CHOICE OF A TERMINATING OVER A NON-TERMINATING SIGNAL IN FREE-OPERANT AVOIDANCE

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Rats chose between two signalled avoidance schedules. Under one schedule, responses in the presence of the signal terminated it and resulted in avoidance of shock; in the other, responses in the presence of the signal resulted in shock avoidance but signal termination was delayed for 10 sec. Pressing a second (changeover) lever produced change from one schedule to the other for 1 min. Once this 1-min period timed out, subjects could remain under the schedule in effect or could reinstate the other schedule for another 1-min period. All four subjects continuously changed over from the non-terminating to the terminating signal schedule. Changeover responding was not maintained when the termination contingency was removed. When changeover responding resulted in a change from a terminating to a non-terminating signal schedule, changeover responding did not occur.

The functional role of stimuli that precede avoidable aversive events has been the focus of considerable experimental attention for a number of years. Initially, the interest in warning signal termination was theoretical and centered on the notion of conditioned fear or acquired aversiveness of the signal. Theorists (*e.g.*, Rescorla and Solomon, 1967) have suggested that avoidance responses occur because termination of the signal (which is assumed to be aversive by these investigators) reinforces responding. More recently, it has been suggested that the signal serves as a discriminative stimulus for the avoidance response (Herrnstein, 1969) and termination of the signal provides feedback for the avoidance response (Bolles and Grossen, 1969). Termination of a signal may also reinforce responding because it results in an immediate shock-free period, since shock does not occur in the absence of the signal (Badia, Culbertson, and Lewis, 1971; Bolles and Grossen, 1969; Weisman and Litner, 1969). Each of these interpretations assigns a functional role to the signal and each suggests that signal termination is a reinforcing event. A number of studies have investigated how responding that terminates a signal differs from one that does not. If responding more effectively avoids the electric

shock when it terminates a warning signal than when it does not, then it is assumed that signal termination is a relatively more reinforcing event.

To date, the evidence is equivocal regarding the effects of terminating over non-terminating signals and avoidance performance. While some studies show better acquisition or maintenance of responding that terminates a signal (*e.g.*, Kamin, 1956; 1957), others do not (*e.g.*, Lewis, 1969; Verhave, 1959). Similar results led Bolles and Tuttle (1967) to suggest that "if there is an acquired negative reinforcement effect here (signal termination), it must be rather puny" (p. 256). Perhaps the problem lies in the use of the avoidance response itself as a measure of the reinforcing properties of signal termination. Several events in addition to signal termination may reinforce the avoidance response, *e.g.*, shock-free periods (Badia *et al.*, 1971) or shock frequency reduction (Herrnstein, 1969). Thus, a terminating signal may or may not have a reinforcing effect, yet this effect may be obscured by several sources of reinforcement when only the avoidance response itself is used as a measure of this effect.

The present study investigated whether signal termination was a reinforcing event by arranging for responses on a second lever to determine whether a terminating signal condition was in effect. Responses on one lever postponed shock under a non-terminating signal condition, but responses on a second lever (changeover) changed the condition to a termi-

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nating one for 1-min periods. This technique allowed a separate analysis of the responses that avoid shock and the response used to measure the reinforcing effects of signal termination.

METHOD

Subjects

Four experimentally naive female, albino rats of the Sprague-Dawley strain (Holzman Co.), 90 to 120 days old at the beginning of the experiment, were housed individually and had free access to food and water.

Apparatus

All subjects were tested in operant conditioning chambers having grid bars perpendicular to the front wall. Two chambers, each with two levers, were enclosed in IAC acoustical chambers. The experimental chambers measured 9.5 in. (22.1 cm) long, 10 in. (25.4 cm) wide, and 5 in. (12.7 cm) high. Each lever required about 20 g (0.196N) to depress and was located 2 in. (5.08 cm) from the side along the 10-in. (25.4-cm) front wall, and 3 in. (7.65 cm) above the grid floor. A 1400-Hz (86-dB) tone served as the preshock signal. Offset of a 0.5 in. (1.27 cm) white jeweled light (24 V) above the left bar signalled the beginning of the experimental session while its onset signalled the end. A 1 in. (2.54 cm) white jeweled houselight (24 V) was mounted above the right lever.

