A RATE MEASURE OF THE RELATIVE AVERSIVENESS OF SIGNALLED VS UNSIGNALLED SHOCK¹

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Five rats were trained on a two-component multiple schedule with each component consisting of a two-link chain schedule. Differential response suppression in the initial links of the chain schedules was used as a measure of the relative aversiveness of events introduced into the subsequent terminal links. When unsignalled shock was scheduled in one terminal link and signalled shock in the other (in addition to equal numbers of food reinforcers), responding was suppressed to a greater degree in the initial link preceding the unsignalled-shock condition. Reversing the terminal-link positions of unsignalled shock and signalled shock led to a reversal of the differential response suppression in the initial links. These results confirm previous findings that signalled shock is less aversive than unsignalled shock and extend the generality of this phenomenon from choice measures to rate measures of aversiveness.

The aversiveness of a stimulus is revealed in several ways: in terms of its capacity to maintain escape or avoidance behavior, and in terms of its capacity to suppress the behavior that produces it. With respect to the aversive properties of electric shock, several studies have indicated that the aversiveness of shock is reduced when a stimulus precedes the shock (Badia, Suter, and Lewis, 1967; Knapp, Kause, and Perkins, 1959; Lockard, 1963, 1965; Perkins, Levis, and Seyman, 1963; Perkins, Seyman, Levis, and Spencer, 1966). In the first demonstration of this phenomenon, Knapp, *et al.*, (1959) showed that rats running to food in the two arms of a T-maze, choose the signalled-shock side more frequently than the other side, where unsignalled shock occurred. Lockard (1963) and Perkins, *et al.*, (1963) subsequently found that rats will spend more time on the signalled-shock side of a shuttle box than on the opposite side where unsignalled shock occurred.

In all the above studies, the conclusion that signalled shock is less aversive than unsignalled

shock came from procedures in which subjects could choose between the two events. The purpose of the present study was to examine the generality of this conclusion with respect to rates of response. Thus, subjects were trained in a single-lever apparatus and aversiveness was assessed through an analysis of differences in lever-pressing rates, rather than through choice indices such as side preference in a shuttle box. The procedure employed a multiple schedule, each of whose two components contained a two-link chain. Responding in the initial link of each chain was established and maintained by providing positive reinforcement in the terminal links. The relative aversiveness of signalled and unsignalled shock then was studied by scheduling signalled shock in one terminal link and unsignalled shock in the other terminal link of the respective chains. The extent to which initial-link rates were suppressed by these contingencies provided the basis for determining whether signalling a shock reduces its aversiveness.

An important methodological consideration in the development of this procedure concerned the possibility that rate differences in the initial links would reflect different degrees of correlation of responses with shocks in the terminal links. The correlation would probably be greater when shock is unsignalled because animals are not likely to respond in the presence of a signal of shock (Estes and Skinner, 1941). This problem was dealt with

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in two ways: (1) by delivering the reinforcers on a non-contingent basis so that responding in the terminal links was not required; and, (2) by delaying each reinforcer for a fixed period of time after any response that did occur.

METHOD

Subjects

Five female albino rats, 90 days old and experimentally naive at the start of the experiment, were obtained from the Holtzman Co., Madison, Wisconsin. Throughout the experiment they were maintained at 80% of the median weight of a non-deprived control group following the method of Davenport and Goulet (1964). Maintenance feeding of dry lab-chow occurred in the home cage at least 30 min after daily experimental sessions. Water was always available in the home cage.

Apparatus

Sessions were conducted in a commercially constructed chamber and chest (Lehigh Valley #1316 and #1316C). Within the chamber, a single response lever protruded through the wall 1 in. (2.5 cm) above the grid floor and 2 in. (5 cm) to the left of a centrally located opening through which a 0.01-cc dipper could be raised. The grid floor of the chamber was connected to a shock generator/scrambler (Grason-Stadler E#1064). Two lamps were available for presenting visual stimuli associated with the various components of the chain schedule: one lamp (1.1 W) was mounted in the wall 2 in. (5 cm) above the lever and a second lamp (7.6 W) was located immediately outside the rear Plexiglas wall of the chamber. The light from both of these lamps was associated with auditory stimuli, a 2000-Hz, 74-dB tone and a 75-dB white noise, delivered through a speaker mounted on the rear wall of the chest. A 28-V dc relay, wired as a buzzer (80 dB), was mounted alongside the speaker and served as a signal preceding shock. Scheduling and recording equipment were located in an adjoining room.

