CHOICE OF HIGHER DENSITY SIGNALLED SHOCK OVER LOWER DENSITY UNSIGNALLED SHOCK¹

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Unsignalled, inescapable shocks were presented to four albino rats in Experiment 1. By pressing a lever subjects could change the condition to signalled shock for 3-min periods after which unsignalled shock was automatically reinstated. All subjects changed from unsignalled to signalled shock when shock density was the same or when the density of signalled shock was two times greater than unsignalled shock. When the density of signalled shock was four times that of unsignalled shock, three subjects changed to the higher density schedule. One subject changed to a density of signalled shock eight times that of unsignalled shock. The second study showed that the two shock schedules most similar in Experiment 1 were discriminably different because subjects chose lower over higher shock densities when both densities were unsignalled. An analysis stressing safe (signal absent) and unsafe (signal present) periods was discussed.

Specifying the reinforcer leading to behavioral control in some aversive situations has often been difficult, and especially so with respect to interpretations of avoidance learning. Various suggestions have been offered relative to avoidance. Sidman (1962) summarized several lines of evidence that identified shock-frequency reduction as a reinforcer. According to Sidman, a response was reinforced if the period of time following it contained fewer shocks than the period would otherwise contain. Herrnstein and Hineline (1966) and Herrnstein (1969) provided additional data in support of the shock frequency notion.

In contrast to the interpretation stressing shock frequency reduction, some investigators have argued that a discriminable period free of shock (safety) is the effective reinforcer for avoidance responding (*e.g.*, Badia and Culbertson, 1972; Hineline, 1970). These latter investigators and others (*e.g.*, Azrin, Holz, Hake, and Ayllon, 1963; Rescorla, 1968; Seligman, 1968; Weissman and Litner, 1971a) have shown that stimuli that identify shock and shock-free periods can result in differential control over

operant performances. In this regard, choice studies contrasting signalled with unsignalled shock are relevant since, with a signal, shock (signal present) and shock-free (signal absent) periods are clearly identified. These studies show that, given an option, subjects choose signalled over unsignalled shock whether it is avoidable, escapable, or inescapable (Badia, Culbertson, and Lewis, 1971; Badia and Culbertson, 1972). In addition, other research has shown that subjects choose stronger or longer signalled shock over weaker or shorter unsignalled shock (Badia, Culbertson, and Harsh, 1973).

The present report extends the safe-period analysis to include shock density. Emphasis in this report centers on the acquisition and maintenance of behavior through the presentation of stimuli that identify shock-free periods. In the first study reported, inescapable and unavoidable (response independent) shocks were presented. Subjects were first given a choice of randomly presented signalled shocks with identifiable safe periods over randomly presented unsignalled shocks with no identifiable safe periods. Except for the signal condition, the shock distributions were identical. After this performance had stabilized, subjects were then given a choice between higher densities of signalled shock over a lower density of unsignalled shock.

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EXPERIMENT I

METHOD

Subjects

Four experimentally naive female albino rats of the Sprague-Dawley strain (Holtzman) 90 to 120 days old served.

Apparatus

All subjects were tested in a two-lever Foringer operant conditioning chamber 36.8 cm long, 25.4 cm wide, 12.7 cm high (14.5 by 10 by 5 in.) modified so that the grid bars were parallel with the 36.8 cm (14.5 in.) wall. The levers required about 20 g (0.196 N) to depress and were 5.08 cm (2 in.) from the side along the 25.4 cm (10 in.) wall, 7.65 cm (3 in.) above the grid floor. A response on either lever changed the unsignalled shock schedule to a signalled one (changeover). A 5-sec 1000-Hz tone (84 dB) served as the preshock stimulus and a 2.54 cm (1 in.) white jewelled lens illuminated with a 24-V bulb (509k) mounted above the right lever served as the stimulus correlated with the signalled shock condition. Termination of a lamp (28ESB) with a 1.27 cm (0.5 in.) jewelled lens cover situated above the left bar signalled the beginning of the experimental session and its onset signalled the end. The operant chamber was enclosed within an IAC acoustical chamber.

A constant wattage shock source (BRS Inc.) delivered a 75-mW shock for 0.5 sec. Grid bars were 0.64 cm (0.125 in.) stainless steel spaced 1.27 cm (0.5 in.) apart center-to-center. Walls and response levers served as one contact in the grid scrambling circuit.