A constant wattage shock source (BRS Inc.) delivered electric shock at 75 mW for 0.32 sec. Grid bars were 0.25 in. (0.64 cm) stainless steel spaced 0.5 in. (1.27 cm) apart center to center. The walls and response levers served as one contact in the grid scrambling circuit.

Procedure—Initial Training

Subjects were studied in sessions 6 hr long every other day and all received the same conditions. At the beginning of the experiment, all subjects were given a minimum of four avoidance training sessions under which terminating and non-terminating signal schedules alternated each hour. Under the terminating signal schedule, each response on the right lever reset the response-signal timer unless the signal-shock interval had begun. If 15 sec elapsed without a response (15-sec response-signal interval), the signal came on and a response terminated it and postponed shock. If a

response terminated the signal and postponed shock, the response-signal interval began where shock would have occurred had a response not been made (10 sec after signal onset). If a response was not made before or during the 10-sec signal, the signal terminated with shock and shock was delivered every 5 sec until a response occurred. The signal was not present during the 5-sec shock-shock interval. Under the non-terminating signal schedule, responses during the signal did not terminate it, *i.e.*, a response during the signal postponed shock but the signal remained on for the full 10-sec signal-shock interval, and a 15-sec response-signal interval began where shock would have occurred had a response not been made. The two schedules were alike in all other respects.

The order of the first condition received on each day was balanced across days. For two subjects, the houselight was on when the signal termination schedule was in effect and off when the non-termination schedule was in effect; for the other two subjects, the relationship between houselight and schedules was reversed. Responses on the left (changeover) lever, as well as time that would have been spent in changeover conditions as a result of these responses, were recorded, though these responses produced no stimulus change.

Changeover to Signal Termination

After stable responding on the right (avoidance) lever was attained under the multiple schedule, subjects began the following session under a non-terminating signal schedule. Responses on the right-hand lever postponed shock as described above; however, depression of the left (changeover) lever resulted in the immediate onset (or offset) of the houselight and initiated the terminating signal schedule. One response on the left lever produced the terminating signal schedule for 60 sec; additional responses on this lever during the 60-sec period were ineffective. At the end of the 60-sec period, the non-terminating signal schedule resumed.

Changeover Extinction

Under this procedure, the non-terminating signal schedule was in effect and neither a stimulus change nor signal termination occurred after a changeover response on the left lever. With this procedure, the non-terminating signal condition always remained in effect.

Changeover From a Terminating to a Non-Terminating Signal

This condition was studied to give subjects the option to change over from the terminating to the non-terminating signal schedule. With this procedure, the terminating condition was in effect and a changeover response changed the condition to a non-terminating condition for 60 sec and produced the associated stimulus (houselight on or off).

RESULTS

Measures of Signal Termination vs Non-Termination

Table 1 presents data from the last three sessions of the multiple schedule training. During this training, there were 3 hr of each schedule per session; thus, each value shown in the table represents 180 min in the condition listed. It can be seen (Table 1) that rate of avoidance responding was lower under the signal termination condition than under the non-termination condition for all subjects. Cumulative records showing this difference are

shown in Figure 1. As noted previously, if no avoidance response occurred until after onset of the signal, 10 sec had to elapse (in either schedule) before a new response-shock interval began, even though a response in the presence of the signal avoided shock. Thus, "avoidance responding/10 sec" in Table 1 refers to the rate of responding during the 10-sec signal period under each signal condition. This responding accounted for some of the higher over-all response rate in the non-termination signal condition. The higher response rate under the non-terminating signal can be seen also in Figure 2 where "changeover" is representative of signal termination and "extinction" is representative of non-termination conditions. Under signal termination conditions, it can be seen that the subjects waited until the signal came on and terminated it with a single response. Under non-terminating signal conditions (extinction), however, the subjects tended to wait for the signal but made a number of responses during the 10-sec signal period. This shows up as heavy blocks of closely spaced avoidance responses in the figure.

Table 1

Data from last three sessions under the multiple training schedule. Since the subject received equal time during each session under both signal conditions each value is the total number obtained during the 3-hr exposures to each condition.