Procedure

The reinforcer for the lever-press response was a 2-sec presentation of the dipper containing full-strength evaporated milk. After the response was shaped, animals were given daily

training sessions over a four-week period with a continuous schedule of reinforcement. Sessions were terminated after 300 reinforcers had been received. During this preliminary phase, auditory stimuli were not presented and the light outside the chamber was on continuously.

Baseline training. The baseline schedule, used during all subsequent phases of the experiment, was a two-component multiple schedule with each component consisting of a two-link chain schedule. Thus, the entire schedule contained four discrete parts, each associated with a different stimulus: the initial link (S1) and the terminal link (S2) of the first chain, and the initial link (S3) and the terminal link (S4) of the second chain. Production of either terminal link was contingent upon the subject's responding during the corresponding initial link; that is, S2 always followed S1, and S4 always followed S3. Upon completion of a terminal link, which always lasted 5 min, the chain ended, and in accord with a multiple schedule, the initial link of the next chain began independently of responding. The sequence of presentation of the two chains was varied randomly so that following a given terminal link, either of the initial links (S1 or S3) could occur.

Within S1 and S3, the first lever press after an average interval of 90 sec (VI 90-sec) produced the respective terminal link (S2 or S4). During the terminal links, the dipper operated automatically every 15 sec on a variable-time schedule (VT 15-sec) but was inoperative for 5 sec after a lever press. This DRO (differential reinforcement of other behavior) contingency was designed to discourage lever pressing in the terminal links by explicitly withholding reinforcement of this response. Sessions continued until 12 terminal links had been presented or until 90 min had elapsed, whichever occurred first.

In summary, the schedule contained four links: a VI 90-sec schedule in each of the two initial links (S1 and S3) and a 5-min period of VT 15-sec reinforcement with a DRO 5-sec in each of the two terminal links (S2 and S4). Each link was associated with a different stimulus as follows: (S1) tone and chamber-light, (S2) intermittent tone and chamber-light (0.5 sec on, 0.05 sec off), (S3) white noise and lever-light, and (S4) intermittent white noise and lever-light.

Baseline training was continued for 60 sessions to establish stable rates of lever pressing in the initial links of the two chains.

Shock vs no-shock training. During the first 10 sessions following baseline training, a 0.2-mA shock of 2-sec duration occurred every 4 min on the average (VT 4-min), independently of behavior, while the animal was in S2; no shock occurred in S4. Shock intensity was increased to 0.4 mA after 10 sessions and to 0.5 mA after 20 sessions. The purpose of this treatment was to determine whether response rates in the initial links of the chain schedules would be differentially affected by the presentation of shock in one of the terminal links. After Session 35, the shock was removed and response rates were allowed to recover.

Buzzer vs no-buzzer training. After 20 recovery sessions, a 5-sec buzzer (the stimulus subsequently employed as the signal) was introduced in S4 on a VT-4 min response-independent schedule. This treatment, which remained in effect for 10 sessions, was used to determine any independent effects the signal might have on response rates.

Shock vs signalled-shock training. In subsequent sessions, offset of the buzzer in S4 was followed immediately by a 0.2-mA shock of 2-sec duration; a similar shock without a signal was scheduled in S2. Both signalled and unsignalled shock were presented on the VT-4 min schedule. Again, after 10 sessions the shock intensity was increased to 0.4 mA, where it remained through the twenty-fifth session. Beginning with the twenty-sixth session, shock and signalled shock were removed from S2 and S4 respectively, and recovery data were obtained for a total of 20 sessions. Then, the component positions of shock and signalled shock were reversed; that is, signalled shock was scheduled in S2 and unsignalled shock in S4. As before, the shock intensity was 0.2 mA when shock was introduced and increased after 10 sessions to 0.4 mA where it remained until Session 32. After this treatment, the experiment was terminated.

In all phases of the experiment, precautions were taken to ensure that (1) the signal, shock, or dipper never occurred within 5 sec after the onset of a terminal link, (2) the signal and/or shock was always presented in its entirety if either or both occurred near the end of a terminal link, and (3) the signal or shock never occurred when an animal was drinking.