Procedure

Subjects were run every other day for 6 hr. Shock was always delivered independently of responding on a variable-time (VT) basis. These VT shock schedules were generated by Fleshler and Hoffman tables (Fleshler and Hoffman, 1962) modified to accommodate the minimum intershock interval (9 sec).

Initial Training (Baseline)

Subjects were exposed to the signalled schedule for a minimum of three sessions. The correlated stimulus was always on and the 5-sec tone preceded each shock during these sessions. Responses on either changeover lever and the

consequent amount of time that would have been spent in the changeover condition had these responses been effective were recorded and served as the initial baseline. Responses at this time produced no stimulus change. Signalled shock was presented independent of responses at irregular intervals averaging 4 min (VT 4-min schedule). Under the signalled condition, shock occurred only under the compound of tone and correlated stimulus. Thus, the presence of the correlated stimulus alone identified a shock-free period in addition to identifying the signalled shock condition.

Initial Changeover

After the operant level on the changeover levers had been determined under the training condition, subjects began the next session in the unsignalled condition where neither correlated stimulus nor signal were presented. A changeover response at this time produced the correlated stimulus and signalled schedule for a period of 3 min. Additional changeover responses during this 3-min period were recorded but they had no effect. At the end of the 3-min period, the correlated stimulus and the signalled schedule terminated. The subject remained in the unsignalled schedule unless the signalled one was reinstated by a changeover response. In this first changeover condition, signalled and unsignalled shock was delivered on a VT 4-min schedule. To avoid spurious contingencies between shock-elicited responding and changing over, a 2.5-sec changeover delay was scheduled beginning with shock onset. During this delay, the changeover contingency was not in effect.

Changeover with Timeout (CO-4)

After three consecutive days of stable changeover responding, a timeout component was inserted during the last 10 min of each hour. The criterion for stable responding was three consecutive days in which the time spent in the signalled condition was within 20 min of each other. This criterion was rigorously applied to all changeover conditions but not for the EXT conditions. During the timeout periods, the contingency was withdrawn and responses produced no stimulus change, *i.e.*, the correlated stimulus and signalled schedule were not presented after a changeover response and responses during this period were recorded separately. During timeout, unsig-

nalled shock was presented on a VT 4-min schedule. The timeout component was included in all further changeover sessions and served to ensure that subjects made contact with the unsignalled condition for a minimum of 60 min during each 6-hr session. Since a timeout period was identical to the extinction condition (see below), no scheduled timeout occurred during extinction.

Changeover to Higher Density Shock (CO-2, CO-1, and CO-0.5)

In the CO-4 condition, shock was always presented on a VT 4-min schedule whether the subject was in the signalled schedule, unsignalled schedule, or in the timeout periods, *i.e.*, subjects always received approximately 90 shocks each session. After three days of stable changeover performance in the CO-4 condition, a series of changeover conditions was initiated in which the density of shock during the signalled schedule was increased. These changeover conditions were separated by extinction sessions. The CO-2, CO-1, and CO-0.5 conditions represent VT schedules of signalled shock presentation of 2 min, 1 min, and 30 sec, respectively. Unsignalled shock during these conditions continued to be presented on a VT 4-min schedule. If a subject remained in the unsignalled schedule for the entire session, it would receive no more than 90 shocks. However, the highest rate of changeover responding could result in the subject's receiving about two times (CO-2), four times (CO-1), or eight times (CO-0.5) as many signalled as unsignalled shocks (as noted, 90 unsignalled shocks were delivered if no changeover responses were made). After each subject stabilized in the CO-2 condition, an attempt was made to eliminate changeover responding (see Extinction below) followed by an attempt to reestablish it under the CO-2 condition. If the response was reestablished under the changeover condition, the subject was again given the extinction condition before exposure to the next higher signalled shock density. This process was continued for each higher density of signalled shock until the level of changeover responding decreased to the operant or extinction level.

Extinction (EXT)

Under the extinction procedure, subjects were placed in the unsignalled condition and

neither the correlated stimulus nor the signalled schedule followed a changeover response. However, as in the baseline condition, responses on the lever and amount of time that would have been spent in the signalled (changeover) condition were recorded. Shock was always presented on a VT 4-min schedule during the extinction condition. A more complete analysis of the control exerted by either the correlated stimulus or signal alone can be found elsewhere (Badia and Culbertson, 1972).

RESULTS

Figure 1 shows the time spent in the signalled situation by all subjects during the last three sessions of each condition.

