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THE EFFECT OF A PRE-SHOCK SIGNAL ON A FREE-OPERANT AVOIDANCE RESPONSE[1]

A. E. ROBERTS[2] AND HARRY M. B. HURWITZ

UNIVERSITY OF TENNESSEE

After 25 free-operant avoidance training sessions, a 1-min signal followed by a brief shock was presented on the average of once every 4 min. During the signal, the avoidance schedule was suspended (20 sessions). Response rates during the signal were markedly reduced. Shock rates during non-signalled periods increased. Fifteen additional sessions were given during which the signal was presented without shock. Response rates during signalled periods were greater than previously observed during signalled periods, indicating that signalled shock had suppressive control over a previously acquired avoidance response rate.

The conditioned anxiety procedure (also referred to as conditioned suppression and CER in the literature) originally described by Estes and Skinner (1941) involves presenting a neutral stimulus followed by a noxious stimulus and measuring changes of the effects of this pairing operation by changes in ongoing behavior. When the ongoing behavior is maintained under a schedule of food reinforcement, decreases in responding during the signal preceding shock are usually found (Estes and Skinner, 1941; Davis, 1968). However, when signalled shock is superimposed on a response rate maintained by a free-operant avoidance schedule (Sidman, 1953), an increase rather than a decrease in the rate of response during the signal has often been reported. Using rhesus monkeys, Sidman, Herrnstein, and Conrad (1957) reported increased rates of responding in the presence of a 5-min signal, but the rates also increased during non-signalled periods. Following many experimental sessions, the rate of response during signalled periods declined until it matched the rate during non-signalled periods. Thus, these experimenters found that enhancement of the response rate was a transient event. In a study by Waller and Waller (1963), dogs were exposed to a multiple schedule consisting of three components: a food reinforcement schedule, a free-operant avoidance schedule, and the extinction of food-maintained behavior. When the signal was superimposed at different times on each of these components, the rates of response in the presence of the signal were increased under the avoidance and extinction components, but a decrease in response rate under the food reinforcement components was not obtained. In short, Waller and Waller (1963) failed to suppress positively reinforced behavior by a pre-shock stimulus but confirmed the earlier finding that the signal enhanced avoidance responding. Transient events, such as those described by Sidman, Herrnstein, and Conrad (1957), were not reported, as enhanced avoidance responding was maintained after many exposures to signalled shock. A study by Belleville, Rohles, Grunzke, and Clark (1963) also showed that monkeys increased the rate of a free-operant avoidance response during a pre-shock signal. As reported by Waller and Waller (1963), enhanced avoidance responding was maintained over sessions and did not decrease as reported earlier by Sidman *et al.* (1957).

A different result has been reported by Hurwitz and Roberts (1969): they reported changes in response rate of rats, as well as changes in shock frequencies, when a 1-min signal, followed by shock, was presented on a response rate that was being maintained under a free-operant avoidance schedule. Response rates during signalled periods were determined not only by the procedure but also by the intensity of shock: low-intensity shock (0.8 mA) initially decreased the rate of response, which decreased below baseline after relatively few sessions; high shock intensity (2.0 mA) also increased rate of response, which declined to

[1]This study was supported by *NSF* Grant GB-8505 to Harry M. B. Hurwitz. Reprints may be obtained from H. M. B. Hurwitz, Department of Psychology, University of Tennessee, Knoxville, Tennessee 37916.

[2]Now at Catawba College, Salisbury, North Carolina.

baseline only after many sessions. These results generally agree with those described by some investigators. However, the major and most consistent finding of the study was a dramatic increase in shock rates during the signalled periods, which was not systematically related to changes in response rates. This increase in the rate of shock in the presence of the signal suggests that the signal has response suppressive functions. The lack of a systematic relation between response rate and shock rate might be due to a computational artifact. If the rate of response measures were obtained using the number of responses in signalled periods as the numerator and the time under the signal as the denominator, the numerator would include responses made to shock. As shock elicits a great many responses (Sidman, 1958), also known as response "bursts", one should eliminate such response bursts from the computation of response rate. If this were done, response rate and shock rate during signalled periods should become inversely related.

It was decided to study the suppressive control of the pre-shock signal more closely by suspending the free-operant avoidance schedule during presentation of the signal. Such a procedure would eliminate the confounding effects of post-shock responses during signal presentation. If this were done, one would have to distinguish effects due to the signal-shock pairing from those attributable to the signalled suspension of avoidance (timeout). A lower rate during the signalled shock period than during signalled timeout would demonstrate suppressive control by the pre-shock signal.