These contingencies were arranged by having the shock tape (which was also the signal tape) and the dipper tape run synchronously on a dual-track tape puller that started 5 sec after the beginning of a terminal component and stopped 10 sec before the end of the terminal component. Judicious placement of the event holes on these two tapes ensured that a signal or shock never occurred simultaneously with the presentation of the dipper.

Summary of conditions. Table 1 presents the sequence of presentation of the experimental conditions. All subjects received the same conditions in the same order throughout the experiment. With the exception of the buzzer vs no-buzzer condition, training in each condition was continued for a minimum of 20 sessions. The arbitrary but stringent criterion for terminating those treatments inducing differential response rates (*i.e.*, the treatments involving shock) was that all five subjects show similar differences for at least nine of the last 10 sessions the treatment was in effect. Table 1 shows that this criterion was attained within 35 sessions in all cases.

RESULTS

Figure 1 shows the individual response rates of each subject in S1 and S3, the initial links, grouped in blocks of two sessions. Only the last 10 sessions of each treatment condition are presented, with connected points indicating consecutive sessions.

Shock vs no shock. The first panel of Figure 1 shows approximately equal rates in S1 and S3 by the end of baseline training, testifying to the equivalence of reinforcement contingencies in the two terminal links during this phase. The effect (on initial-link response rates) of presenting shock in one terminal link but not in the other is shown in the second panel. The occurrence of shock in S2 produced a greater degree of response suppression in the initial link (S1) preceding the shock condition than in the initial link (S3) preceding the no-shock condition. Since this difference was consistent across subjects, these results suggested that the procedure might be sufficiently sensitive to answer the primary question of whether shock or signalled shock would produce the greater degree of response suppression when these events were scheduled in the separate terminal links.

Table 1

Summary of Conditions

Condition	# of Sessions	Links of Chain Schedules			
		S1	S2	S3	S4
Baseline	60	VI 90	VT 15"	VI 90	VT 15"
Shock vs no shock	35	VI 90	VT 15" + shock	VI 90	VT 15"
Recovery 1	20	VI 90	VT 15"	VI 90	VT 15"
No buzzer vs buzzer	10	VI 90	VT 15"	VI 90	VT 15" + buzzer
Shock vs signal-shock	25	VI 90	VT 15" + shock	VI 90	VT 15" + sig-shock
Recovery 2	20	VI 90	VT 15"	VI 90	VT 15"
Signal-shock vs shock	32	VI 90	VT 15" + sig-shock	VI 90	VT 15" + shock

*5' RIR = 5-min Response-Independent Reinforcement

Fig. 1. Individual response rates, grouped in two-session blocks, of the five subjects in S1 and S3, the initial links of the chain schedules, under each experimental condition. Only the last 10 sessions of each treatment condition are presented, with connected points indicating consecutive sessions.

Recovery 1. When shock was removed from S2, response rates in the initial links recovered (Figure 1, panel 3). After return to baseline level, the rates diverged slightly with higher rates occurring in the link (S1) previously associated with shock. Although the reason for this divergence is not clear, the effect did occur with few exceptions in all subjects during the latter half of this recovery phase.

No buzzer vs buzzer. Scheduling the buzzer in S4 produced no noticeable change in response rates in either S1 or S3 (Figure 1, panel 4), suggesting that the buzzer was sufficiently "neutral" to allow its use as a signal of shock in the major treatment condition.

Shock vs signalled shock. Figure 1 (panel 5) shows that when shock occurred in S2 and signalled shock occurred in S4, every subject responded at a lower rate in the link (S1) preceding the shock condition than in the link (S3) preceding the signalled-shock condition. These lower rates in S1 were particularly impressive because response rates had been generally higher in this link during the prior buzzer vs no-buzzer condition (panel 4).

Recovery 2. Removing shock and signalled shock from the terminal links resulted in a recovery of initial-link response rates (Figure 1, panel 6). Here again, as was the case in the first recovery phase, response rates not only recovered to the original baseline level but then began to diverge slightly with a higher rate occurring in the link (S1) previously associated with the greatest suppression. A close examination of these data suggests that the divergence during the second (and to a lesser degree the first) recovery phase was due mainly to S1 rates recovering to a level slightly above the original baseline level, while S3 rates recovered only to baseline. Although responding in excess of baseline rates after shock punishment was removed has been observed by other investigators (Azrin, 1960; Holz, Azrin, and Ulrich, 1963), it is not yet clear what the necessary and sufficient conditions are to produce this so-called "compensation" effect. Certainly, this effect is not restricted to situations involving punishment, since in the present study shock was presented independently of responding.