During the initial changeover sessions (not shown in Figure 1), all subjects chose the signalled over the unsignalled condition when shock density was the same. Subjects HF 1, HF 4, and HF 5 began changing from unsignalled to signalled conditions the first day the changeover contingency was introduced and within five sessions, responding was stable. Subject HF 7 acquired the response more slowly and required 11 sessions before responding reached a stable rate. The pattern of changeover responding was similar to that reported by Badia *et al.* (1971, 1972) and Badia and Culbertson (1972). Once contact with the changeover contingency was made, frequency of responding immediately increased. The control exerted by the correlated stimulus was also similar to previous studies in that event records indicated that when the changeover period timed out (termination of the correlated stimulus), subjects generally reinstated it immediately and few nonfunctional responses were made in the presence of the correlated stimulus (see Badia and Culbertson, 1972, Figure 1).

The addition of the 10-min timeout periods each hour during the CO-4 condition had no noticeable effect on the percentage of time spent in the signalled condition. Therefore, the initial changeover sessions without the timeout periods are not included in Figure 1. During the timeout periods, subjects tended to respond at rates much higher than under the changeover condition at the onset of timeout, and although response rate decreased during the latter portion of the timeout period it still remained above that of the changeover condition. This response pattern resulted in

Fig. 1. Per cent of session time spent in the signalled shock condition for Subjects HF 1, HF 4, HF 5, and HF 7 for the last three sessions of each condition. Conditions appear in the order that they were administered. Blank spaces along the abscissa indicate that the subject did not receive that condition.

the subject quickly coming into contact with the changeover contingency when it was again scheduled.

After responding had stabilized under the CO-4 condition, the density of signalled shock was increased to about twice (VT 2-min) that of unsignalled shock (VT 4-min). This condition is labelled "CO-2" on Figure 1. As shown in this figure, increasing the density of shock about two-fold had no noticeable effect on changeover responding. All subjects continued changing to the signal condition rather than remain in the unsignalled one.

Extinction sessions (EXT) were conducted after changing over had stabilized at each shock density of VT 2-min or higher. During extinction, the signal and correlated stimulus were withheld and shock density remained at VT 4-min. Extinction sessions were conducted to ensure that responding was completely under the control of the changeover contingency and not of any spurious contingency. As shown in Figure 1, changeover responding during extinction dropped to or near baseline levels for all subjects. Although not shown in the figure, a considerable reduction occurred on the first day of the EXT condition for all subjects.

After responding stabilized under EXT, the CO-2 condition was repeated. As shown in Figure 1, response rate again increased to a level similar to that under the initial CO-2 condition. Extinction was again presented and responding for all subjects returned to or near operant levels.

The remainder of Figure 1 shows that when subjects were given a choice between an unsignalled VT 4-min shock schedule and a signalled VT 1-min shock schedule (CO-1), Rats HF 1, HF 4, and HF 7 chose the higher density signalled schedule. However, following extinction and then a repeat of the CO-1 condition, only HF 1 reacquired the changeover response. The shock density for the signalled condition was increased further for this latter subject to a VT 30-sec shock schedule (CO-0.5). When Subject HF 1 was given this option of VT 30-sec signalled shock over VT 4-min unsignalled shock, changeover responding stabilized at a fairly high level but a level noticeably lower than under the previous changeover conditions. After responding stabilized under CO-0.5, extinction was presented and was followed by another attempt to reacquire changeover responding at CO-0.5. However, the lat-

ter attempt was unsuccessful. As seen in Figure 1, once subjects stopped responding at the higher densities of signalled shock, additional attempts to reacquire changeover responding at these densities were unsuccessful. However, at the lower shock density, all subjects readily reacquired the changeover response.

EXPERIMENT 2

The first study did not provide independent evidence of whether the two most similar shock schedules (VT 4-min and VT 2-min) were discriminably different, thus, it could be argued that doubling the density of signalled shock had no effect on rate of changeover responding simply because subjects could not discriminate between a VT 4-min and a VT 2-min schedule. Whether subjects could discriminate between these two schedules can easily be tested using only unsignalled shock. Would subjects choose low over high density *unsignalled* shock? If so, could this choice then be altered by providing a signal before shock under the higher density schedule? The second study answers both questions.

METHOD

Subjects and Apparatus

Two naive female albino rats of the Sprague-Dawley strain (Holtzman) 90 to 120 days old served. Except for the following changes, all other conditions were the same as in the previous study.