METHOD

Subjects

Nine experimentally naive female hooded rats, purchased from Blue Spruce Farms, New Jersey, weighed about 175 g at the beginning of experimentation. Subjects were housed three to a cage with food and water always available.

Apparatus

Three 9 by 9.5 by 9.5 in. (23 by 24 by 24 cm) lever-pressing chambers were used, each having a 2 in. (5 cm) wide bar protruding 1 in. (2.5 cm) into the chamber 2 in. (5 cm) above the grid floor. A weight of 10 g was needed to depress the lever. The grids consisted of 10 in. (25 cm) brass rods spaced 0.5 in. (1.3 cm) apart parallel to the lever. A constant current shock generator delivered shock via a mechanical stepper to the grids, lever, and sides of the chamber. Each chamber was placed in a larger sound insulated box with an exhaust fan to provide ventilation and masking noise (80 db). The clicking stimulus added 10 db to the noise level. All three boxes were housed inside a sound-attenuated man-sized cubicle. Automatic scheduling and recording equipment were placed outside of this cubicle.

General Procedure

The experiment consisted of several phases. First, all subjects were trained to respond under a free-operant avoidance schedule. Then, a signal-shock sequence was presented at irregular intervals, during which time the free-operant avoidance schedule was suspended. Following this procedure, the signal was presented without shock. The avoidance schedule remained in effect between successive signal presentations. Subsequent phases of the experiment involved presenting the signal either during free-operant avoidance extinction or during the free-operant avoidance schedule. The experimental phases are summarized in Table I.

Table 1

The seven experimental phases and the number of sessions under each phase.

Exp. Phase	*Free-Operant Avoidance Baseline*	*Superimposed Stimuli*	*Number of Sessions*
A	Yes	None	28
B	Yes	Signal–Shock	20
C	Yes	Signal–alone	15
D	No	Signal–alone	4
E	Yes	Signal–alone	8
F	No	Signal–alone	5
G	Yes	Signal–alone	5

Phase A: Training. Under the free-operant avoidance procedure, a subject would receive a 0.1-sec shock every 5 sec (the S–S interval) unless a lever press occurred, in which case shock would be postponed for 20 sec (the R–S interval). Each lever press resulted in a 0.1-sec offset of houselights. Subjects were randomly assigned to three group conditions (three subjects per condition) and trained under the following shock intensities: Group *L,* 0.8 mA; Group *M,* 1.4 mA; and Group *H,* 2.0 mA. Response rates were obtained from the same periods of the session during which the signal would later be presented; the signal was not presented during these periods as earlier studies have indicated that to do so would retard suppression (Carlton and Vokel, 1967; May, Tolman, and Schoenfeldt, 1967; Baron and Kaufman, 1968). Each daily session was 120 min long except for the first and second day, when session length was 15 and 30 min, respectively. A total of 28 training sessions was given.

Phase B: Signal–Shock. A 1-min signal consisting of 10 auditory clicks per second was presented on the average of once every 4 min; during the signal period, the free-operant avoidance schedule was suspended. Coincident with the termination of the signal, a 1-sec unavoidable shock[3] having an intensity corresponding to that used in the free-operant avoidance schedule was given. This was the only phase of the experiment in which the signal was followed by unavoidable, inescapable shock.

A total of 30 signal–shock pairings was presented during each session with 20 sessions being given in this phase of the experiment.

Phase C: Signal–Alone. For 15 sessions, the signal was presented and shock omitted. Except for the signalled periods, the free-operant avoidance schedule remained in effect.

Phase D: Signal–Alone, Avoidance–Extinction. For four sessions, the shock source was disconnected and the signal was presented during free-operant avoidance extinction.

Phase E: Signal–Alone. The free-operant avoidance schedule was reinstated and the signal was presented without shock; *i.e.,* a repetition of Phase C. During signalled periods, the free-operant avoidance schedule was suspended. Eight sessions were given in this phase of the experiment.

Phase F: Signal–Alone, Avoidance–Extinction. For five sessions, the signal was again presented during free-operant avoidance extinction; *i.e.,* a repetition of Phase D.