Signalled shock vs shock. When signalled and unsignalled shock were scheduled in the terminal links opposite to the ones in which they had previously been presented, the major findings of the experiment were replicated—

response rates in the link (S3) preceding the unsignalled-shock condition were lower than in the link (S1) preceding the signalled-shock condition (Figure 1, panel 7). Here, however, the effect was less impressive than in the first presentation of this treatment because the rate difference that occurred, although doubled in magnitude, was in the same direction as in the prior recovery phase (panel 6). Perhaps a more important consideration is that every subject during the last 10 sessions of this treatment condition responded at a consistently lower rate in the initial link preceding the unsignalled-shock condition.

Terminal-link response rates. It will be remembered that the DRO contingency was used in the terminal links in order to reduce responding to very low levels, thus precluding the possibility of differential punishment in these two links. Table 2 shows the mean responses per minute of the five subjects in S2 and S4 for the last 10 sessions of each experimental condition. As may be seen in this table, response rates were generally less than one response per minute and rate differences between the two terminal links are small and unsystematic.

DISCUSSION

When signalled shock was scheduled in the terminal link of one chain schedule and unsignalled shock in the terminal link of another, response rates were lower in the link leading to unsignalled shock. As pointed out earlier, one explanation of this difference is that responding was punished differentially in the two terminal links. However, the finding that relatively few responses were made in either terminal link, and that response rates were equivalent in the two terminal links argues effectively against this possibility.

The present results, together with previous findings that animals choose signalled shock in preference to unsignalled shock (*e.g.*, Lockard, 1963), support the hypothesis that signalling shock reduces its aversiveness. In addition, the results provide the first demonstration of this phenomenon when response rates (rather than choice indices) serve as the dependent measure, and when the behavior of individual organisms (rather than group averages) is the basis of the data analysis. The reason why signalled shock is less aversive than

Table 2

Mean responses per minute of each subject in S2 and S4, the terminal links of the chain schedules, for the last 10 sessions of each experimental condition.

Subjects	A1		A2		A3		A4		A5	
Links	S2	S4	S2	S4	S2	S4	S2	S4	S2	S4
Baseline	0.47	0.63	0.20	0.22	0.17	0.20	0.18	0.06	0.74	0.56
Shock (S2) <i>vs</i> No Shock (S4)	0.30	0.41	0.50	0.27	0.51	0.15	0.72	0.11	1.10	0.21
Recovery 1	0.62	0.51	0.33	0.42	0.31	0.26	0.01	0.06	0.50	0.26
No Buzzer (S2) <i>vs</i> Buzzer (S4)	0.37	0.32	0.43	0.60	0.66	1.02	0.04	0.03	0.44	0.32
Shock (S2) <i>vs</i> Sig. Shock (S4)	0.03	0.08	0.92	0.59	0.54	0.29	0.18	0.14	0.19	0.37
Recovery 2	0.54	0.78	0.77	0.61	0.24	0.23	0.06	0.07	0.31	0.29
Sig. Shock (S2) <i>vs</i> Shock (S4)	0.26	0.18	0.51	0.31	0.14	0.09	0.02	0.03	0.19	0.19

unsignalled shock remains to be clarified. It has been argued that reductions in aversiveness are due to the role of the signal in providing information about the onset of shock and that such information is either inherently reinforcing (Berlyne, 1960) or is reinforcing because it allows preparation for the subsequent shock (Perkins, 1955).

One advantage of the methodology used in the present study is that it provides an approach to the question of the relative aversiveness of signalled *vs* unsignalled events other than shock. For example, questions about the relative aversiveness of signalled *vs* unsignalled "response cost" (Weiner, 1962), "effort" (Chung, 1965), or "timeout" from positive reinforcement (Leitenberg, 1965) seem more amenable to experimental investigation with a rate measure than with choice measures, such as side preference in a shuttle box. Answers to these questions would also provide a broader basis for the hypothesis that signalled shock is less aversive than unsignalled shock because of the role of the signal in providing information about the onset of shock.

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