 0.1-sec offset of houselights. Subjects were randomly assigned to three conditions (three subjects per group) and trained under one of three shock intensities: Group *L*, 0.8 mA; Group *M*, 1.4 mA; Group *H*, 2.0 mA. All sessions were 120 min in duration except for the first and second session, which were 15 and 30 min, respectively. Subjects were run until they met the training criterion of less than 1.0 shock per minute over five consecutive sessions. One subject from Group *H* was discarded for failing to meet this criterion. A total of 39 daily training sessions were given.

B: Signal-shock procedure. A one-min signal consisting of 10 auditory clicks per second, was imposed on the free-operant avoidance schedule approximately once every 4 min; thus, there were 30 signal and shock presentations per session. Coincident with the termination of the signal, was a 1-sec unavoidable shock with an intensity corresponding to that used in the free-operant avoidance schedule. Pilot experimentation indicated that using a relatively longer unavoidable shock facilitated the suppressive control by the signal over ongoing avoidance behavior.

The number of shocks during non-signalled periods, and the number of shocks received under the free-operant avoidance schedule during signal presentations were recorded. The number of responses during the 60-sec period before the signal and during signalled

periods was also obtained. Twenty sessions were given under the signal-shock procedure.

C: Signal-alone procedure. For 11 sessions, the signal was presented alone, with unavoidable shock being omitted; the free-operant avoidance schedule was maintained throughout the signal-alone sessions. Response measures were the same as those obtained previously under the signal-shock procedure.

RESULTS

The experiment consisted of three phases: training under a free-operant avoidance schedule; the intermittent presentation of signal-shock pairings superimposed on the free-operant avoidance schedule; and finally, the omission of the unavoidable shock at the end of each signal presentation. These procedures were studied under three shock intensities: 0.8 mA (Group *L*); 1.4 mA (Group *M*); and 2.0 mA (Group *H*). The effects of the signal-shock procedure were assessed in two ways: by comparing response rates during signalled periods with response rates obtained during a 1-min period before the signal; by comparing shock rates obtained during free-operant avoidance training sessions with shock rates obtained during signalled and non-signalled periods in the signal-shock procedure.

Figure 1 presents response measures for the subjects of Groups *L* and *H* which showed the effects of the signal-shock procedure most clearly. Response data are given in terms of a ratio of the number of responses during signalled periods to the number of responses before the signal. Values above 1.0 indicate increased responding during the signal; values less than 1.0 indicate reduced rates. For clarity, the ratios were based on the averages of response measures over blocks of two sessions, except for Session 70. During Sessions 40 to 59, the signal terminated with unavoidable shock; during Sessions 60 to 70, unavoidable shock was omitted.

A: Free-operant avoidance training. Table 1 presents mean response rates for each subject over the final five sessions of training. After 39 training sessions, systematic differences in response rates attributable to shock intensity were not evident.

Table 2, row FOA presents mean shock rates during non-signalled (NS) periods for each subject over the final five training ses-

Table 1
Mean response rates during baseline (BL) and signalled (S) periods for each subject in each experimental phase: the last five free-operant avoidance training sessions (FOA), the first 10 and last 10 Signal-Shock sessions, and the first and final five Signal-Alone sessions.

	Group L						Group M						Group H					
	L _A			L _B			L _C			M _A			M _B			M _C		
	BL		S	BL		S	BL		S	BL		S	BL		S	BL		S
	BL	S		BL	S		BL	S		BL	S		BL	S		BL	S	
FOA	Last 5	8.74		14.27		7.91				11.37		11.34				6.01		11.16
Signal-Shock	First 10	10.53	8.04	9.72	8.71	10.90	8.01			11.40	7.84	10.76	16.61	5.90	4.33	12.22	13.72	11.67
	Final 10	8.99	5.33	11.58	9.15	10.07	7.62			11.32	7.60	9.03	15.17	7.11	5.35	9.87	11.15	10.24
S ₁	First 5	8.33	5.70	9.54	12.08	10.31	10.22			12.16	8.66	12.03	14.79	7.78	9.54	10.30	11.41	11.38
	Final 5	8.92	6.54	9.09	11.43	8.17	11.05			11.53	10.60	9.56	12.89	6.80	8.54	10.45	10.11	12.31

Fig. 1. The ratio of the number of responses during a pre-shock signal to the number of responses during baseline (60-sec before the signal) for each subject in Group L (0.8 mA) and Group H (2.0 mA). Except for Session 70, all figure points represent blocks of two sessions.

sions: the highest mean shock rate was 0.68, the lowest 0.04 shocks per minute. This must be evaluated against the possibility of receiving 12 shocks per minute if the subject failed to respond and against three shocks per minute if the subject responded only to shocks occurring at the end of an elapsed R-S inter-

val. All subjects avoided shock except Subject H₃, whose rate was 2.04 per minute and who was dropped from further experimentation.