Phase G: Signal–Alone. For five sessions, the conditions described for Phases C and E were in effect: during signal presentations, the avoidance schedule was suspended, and the signal was not followed by shock, but the free-operant avoidance schedule was in effect during non-signalled periods.

Measures

Response events were recorded in 60-sec periods before, during, and after the signal. Each 60-sec period was divided into five 12-sec intervals and responses during each interval were recorded separately. In addition, the number of responses occurring within 4 sec after termination of a signal–shock sequence was recorded as a measure of post-shock responding. The number of avoidable shocks each subject received during a session (*i.e.,* during non-signalled periods) was also recorded.

RESULTS

The mean response rate obtained for each 12-sec interval during the three 60-sec periods for experimental Phases A through H is presented in Fig. 1, 2, and 3. Figure 1 presents mean response rates for subjects trained under 0.8-mA shock intensity (L_1, L_2, and L_3); Fig. 2 presents mean response rates for subjects trained under 1.4-mA shock intensity (M_1, M_2, and M_3); and Fig. 3 presents mean response rates for subjects trained under 2.0-mA shock intensity (H_1, H_2, and H_3). For details of the number of sessions used to calculate data points see the pertinent sections below.

Table 2 presents mean shock rates for each subject over the seven experimental phases. The free-operant avoidance schedule was suspended during signalled periods so that the data were obtained during non-signalled periods.

Phase A: Training. Panels A of Fig. 1, 2, and 3 present mean response rates for each subject over the last five sessions under free-operant avoidance training Phase A. The rates of responding during these last five free-operant avoidance training sessions did not differentiate subjects trained under the three shock intensities, although two subjects from Condition M responded at considerably lower rates than the other seven subjects. The shock rate data presented in Table 2, Row A, indicate that the subjects were avoiding most of the shocks (range 0.25 to 1.26 shocks per minute).

[3]Pilot experimentation indicated that using relatively longer unavoidable shock facilitated the suppressive control by the signal over ongoing research rates.

Table 2

Mean shock rates for each subject over the seven experimental phases. The free-operant avoidance schedule was suspended during signalled periods so that the data were obtained during non-signalled periods only.

	Condition L: *0.8 mA*			*Condition* M: *1.4 mA*			*Condition* H: *2.0 mA*		
	L_1	L_2	L_3	M_1	M_2	M_3	H_1	H_2	H_3
A	0.41	0.47	0.40	1.26	0.25	1.03	1.01	0.73	0.27
B_1	0.67	0.62	0.40	1.88	0.40	1.89	1.73	1.07	0.63
B_2	0.58	0.36	0.21	1.63	0.35	1.36	0.98	0.78	0.30
C	0.49	0.36	0.36	1.21	0.38	1.46	1.00	0.86	0.22
D	x	x	x	x	x	x	x	x	x
E	0.30	0.30	0.28	0.95	0.29	0.97	0.80	0.61	0.13
F	x	x	x	x	x	x	x	x	x
G	0.32	0.17	0.31	0.60	0.27	0.70	0.93	0.43	0.09

Phase B: Signal–Shock. The effects of the signal–shock procedure are presented in terms of the first 10 and the final 10 sessions during which the avoidance schedule was suspended during signalled periods (Panels B_1 and B_2, respectively of Fig. 1, 2, and 3).

Over the first 10 sessions, with the exception of one subject, response rates during the pre-signal period were the same as, or slightly lower than, rates obtained during comparable periods sampled during free-operant avoidance training sessions; that is, under the baseline conditions. Response rates during signalled periods were systematically lower than rates during the pre-signal periods.

Increased response rates during the signalled period, compared to the pre-signal period, were apparent for seven of nine subjects during the first sessions under this procedure. However, by the end of the second session, responding during the signal had declined to levels less than the pre-signal response rate for all but one subject. Inspection of Panels B_1 of Fig. 1, 2, and 3, which summarize the response-rate data for each subject over the first 10 sessions, shows a characteristic pattern of responding during the signal: the response rates often increased at the signal's onset followed by a sharp decrease that was maintained throughout the signal, although in several cases a slight increase was observed toward the end of the signal. The relatively high rates of response noted for all subjects during the first interval of the post-signal period reflect shock-elicited response rates; however, the rates quickly decreased to match those of the pre-signal period.