Initial Training (Baseline)

Within each 6-hr session, subjects received 3 hr of shock presented on a VT 4-min schedule identified by the correlated stimulus of light and 3 hr of shock presented on a VT 2-min schedule identified by the correlated stimulus of darkness. Shock was unsignalled for both conditions. A minimum of three 6-hr sessions was given.

Changeover from High to Low Density Unsignalled Shock

After the operant level on the changeover levers stabilized under training, subjects began the next session under the VT 2-min schedule of unsignalled shock identified by the correlated stimulus of darkness. A response at this time produced the correlated stimulus of light and the unsignalled schedule of VT 4-

min shock for a 3-min period. Additional responses during this 3-min period were recorded but they had no effect. At the end of the 3-min period, the correlated stimulus and VT 4-min shock schedule terminated. Unless another changeover response was made, the subject remained on the VT 2-min schedule.

Extinction

Under the extinction procedure, subjects were placed in the VT 2-min shock condition and neither the correlated stimulus nor the VT 4-min shock schedule was presented following changeover responding.

Signalled Shock Training

After testing under the unsignalled shock conditions was completed, subjects were trained under the signalled shock condition. Under this condition, a 5-sec signal preceded shock for the VT 2-min schedule but not for VT 4-min. Three days of training were given with 3 hr of each session under signalled shock and 3 hr under unsignalled shock. The inclusion of a signal under the VT 2-min schedule was the only difference between this training session and initial training sessions.

Changeover from High Density Signalled Shock to Low Density Unsignalled Shock

After three days of signalled training, each subject was returned to the changeover situation. Subjects could change to lower frequency unsignalled shock (VT 4-min) or remain in the higher density signalled shock (VT 2-min).

RESULTS

As shown in Figure 2, both subjects changed from the higher density VT 2-min shock schedule to the lower density VT 4-min shock schedule. Both subjects changed over at a rate sufficient to remain in the lower density VT 4-min condition for more than 90% of the time. Acquisition of the changeover response showed the same pattern as in the previous experiment. Responding increased immediately once contact with the contingency was made. Again, as in the first study, when the correlated stimulus terminated (3-min changeover period ended) both subjects reinstated it immediately and few non-functional responses were made in its presence.

Under the extinction condition (EXT), shock was always presented on a VT 4-min

schedule and no change in the stimulus condition occurred. Changeover responding dropped to the baseline level for Subject HFC 12 but only partially for HFC 9 (Figure 2). When the contingency was reinstated, responding again increased to the previous high level where both subjects were spending about 90% of the time in the changeover condition. Since the response rate of Subject HFC 9 did not drop to baseline under the extinction condition, another attempt to reacquire and extinguish changeover responding was made (Figure 2). As shown in Figure 2, Subject HFC 9 performed in the same manner as before.

After demonstrating that subjects would changeover from a high density schedule of unsignalled shock (VT 2-min) to a low density one (VT 4-min), the effects on changeover of high density signalled shock over low density unsignalled shock were studied. Both subjects received training under a schedule of VT 2-min signalled shock and VT 4-min unsignalled shock. The baseline for changeover responding under this training procedure is found in the next to last column of Figure 2. Following this, the changeover option was introduced of going from the signalled shock schedule of VT 2-min to an unsignalled one of VT 4-min. It is obvious from Figure 2 that both subjects ceased changeover responding under these conditions. Both subjects remained in the higher density signalled shock condition rather than change to the lower density unsignalled schedule.

DISCUSSION

The results of the first study showed that each subject chose the condition where both safe (correlated stimulus) and unsafe periods (signal) were identifiable. Subjects chose this signal condition when shock density was the same (VT 4-min) and when it was two times greater than that of the unsignalled condition. When the density of signalled shock was four times (VT 1-min) that of unsignalled shock (VT 4-min), three of the four subjects still chose the higher density schedule. However, when the latter condition was repeated after a series of extinction sessions, only one of these subjects (HF 1) reacquired the response. This subject (HF 1) also chose a density of signalled shock eight times (VT 30-sec) greater than that of unsignalled shock (VT 4-min) the first time

Fig. 2. Per cent of session time spent in the unsignalled 4-min condition for the last three days of each condition. In the changeover (CO) conditions, subjects were first given the option to change from a 2-min unsignalled shock schedule to a 4-min unsignalled one (2U-4U). Subjects were also given the option to change from a 2-min signalled shock schedule to a 4-min unsignalled one (2S-4U). Blank spaces along the abscissa indicate that the subject did not receive that condition.

this condition was later repeated. The second study showed that the two shock schedules most similar in density were discriminably different because: (1) subjects chose lower over higher unsignalled shock densities; (2) subjects did not choose lower over higher shock densities when safe and unsafe periods were identifiable for the higher density.