B: Signal-shock procedure. The signal-shock procedure (Sessions 40 to 59) did not affect baseline rates of response uniformly *i.e.*, the 60-sec period before the signal (Table 1, first 10, compared to FOA).

However, the signal-shock procedure resulted in several changes in response rates during signalled periods. As seen in Fig. 1, the response rates during signalled periods were marginally higher at first than during pre-signal periods for the two presented conditions. After several sessions, the response rates during signalled periods by subjects in Group L (0.8 mA) had drifted below pre-signal rates. The effect of the 2.0-mA shock intensity (Group H) was to maintain relatively high response rates in the presence of the signal, which tended to decrease only after many sessions. For two subjects under 1.4-mA shock intensity (Group M), responding during the signal followed the course described for Group L; the response-rate of the third subject followed the course described by Group H (Table 1, first 10 and final 10). Although rates of response during training were not differentially affected by shock intensity, shock intensity did result in differential rates of response during signalled periods: responding under 2.0 mA was consistently higher than under 0.8 mA throughout all 20 signal-shock sessions (see Table 1). However, over these same sessions, baseline response rates during pre-signal periods remained undifferentiated by shock intensity.

The data in Table 2 indicate that the effect of the signal-shock procedure on shock rates was dramatic. Mean shock rates for all subjects increased during non-signal periods compared to training, from 20% to as much as 600% (Subjects H₁ and H₂, respectively). For all subjects but one, mean shock rates during signalled periods were considerably higher compared to mean shock rates during non-signal periods. The increase ranged from about 40% to 300% (Subjects H₂ and L₃, respectively). The differences in shock rates, which were maintained over all 20 signal-shock sessions, did not seem to be differentially affected by shock intensity.

Figure 2 presents sample cumulative records for Subject L₃ obtained during the last

Table 2

Mean shock during signalled (S) and non-signalled (NS) periods for each subject during each experimental phase.

Experi- mental Procedure	Sessions	Group L: 0.8 mA						Group M: 1.4 mA						Group H: 2.0 mA			
		L ₁		L ₂		L ₃		M ₁		M ₂		M ₃		H ₁		H ₂	
		NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
FOA	Last 5	0.57	x	0.11	x	0.31	x	0.30	x	0.16	x	0.68	x	0.29	x	0.04	x
Signal- Shock	First 10	0.87	1.42	0.28	0.72	0.50	1.58	0.72	1.44	0.32	0.15	1.76	2.56	0.35	1.10	0.25	0.36
	Last 10	0.98	1.91	0.21	0.51	0.42	1.35	0.39	1.33	0.27	0.17	1.02	2.30	0.48	0.87	0.24	0.40
Signal Alone	First 5	1.33	1.93	0.28	0.25	0.37	1.25	1.35	0.79	0.28	0.16	1.07	1.31	0.57	0.64	0.25	0.19
	Last 5	0.58	0.50	0.34	0.20	0.34	0.28	0.37	0.35	0.49	0.16	0.54	0.31	0.43	0.59	0.19	0.13

Subject L₃

Session 39:

Session 43:

Fig. 2. The cumulative records sampled from the middle of the last free-operant avoidance training session (#39) and the fourth session under the Signal-Shock procedure. Downward deflections of the pen indicate the occurrence of shock; deflections in the horizontal record at the base of the figure indicate the presence of the pre-shock signal. An enlarged portion of the record obtained during Session 43 is presented in the inset.

free-operant avoidance session (#39) and the fourth signalled-shock session (#43). Figure 2 shows that shocks tended to occur in clusters of twos and threes during signalled periods of Session 43. On the other hand, relatively few shocks occurred during non-signalled periods.