Table 2, Row B_1, shows that the introduction of the signal–shock procedure resulted in increased sessional shock rates during non-signalled periods for all but one subject (L_3). The increase in shock-rates ranged from 32% (Subject L_2) to 133% (Subject H_3).

Panels B_2 of Fig. 1, 2, and 3 indicate that pre-signal response rates observed over the last 10 signal–shock sessions generally matched those in the first 10 signal–shock sessions. The suppression of responding during the signal, after the initial high response rates to the onset of the signal, was more complete. The characteristic pattern of responding observed during signal over the first 10 sessions was even more pronounced for all subjects.

Table 2, Row B_2, shows that shock rates over these last 10 signal–shock sessions decreased and, for some subjects, matched shock rates observed during free operant avoidance training sessions.

Phase C: Signal–Alone. Panels C of Fig. 1, 2, and 3 present mean response rates over the last 10 sessions of presenting the signal without shock. Responding in pre-signal periods was generally maintained except for two subjects trained under 1.4-mA shock intensity. In all cases, except subject M_3, responding during the signal, when the signal was not followed by shock, was greater than when the signal was followed by shock (Phase B). For six of the nine subjects, a characteristic pattern of responding during the signal when presented without unavoidable shock, was an intial decline from the rate during the first 12 sec of signal presentation followed by a slight increase of the response rate between the onset and termination of the signal. Even though responding in the presence of the signal increased over sessions under this procedure, response rates remained considerably lower