The present data are unusual, since they show that a stimulus correlated with a higher shock density served as a reinforcer. The absolute amount that density was increased is of less interest to the authors than the fact that subjects chose greater signalled over lesser unsignalled shock densities (Experiment 1). It is not surprising that subjects chose low over

high shock density (Experiment 2) because this was the main finding of Herrnstein and Hineline (1966). It may be that a reduction in shock density *per se* is reinforcing. However, Hineline (1970) showed that rats will acquire a response that does not reduce overall shock density.

The Hineline study and the present one suggest an alternative to interpretations that emphasize shock density reduction and they also provide further support for the analysis offered by Badia *et al.* (1971, 1972) and Badia and Culbertson (1972). This analysis stresses the reinforcing effects of stimuli that identify shock-free periods and is in some ways similar to that of Rescorla (1969) and Seligman (1968). The analysis is as follows. When signalled and un-signalled events are investigated, three distinct stimulus conditions exist: (1) the presence of the signal in the signalled condition, (2) the absence of the signal in the signalled condition, (3) the unsignalled condition. In the present study, when subjects were in the signalled condition, the compound of correlated stimulus and signal identified a shock period while the correlated stimulus in the absence of the signal identified a shock-free period. Therefore, under the signalled condition the shock period was discriminable and relatively brief, at most, lasting only as long as the signal duration. Further, the shock-free period, identified by the correlated stimulus alone, was also discriminable but much longer than the shock period, since it consisted of the total inter-shock time minus the signal duration. In contrast to the signalled condition, neither shock nor shock-free periods could be identified in the unsignalled one and the entire inter-shock interval may have acquired the properties of a shock period.

The two notions of shock-frequency reduction and shock-free periods are not incompatible. Indeed, some might argue whether a clear distinction between them can be made. Conceivably, when shock-free periods are not identifiable (Experiment 2, first part) a shock frequency interpretation may account for the data. However, when the subject is able to identify shock-free periods, its responding may be relatively independent of shock-frequency reduction (Experiment 1).

There are additional data that demonstrate the differential control acquired by stimuli that identify shock and shock-free periods.

Rescorla and LoLordo (1965) trained dogs on a Sidman avoidance task and then gave them a number of exposures to stimuli that identified shock (CS+) and shock-free (CS-) periods. Later, when the CS+ and CS- were superimposed on the avoidance task, facilitation and suppression, respectively, were observed. Similar findings were obtained by Weisman and Litner (1969) with rats. In addition, these latter investigators showed that the stimulus identifying the shock-free (CS-) period maintained its effect on avoidance responding for 14 sessions after the exposures to CS+ and CS-. It was subsequently shown that the duration of the shock-free period was also an important factor (Weisman and Litner, 1971a).

It is becoming evident that the presentation of stimuli, in addition to their withdrawal, is an important factor in aversive situations and data are accumulating that support the role of "positive reinforcement" (safety) within an aversive context (*e.g.*, Badia and Culbertson, 1972; Weisman and Litner, 1971b). This safe period notion may be applied to various situations where aversive stimuli are used and where periods of safety are identifiable by reason of stimuli or the distribution pattern of the aversive events. It should also be noted that an analysis in terms of safe and unsafe periods is analogous to that of timeout and the evidence suggests that timeout from aversive stimulation is an effective reinforcer (Sidman, 1962; Verhave, 1962).

Some have argued that the signal condition is chosen because the signal allows preparation for the receipt of shock (Perkins, 1955). Preparation, in turn, is said to reduce the noxiousness of shock. There are several reasons why this interpretation is inadequate over and above its appeal to hypothetical internal states. As noted above, the stimulus correlated with safety was presented immediately following a changeover response while the signal itself was relatively far removed from the response. It has been shown that this stimulus alone, without a signal, was capable of maintaining changeover responding over a number of days, but the signal without the correlated stimulus was not able to maintain changeover responding (Badia *et al.*, 1971; Badia and Culbertson, 1972). In addition, several studies have shown that subjects would respond for stimuli that identified shock-free periods (Defran, 1972), or food periods (Dinsmoor, Flint, Smith, and

Viemeister, 1969) but they would not respond for stimuli that identified shock periods (to which preparation could be made). This latter finding would argue against an information-seeking as well as a preparation interpretation.

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