C: Signal-alone procedure. During the final phase of the experiment, when the signal was presented without unavoidable shock (Sessions 60 to 70), response rates during signalled periods tended to be greater than pre-signal response rates (Fig. 1). An enhancement in response rates was observed for seven of the subjects during the earlier sessions under this procedure and was maintained for four subjects during the final session.

Table 2 shows that shock rates decreased during signalled periods for all subjects but one over the first five signal-alone sessions as compared to the last 10 sessions under the signal-shock procedure. Mean shock rates over the first five and last five signal-alone sessions indicated that the differential effect of the signal on shock rates had decreased: shock rates approximated those obtained over the last five sessions of free-operant avoidance training.

DISCUSSION

The major results of this experiment were as follows: first, superimposing signalled-shock on ongoing avoidance behavior resulted in an overall increase in shock rates in non-signalled periods. Second, during the pre-shock signal, shock rates were considerably greater than during non-signalled periods. Third, response rate during non-signalled periods did not systematically differ from response rates observed during free-operant avoidance train-

ing. Fourth, contrary to common supposition, the changes (*i.e.*, increase) in shock rate during signalled periods were not systematically related to changes in response rate: subjects trained under low shock intensity (0.8 mA) showed reduced response rates and subjects trained under high shock intensity (2.0 mA) showed increased response rates. However, all subjects showed increased shock rates. Finally, when the signal was presented without shock, response rates during the signal increased for a majority of the subjects. In summary, the introduction of signalled-shock resulted in an overall increase in avoidable shocks with the increase greater during signalled periods; the increased shock rates were not systematically related to changes in response rates

If avoidance is suppressed, as the data presented in this study suggest, why did shock rates and not response rates reflect the suppression? One reason is that the rate measure represents an average of individual interresponse times (IRTs). Unless one can assume that IRTs are normally distributed, the measure of rate should be used sparingly and with caution. In the present instance, such an assumption would have been unwarranted because IRTs produced by a free-operant avoidance schedule are known to be determined by two factors, each of which generates skewed distributions. The first IRT distribution reflects shock-elicited response bursts (Sidman, 1958) and the second represents an extinction factor that produces increasingly long IRTs as a function of time since the last shock (Wertheim, 1965). Using shock-rate as the primary measure was tantamount to selecting the IRT value that equalled the response-shock postponement interval. The frequency of this value may therefore be used to assess its probability on the outcome of different experimental arrangements.

It will be recalled that Sidman *et al* (1957) reported in their original study of the effects of the signalled shock procedure on the maintenance of a free-operant avoidance rate that, at first, the response rate during the signal was enhanced. After many presentations of signalled shock the response rate during the signal gradually declined. In this respect only, there is agreement between the present results and the earlier study, at least when a low shock was used. Of course, procedurally the two studies differed in many respects.

Thus, the rate of presenting signalled shock was relatively high in the present study and as a result the number of shocks relative to the frequency of shock obtainable under the free-operant avoidance procedure was substantially increased. It is possible that such an increase in shock rates could have deleterious effects—as happened—and that this effect would be concentrated in the periods identified by the signal. If signalled shock were less frequently presented, the opposite result may have occurred; that is, an enhancement of avoidance rather than a deterioration might have been found. Also in the present study, the interval between signal and shock was 1 min compared to 5 min in several earlier studies. At present we do not know whether the suppression effect depends on the length of the signal-shock interval or to what extent this variable interacts with the principal parameter of the avoidance schedule, the response-shock postponement interval, R-S. It should also be noted that in the present experiment the duration of the signalled shock was relatively longer than the avoidable shock. This procedure may not only have enhanced the discriminability between the two shocks—and, consequently, aided the identification of the relation between the signal and the unavoidable shock—but such long shocks themselves may be primarily responsible for the breakdown of the rate of response developed under the avoidance schedule. Some evidence in support for this notion has already been obtained in this laboratory and will be reported later. Furthermore, by increasing the discriminability between the two shocks, one may also have changed the function of the signal so that it resulted in localizing the suppression effect to the period of the signal, rather than being spread throughout the whole session. However, the availability of a signal did not prevent a deterioration of avoidance during non-signalled periods. Additional research is clearly necessary to determine whether the suppression effect can be constrained to the periods indicated by the signal, or whether the generalization gradient necessarily remains flat.

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