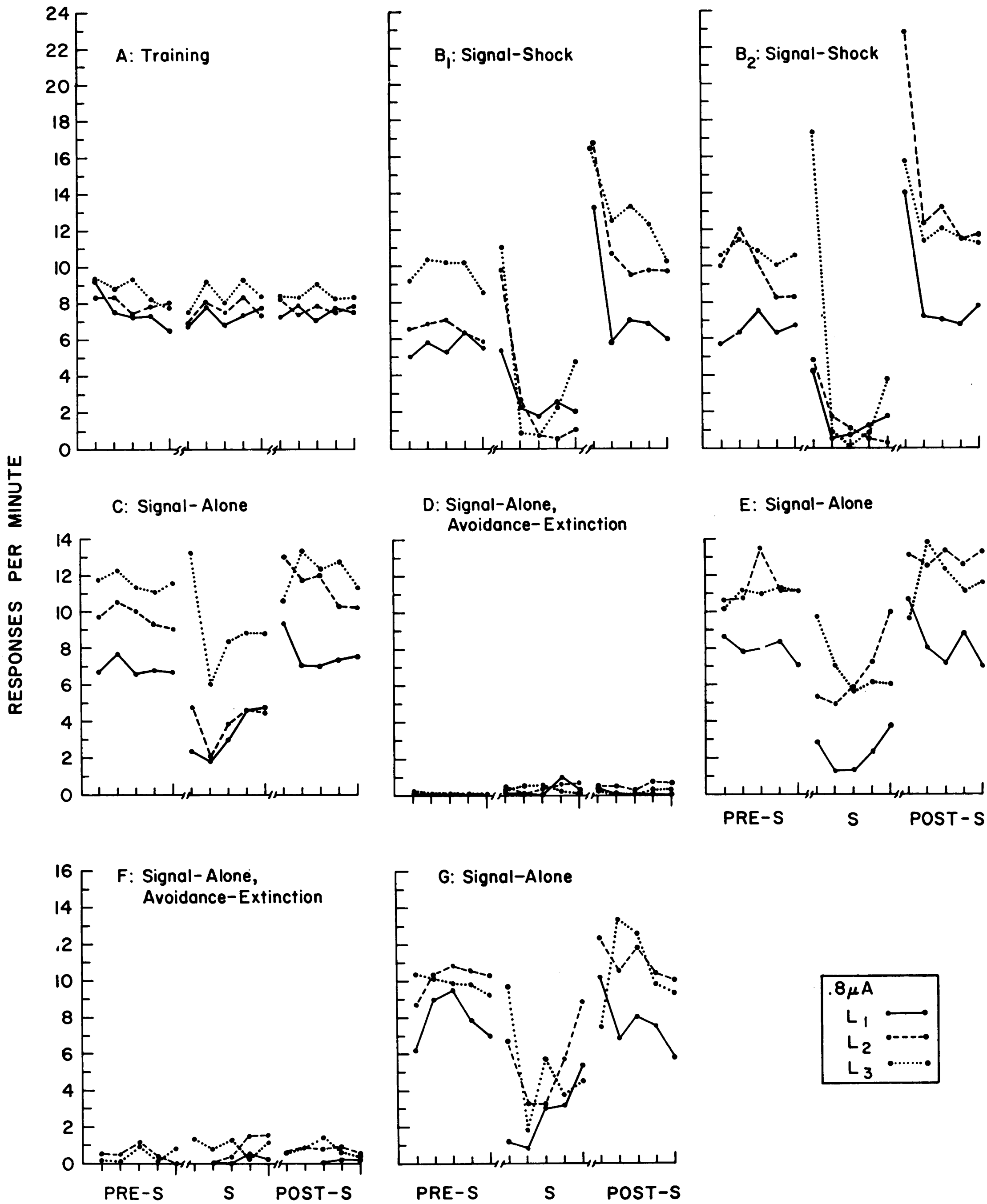

Fig. 1. Mean response rates for each 12-sec interval during the three 60-sec periods for subjects (condition L) trained under 0.8 mA shock intensity. Panel *A* presents mean response rates over the last five sessions of free-oprant avoidance training. Panels B_1 and B_2 present mean response rates for the first and last 10 Signal–Shock sessions, respectively. Panel C presents mean response rates for the last 10 Signal–Alone sessions. Panel D presents mean response rates during the last recorded Signal–Alone, Avoidance-Extinction session. Panel E presents mean response rates over the last six Signal–Alone sessions. Panel F presents mean response rates during the last recorded session of the second Signal–Alone, Avoidance–Extinction procedure. Panel G presents mean response rates for the last recorded sessions of the third Signal–Alone procedure. Panels A through G depict the same response rate classifications in Figs. 2 and 3.