Subject	Last Three Days in Condition					
	Terminate Signal			No-Terminate Signal		
	1	2	3	1	2	3
<i>N10</i>						
AV Responses	485	532	480	1224	932	898
AV Responses/10 sec*	435	493	458	600	563	596
Shocks	6	3	3	25	12	16
Signals	415	416	416	323	355	380
<i>N11</i>						
AV Responses	474	450	454	782	776	791
AV Responses/10 sec	431	426	419	614	574	580
Shocks	11	5	14	38	26	49
Signals	415	417	414	398	389	388
<i>N15</i>						
AV Responses	527	534	612	1526	1188	1080
AV Responses/10 sec	498	478	502	924	819	766
Shocks	4	84	5	55	9	38
Signals	415	398	402	342	368	371
<i>N17</i>						
AV Responses	581	589	723	1356	1444	1165
AV Responses/10 sec	468	438	480	726	673	683
Shocks	3	3	54	26	66	26
Signals	392	380	374	308	289	334

*Avoidance responses during the 10-sec signal period.

Fig. 1. Representative cumulative records from both signal terminating and non-terminating signal conditions. The stepping pen recorded avoidance responses while the pip recorded shock.

Table 1 shows that all subjects received more signals under termination conditions. Subject N10, for example, averaged 353 signals under the non-termination signal schedule and 416 in the termination schedule. Two other subjects showed about the same magnitude of difference, while one (N11) averaged only 22 more signals under signal terminating conditions. In spite of this, however, it is clear that subjects primarily waited for the signal

in both conditions, rather than respond in its absence. It can be seen also in Table 1 that during multiple schedule training all subjects had higher shock rates under the non-terminating signal schedule. These differences in responses, signals, and shocks remained throughout the experiment, although the differences in shock rate tended to become relatively small in the performances of two subjects (N10 and N15).

Fig. 2. Typical event records from both changeover to signal termination and extinction conditions. The records represent about 45 min from the middle of a session. Upward deflections of the bottom two pens indicate events. Avoidance (AV) and changeover (CO) responses were recorded from pulsed output, whereas signal and changeover period pens remained deflected for the duration of the event.

Changeover to Signal Termination (CO Term)

All subjects acquired and maintained a high rate of responding on the left lever when responses on that lever produced a change from non-terminating to terminating signal conditions. Figure 3 shows the performance of Subject N11 through every session in the experiment. As seen in the figure (Sessions 1 to 7), the operant level of left-lever (changeover) responses was quite low when responses on the left lever had no effect on the schedule and stimulus conditions. However, when the session began with the non-terminating condition and responses on the changeover lever resulted in the terminating condition for 60-sec periods (Figure 3, Session 8), the amount of time spent in the changeover condition immediately increased. The subject began consistently producing the terminating signal condition during the first session and stabilized at a high and constant level of time in this condition. Table 2 contains data showing changeover performance for all subjects. All subjects spent nearly the same amount of time per session under the terminating schedule (about 290

min or 80% of the time). A typical event record (Figure 2, top) shows that the subject initiated each changeover period with a single response and that most of the session was spent under the terminating signal condition. Very few extra changeover responses occurred. This can be seen by noting the correspondence between the number of changeover responses and the number of minutes spent in the changeover conditions (Tables 2 and 3). For example, during the last three days of initial exposure to signal termination, Subject N10 emitted an average of 310 changeover responses (Table 3) and spent an average of 295 min (Table 2) in the changeover condition. Thus, only approximately 15 extra responses were recorded throughout this 6-hr session.

A certain sequence of responding frequently followed presentation of the stimulus associated with the non-terminating schedule. The subject would wait until the signal came on, then press the changeover lever initiating the signal termination condition before making an avoidance response. The spacing of changeover periods in the event record shown in Figure 2 reflects this behavior.

Fig. 3. Number of minutes per 6-hr session produced by changeover responding. All conditions appear in the order they were given. It should be noted that no stimulus or schedule change occurred under "mult" or "EXT" conditions and the data reflect the number of minutes that would have occurred as a result of responding under these conditions.

Table 2

Time in minutes spent in changeover for four rats during the last three sessions of: (A) Training, (B) Changing over to the signal terminating schedule, (C) Extinction, and (D) Changing over to the non-terminating schedule. Maximum duration was 360 min (6-hr sessions). Only two changeover replications are shown. Numbers in parenthesis refer to number of 6-hr sessions spent in each condition.