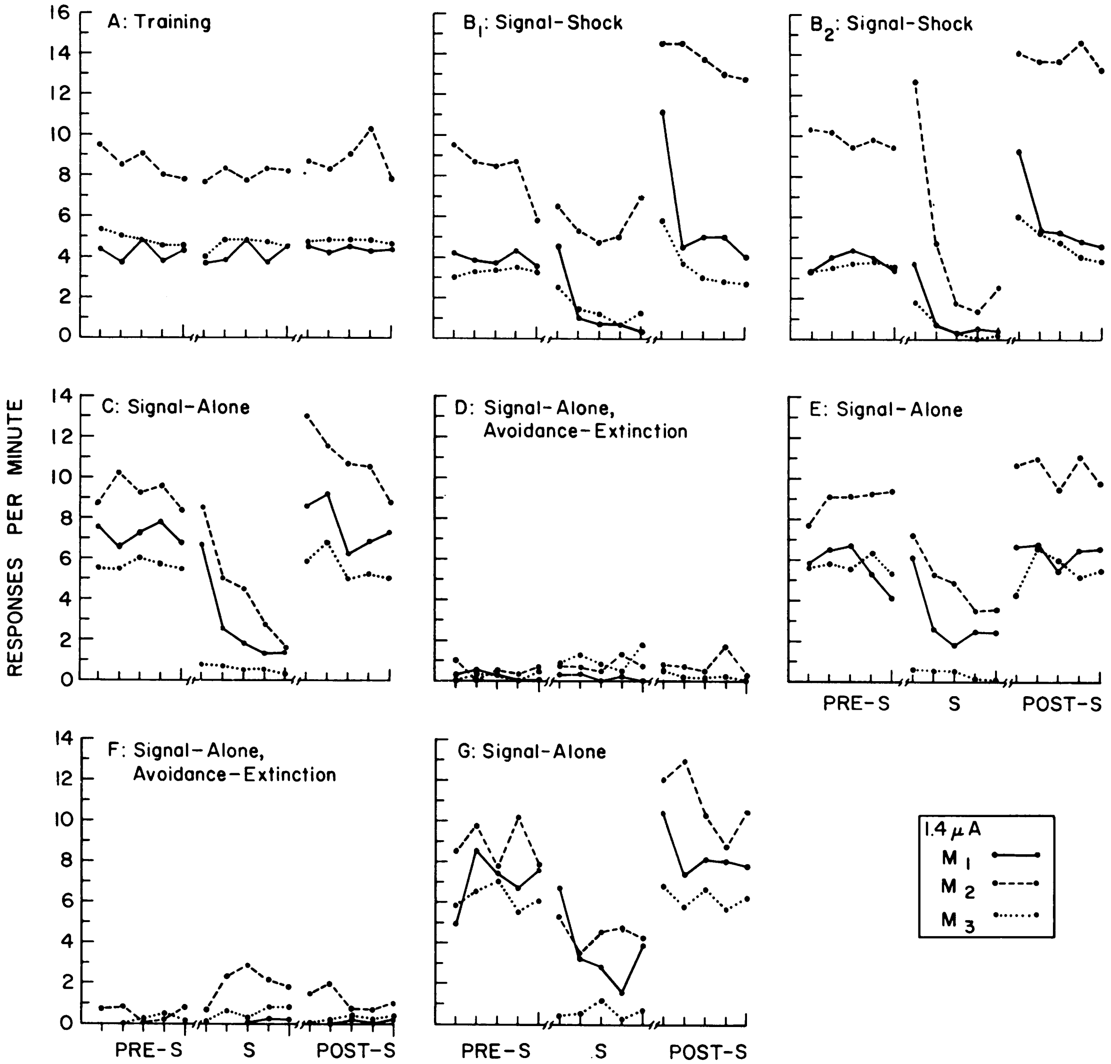

Fig. 2. Mean response rates for each 12-sec interval during the three 60-sec periods for subjects (condition M) trained under 1.4 mA shock intensity. See Fig. 1 legend for details.

than pre-signal rates. Response rates recorded in the first 12 sec of the post-signal period were increased relative to pre-signal responding, but the sharp increase in this post-shock period observed when the signal was followed by shock (Panels B_1 and B_2) had decreased. The response rate following termination of the signal was higher than the pre-signal rate, which suggests that either a high rate of response had been conditioned to signal termination, or the high response rate could be due to the subject emitting response "bursts" after receiving the first avoidable shock following signalled periods. We have no measures to decide between these two alternatives.

Table 2, Row C, shows that shock rates during this phase had generally returned to levels observed under free-operant avoidance training for all but one subject.

Phase D: Signal–Alone, Avoidance–Extinction. Response rates for the last recorded session in which the signal was represented on an avoidance–extinction baseline are presented in Panels D, of Fig. 1, 2, and 3. Although the actual response rates were greatly reduced—less than one response per minute over the entire session—response rates for all subjects during signal presentations were greater than either pre-signal, or post-signal response rates. If one were to calculate a traditional suppression ratio measure, B/A + B, where B represents response measures during signalled periods, and A represents response measures before the signal, it will be seen that we replicate the result of enhanced responding during signalled periods reported by other investigators (Rescorla and LoLordo, 1965; Rescorla, 1967; Grossen and Bolles, 1968; Kamano,

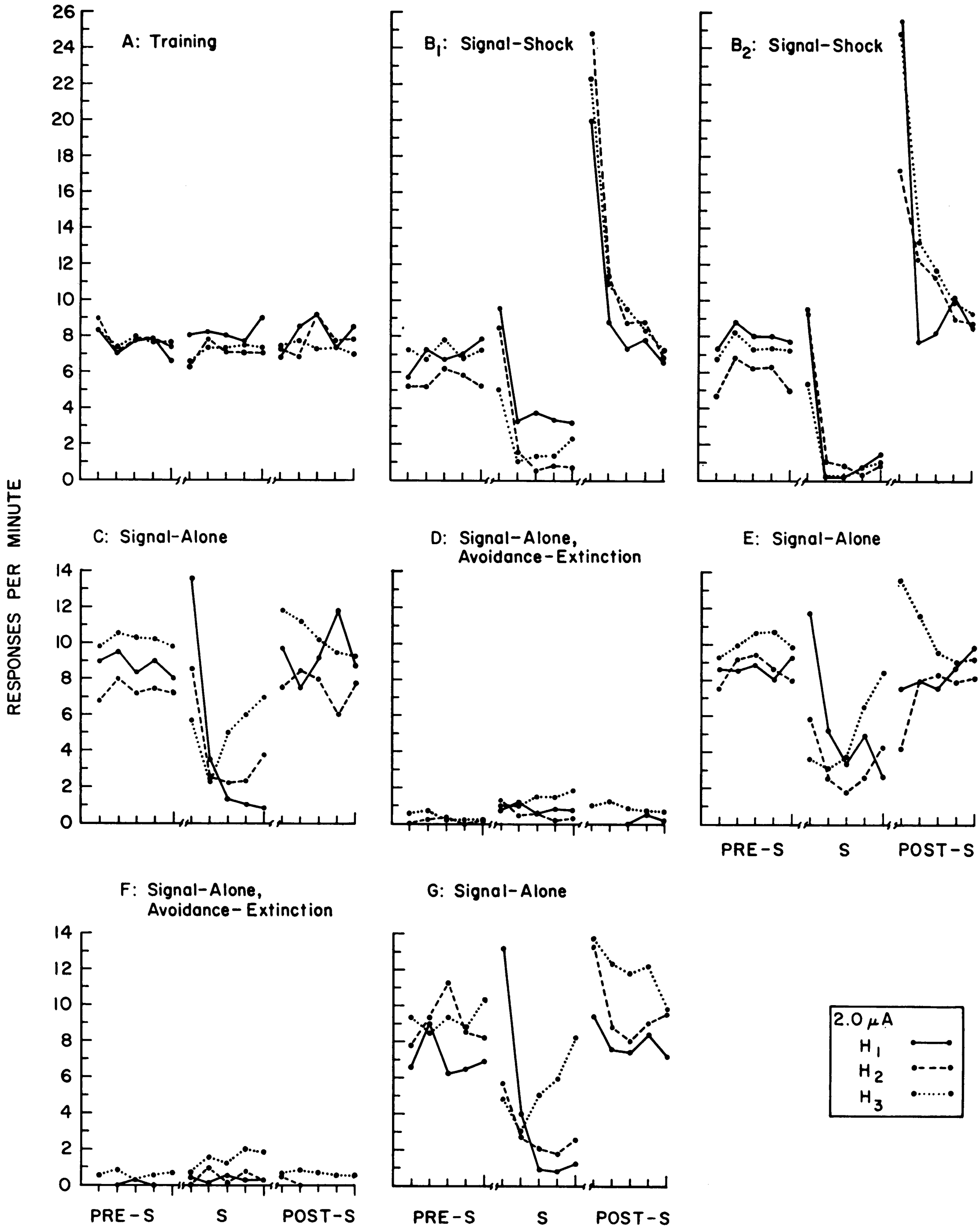

Fig. 3. Mean response rates for each 12-sec interval during the three 60-sec periods for subjects (condition H) trained under 2.0 mA shock intensity. See Fig. 1 legend for details.

1968). The results are given in Table 3 for both Phase D and Phase F (see below) of the experiment. Examination of the cumulative records indicated that all responding, including responding in the presence of the signal, was restricted to early parts of the sessions.

Phase E: Signal–Alone. The free-operant avoidance schedule was reinstated during this phase and the signal was presented without being followed by shock. The mean response rates over the last six sessions are presented in Panels E of Fig. 1, 2, and 3 and indicate that response rates during the pre-signal periods, the characteristic response patterns during signalled periods, and relatively high response rates in the first interval of post-signal periods tended to match those obtained under the first Signal–Alone procedure, Phase C.

Phase F: Signal–Alone, Avoidance–Extinction. The procedure was the same as described for Phase D. For five sessions, the free-operant avoidance schedule was suspended and the signal without shock was presented at irregular intervals. Panels F of Fig. 1, 2, and 3 present response rates over the last recorded session under this procedure. The data closely matched that reported under the first Signal–Alone, Avoidance–Extinction procedure, Phase D. Although overall responding was relatively low, response rate during the signal was greater than during either pre-signal or post-signal periods (see Table 3 where the response rate during the signal is examined as relative to pre-signal rate).

Phase G: Signal–Alone. The free-operant avoidance schedule was reinstated for five sessions, and the signal without shock was presented at irregular intervals during each session. Response rates during pre-signal, signal, and post-signal periods, and the response patterns during the signal as presented in Panels G of Fig. 1, 2, and 3, tended to match those obtained under the earlier Signal–Alone procedure, Phases C and E. For all but one subject, the response rates during signalled periods were considerably greater than those obtained when the signal was presented during avoidance–extinction, Phases D and F.