Subject	Last Three Days in Condition									Changeover to Signal		
	Training			Changeover to Signal			Extinction			No-Terminate		
	1	2	3	1	2	3	1	2	3	1	2	3
Exposure 1	3	0	2(7)	303	289	294(7)	64	32	15(3)	21	8	5(3)
N10 Replication				267	274	278(7)	39	30	22(3)	7	7	9(3)
Exposure 1	25	14	11(7)	289	292	290(6)	94	43	14(3)	19	7	1(4)
N11 Replication				290	293	283(4)	33	10	19(3)	2	2	2(4)
Exposure 1	57	78	89(6)	291	284	288(7)	134	138	144(8)	1	7	5(3)
N15 Replication				289	286	286(4)	88	79	85(5)	6	17	13(3)
Exposure 1	137	123	131(4)	291	298	290(8)	121	20	12(3)			
N17 Replication												

Changeover Extinction (EXT)

During extinction, subjects always remained in the non-terminating condition and responses on the left lever had no effect. Figure 3 shows that Subject N11 quickly ceased responding on the left lever on Days 14 to 16

when the extinction condition was in effect. The event record in Figure 2 is typical of performance throughout these extinction sessions and it can be seen that subjects responded only occasionally on the left lever throughout these sessions. When responses on the left lever once again produced the terminating signal

Table 3

Mean data from the last three days of each condition listed in order obtained for each subject in the experiment.

Subject and Data	Training	CO Term	Ext	CO Term	Ext	CO Term	CO No-Term	CO Term	CO No-Term
N10									
AV Responses	1520.0	1176.7	1715.0	1277.3	1937.0	1158.0	982.3	1110.7	1005.7
CO Responses	1.7	310.7	46.3	218.0	47.0	271.7	28.7	266.0	18.3
Shocks	21.7	10.3	7.3	2.7	7.7	4.0	2.7	5.0	3.0
Signals	768.3	798.0	687.3	801.7	659.0	800.7	817.3	805.3	812.7
N11									
AV Responses	1242.3	924.0	2252.3	914.3	2147.3	894.3	926.7	908.7	873.3
CO Responses	21.7	331.7	102.7	306.3	38.6	312.7	11.3	289.7	3.3
Shocks	47.7	33.7	61.3	24.7	65.0	28.0	28.0	19.7	14.7
Signals	807.0	826.0	668.0	825.0	731.3	828.3	822.3	830.7	833.0
N15									
AV Responses	1822.3	1133.3	2055.0	1047.7	1899.3	1074.0	1029.7	1055.0	1145.7
CO Responses	135.3	319.0	246.3	277.3	113.7	300.0	18.7	299.0	19.7
Shocks	65.7	11.6	20.7	9.3	15.0	10.7	13.7	10.7	16.3
Signals	765.3	819.3	724.0	828.0	734.7	814.7	811.0	810.3	791.3
N17									
AV Responses	1952.7	960.7	1234.0						
CO Responses	257.0	319.0	115.0						
Shocks	59.3	109.3	333.0						
Signals	692.3	797.6	743.3						

schedule on Day 17 (Figure 3), time spent in that condition again returned to the high and stable level seen previously. It can be seen that when the extinction condition was repeated, time in changeover, and hence responding on the left lever for Subject N11, decreased sharply. All subjects performed similarly (Table 2). When the changeover contingency of signal termination was reinstated, responding on the left lever quickly increased for all subjects.

Table 3 shows that the number of responses decreased for all subjects during extinction. However, there is not the close one-to-one correspondence between number of responses and time spent in the changeover condition found during the regular changeover condition. When changeover responding during extinction did occur, it consisted of quick bursts. This loss of stimulus control is most apparent for Subject N15 during the first extinction exposure (Table 3). It can be seen that this subject emitted 246 responses, yet accumulated only half that many minutes in changeover time (Table 2).

Subject N17 was dropped from the experiment after the first extinction exposure. During reacquisition of changeover to signal termination, this subject's shock rate increased and the subject was found lying on its back on the grid bars, thereby avoiding shock.

Changing over to a Non-Terminating Shock (CO No-Term)

Under this condition, responses on the left lever changed conditions from the signal terminating schedule to the non-terminating signal schedule for 60-sec periods. As shown in Figure 3, Subject N11 made few changeover responses in this condition during either exposure (Days 28 to 31 and Days 36 to 39). Placing subjects in this condition resulted in an immediate and almost complete cessation of responding on the changeover lever on the first day. Table 2 presents these data for all subjects and it can be seen that responding was suppressed below the extinction condition for all subjects and even below operant level for Subjects N11 and N15.

DISCUSSION

The results can be briefly summarized: (1) changeover responding was acquired and

maintained by a change from a non-terminating to a terminating signal condition; (2) changeover responding was not maintained when the signal termination schedule was removed; (3) changing from a terminating to a non-terminating schedule did not maintain responding.

It could be inferred from some previous studies (Kamin, 1956, 1957) that signal termination should be chosen over non-termination because avoidance acquisition in these studies was retarded under non-termination conditions. These studies were taken as support for the position that signal termination reinforces the avoidance response, *i.e.*, signal termination was a reinforcing event. At least two other studies, however, have suggested that differences between the terminating and non-terminating signal conditions were minimal and that avoidance responding could be maintained adequately under either condition (Lewis, 1969; Verhave, 1959). Lewis (1969) found that responses seldom occurred before signal onset under either condition and that shock rates were not systematically higher across animals under either condition. These results led Lewis to suggest that signal termination may not be reinforcing. Others (*e.g.*, Bolles and Tuttle, 1967) have suggested the same thing. It appears that other sources of control over avoidance responding in previous studies have obscured evaluation of the reinforcing effects of signal termination and that the present design overcomes these difficulties. The present results illustrate the importance of using a response other than the avoidance response to evaluate the reinforcing effects of signal termination over non-termination.

Two-factor theory has been useful in accounts of avoidance conditioning but, as Herrnstein (1969) pointed out, it has some limitations. It has been shown that avoidance responding is maintained whether signal termination occurs or not (Lewis, 1969) and in the absence of any stimulus termination at all (Herrnstein, 1969). In view of this, it is reasonable to suggest that the reinforcement derived from signal termination in the present study could have evolved from some source other than removal of a conditioned aversive stimulus.

Studies have shown that feedback stimuli following a response facilitate avoidance responding (Bolles and Popp, 1964) and this

occurs even though signal termination is not response dependent (Bower, Starr, and Lazarovitz, 1965; D'Amato, Fazzaro, and Etkin, 1968). These findings suggest the importance of stimulus change accompanying the avoidance response. A suggestion of how this stimulus change might acquire reinforcing properties is provided by noting that in the signalled avoidance experiment, two stimulus situations exist—the presence and the absence of the signal. The presence of the signal is a shock-correlated period setting the occasion for reinforced responses, while absence of the signal is a shock-free period because shock rarely, if ever, occurs in its absence once responding begins. (Shock in this latter instance would occur only during the shock-shock interval, which seldom occurs once subjects begin responding). It is a common finding that subjects in signalled free-operant avoidance wait for the signal rather than respond in its absence. Thus, the avoidance response comes under the discriminative control of the signal because in its absence the shock contingency is, in effect, absent. As noted earlier, it has become increasingly evident that avoidance responses may be reinforced by shock-frequency reduction (Herrnstein, 1969) or by shock-free periods (Badia, *et al.*, 1971). Given this, it is reasonable to assume that stimuli correlated with these shock-free periods should acquire control over responding, much as conditioned responses in the positive reinforcement situation. Some evidence is available to this effect (Dinsmoor, 1962; Dinsmoor, Flint, Smith, and Viemeister, 1969). Badia *et al.* (1971) showed that subjects choose signalled over unsignalled avoidance and that the control over subject's choice was exerted by the stimulus correlated with shock-free periods. A similar interpretation may be given to the present results. Termination of the signal may be reinforced by the immediate presentation of a period free from aversive stimulation. In the non-termination schedule, however, this reinforcement is delayed.

Based on the present data, it could also be argued that avoidance response rates or shock rates may account for the changeover results. Sidman and Boren (1957) argued that avoidance schedules that generate higher avoidance rates are more aversive than ones that generate lower rates. Similarly, Hake (1968) argued that schedules resulting in higher rates of delivered shock are more aversive than schedules that

result in a lower rate of shock delivery. In the present study, both lower shock and avoidance rates occurred under the signal termination condition. Thus, it may be argued that signal termination *per se* is not a reinforcing event. It could be that the discriminative properties of signal offset under terminating signal schedules yield very different performances and it is the result of these performances on response and shock rate that results in the changeover from non-terminating to terminating signal schedules. Taking this into account, it could be said that changeover responses are reinforced when they produce the stimulus associated with signal termination conditions, since this stimulus is the occasion for lower response and shock rates.

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