DISCUSSION

The primary purpose of this experiment was to study the effects of a pre-shock signal on a response rate previously maintained under a free-operant avoidance schedule. As reported by Hurwitz and Roberts (1969) when a stimulus followed by shock is introduced during responding maintained under a free-operant avoidance schedule, avoidance is impaired during signalled periods; that is, shock rates increase. Because unavoided shocks generally result in bursts of responses, one can only evaluate the control exerted by the signal over response rates when the confounding effects of these response bursts are eliminated. One way of doing this would be to suspend the free-operant avoidance procedure during the signalled periods that precede shock. However, the control procedure introduces a different source of confounding; namely, a period of timeout from the avoidance schedule. If the rate of response during signalled timeout periods is compared to the rate of response during a pre-shock signal, three outcomes are probable: first, the rate of response during the interval between onset of the signal and shock may be greater than during the signalled timeout and may also exceed the rate of response under the avoidance schedule. Such a result would lend support to the view suggested by Rescorla and Solomon (1967) that the pre-shock signal has response enhancing functions. Second, the rate of response during the signalled pre-shock period may be at first greater

Table 3

Suppression ratio measures for each subject as calculated over the final session in which the Signal–Alone was presented on an extinction baseline (Phases D and F). Suppression ratios were computed by the formula B/A + B, where A represents response rates during pre-signal periods and B represents response rates during signalled periods. A ratio value of 0.50 indicates no change in response rates. Values less than 0.50 indicate reduced responding; values more than 0.50 indicate enhanced responding.

	L_1	L_2	L_3	M_1	M_2	M_3	H_1	H_2	H_3
Phase D	0.92	0.79	1.00	0.69	0.61	0.82	0.82	0.81	0.86
Phase F	0.68	0.57	1.00	0.70	0.94	0.84	0.70	1.00	0.72

than during signalled timeout. After many sessions the respective rates could become comparable. If the number of presentations needed to reach the point of equivalence is greater for signalled shock than for signalled timeout, one could also conclude that a signal paired with shock has response enhancing properties. The experimental design appropriate to test this prediction would differ in some respects from the design used in the present study. The third outcome would be the opposite of the two mentioned above. It would consist of the rate of response during signalled shock being less than the rate of response during signalled timeout. This outcome was observed in the present experiment. The results, therefore, demonstrate that the pre-shock signal had acquired response suppressive functions.

It should be noted that our procedures and results differ somewhat from those reported by Appel (1960). In the Appel (1960) experiment, two conditions were studied. First, when signalled timeout was introduced, the response rates declined during the signal; this result was also found in the present study. In the second condition, unavoidable shocks were frequently presented during signalled timeout; response rates during signalled periods were comparable to response rates during non-signalled periods. As previously suggested, this outcome may have resulted from response bursts elicited by unavoidable shocks. In the present study, unavoidable shock was delivered only at the termination of the signal; response rates were reliably lower than when the avoidance schedule was in effect.

Figures 1, 2, and 3 showed that response rates changed in a consistent manner during the course of a signal-shock period: following onset of the signal the rate of response declined but later increased. When the signal was not followed by shock, as in Phases C, E, and G, the rate of response was higher than when the signal was followed by shock, but was lower than under avoidance. An unexpected finding was that five of nine subjects responded at a relatively high rate to the onset of the signal for as long as the signal-shock procedure was in effect (*cf.* the first 12-sec interval of the signal period); when the signal was presented alone, these initial high rates diminished. Had we used a signal-probe of short duration, the results might have indicated enhanced avoidance responding during the pre-shock signal. For example, Rescorla and LoLordo (1965) and Grossen and Bolles (1968) both reported an increase in avoidance responding in the presence of a signal of 5 sec duration; Rescorla (1967) and Kamano (1968) similarly found an increase in the rate when the signal was 30 sec in duration.

We should point out that the present experiment included three of the five procedures frequently employed to study the effects of the conditioned suppression procedure on an avoidance response: presenting signalled shock when the avoidance schedule was suspended during signalled periods; presenting the signal–alone when the avoidance schedule was suspended; and presenting the signal–alone on an avoidance-extinction baseline (*cf.*, Rescorla, 1967; Grossen and Bolles, 1968). Each of the three procedures yielded different results. First, a marked reduction in responding relative to baseline (pre-signal response rate) was observed when signalled shock was presented with the avoidance schedule suspended. Second, reduced responding was observed when the signal–alone was presented with the avoidance schedule suspended. Third, increased responding was observed when the signal alone was presented on an avoidance-extinction baseline [see Table 3]. However, response rates were minimal.

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