CHOOSING BETWEEN PREDICTABLE SHOCK SCHEDULES: LONG- VERSUS SHORT-DURATION SIGNALS

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Two experiments assessed the relative aversiveness of different duration preshock signals (5 and 20 seconds) and different duration stimuli identifying shock-free periods. In the first experiment, the responding of 15 of 18 rats was maintained when it produced changes from a predictable-shock condition with a 5-second preshock signal to an identical schedule with a 20-second preshock signal; responding was not maintained when it produced the opposite changes. These results occurred with intershock intervals of both 120 seconds and 240 seconds. The second experiment assessed whether changing to the 20-second schedule was maintained by properties of the preshock signals identifying the shock periods or by properties of the stimuli identifying the shock-free periods. Four subjects were given training with the two signaled schedules in an operant chamber and then later given off-baseline preference tests in a shuttlebox. When given a choice between preshock signals, subjects chose the 5-second signals over the 20-second signals. However, when given a choice between stimuli identifying shock-free periods, subjects chose the stimulus identifying the shorter shock-free periods (i.e., the one previously correlated with the 20-second signals). These findings are discussed within the Rescorla and Wagner model of stimulus compounds and within the context of safety as a contrast phenomenon.

Key words: signaled shock, predictability, choice, preference, safety, lever press, rats

It is well established that subjects choose signaled over unsignaled shock (Badia, Harsh, & Abbott, 1979), but why they do so is not. Addressing the latter question, a recent study (Abbott & Badia, 1979) examined preference for signaled- over unsignaled-shock schedules as a function of signal lengths ranging from 0.5 to 2.0 s. Preferences emerged slowly, or not at all, when signals were 1 s or less, but became strong in all subjects at lengths of 2.0 s. At the latter value, subjects spent 80% to 95% of session time in the signaled condition. Similar levels of preference have been obtained in other studies using the same method and signals of 5-s or longer durations (e.g., Badia & Culbertson, 1972; Badia et al., 1979). However, because of "ceiling effects" correlated with the preference measure, it could

not be determined whether signals longer than 5 s would produce stronger preferences. Experiment 1 addresses this issue.

Subjects were given a choice between two signaled-shock conditions differing only in the length of the signal. In one condition signals were 5 s in duration and in the other condition they were 20 s in duration. A changeover procedure was used to assess preference and subjects were given the opportunity to change both from the 5-s to the 20-s signal condition and vice versa. In addition, some subjects were tested with an average intershock interval of 120 s and others were tested with an interval of 240 s.

EXPERIMENT 1

METHOD

Subjects

Eighteen naive female Sprague-Dawley rats (Holtzman Co., Madison, WI) served in 6-hr sessions on alternate days. Subjects were housed in individual home cages and given continuous access to food and water. The colony room was maintained on a

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reversed 12-hr light-dark cycle and experimentation took place during the dark part of the cycle.

Apparatus

All experimental procedures were conducted in four identical chambers, each enclosed by a sound-attenuating box. Chambers were constructed from aluminum sheet and measured 22.9 cm wide by 23.5 cm deep by 21.1 cm high. The door (front wall) and ceiling were Plexiglas. A removable Plexiglas false ceiling, installed 11.4 cm above the floor, served to reduce the incidence of unauthorized avoidance. The floor consisted of 12 stainless steel rods (0.64 cm in diameter) spaced 1.91 cm apart, center to center.

The front panel (right wall) held two rodent levers (Gerbrands Model G6312) mounted 4.4 cm above the floor and centered 6.0 cm from the panel edges, two cue lights (#313 28-V dc bulb covered by a 1.3-cm white jeweled lens cap) mounted 14.3 cm above the floor, and two houselights (#509 28-V dc covered by 2.5 cm white lens caps) mounted directly over the cue lights and 31.6 cm above the floor. Only the left houselight and right cue light were used in the experiment. The levers required 20 g (0.196 N) to depress.

Signals (1000 Hz, 86 dB tones, C-scale) were produced by a 7.6-cm., 8-ohm speaker centered on the permanent ceiling. Scrambled shock (0.5 s, 75 mW) was provided to three chambers by separate BRS constant-wattage shock-scramblers (Model SGS-001). BRS shock generators provided nine output lines, so grid bars 1 and 12, 2 and 10, and 3 and 11 were paired to the same lines. A Grason-Stadler unit (Model E 1064GS) provided scrambled shock (0.5 s, 1.0 mA) to the fourth chamber via independent output lines. The metal walls and levers of each chamber formed part of the scrambler circuit.

The shock parameters used are known to support strong preference for signaled shock (e.g., Abbott & Badia, 1979) and also efficient escape and avoidance responding (e.g., Badia & Culbertson, 1972; Badia, Culbertson, & Lewis, 1971).

Procedure

Sessions began with termination of the right cue light and ended with its illumination. Each subject received two signaled-shock conditions, a 5-s tone signal (1000 Hz, 86 dB) and a 20-s tone (same tone) before shock. Each signal terminated with shock onset. Illumination of the left houselight identified one condition and the absence of illumination identified the other. Conditions and correlated stimuli were counterbalanced across subjects.

Throughout the experiment, shock was delivered on a variable-time (VT) schedule that ran independently of the conditions present. Three groups of six subjects were run. Group 1 received a VT 120-s schedule having a 23-s minimum intershock interval. Group 2 also received a VT 120-s schedule but the minimum intershock interval was raised to 43 s. Group 3 received a VT 240-s schedule having a minimum intershock interval of 43 s. Each schedule was constructed by generating a 12-interval constant probability schedule (Fleshler & Hoffman, 1962) and adding a constant to each interval. For Group 1, 20 s was added to each interval of a VT 100-s schedule; for Group 2, 40 s was added to each interval of a VT 80-s schedule; and for Group 3, 30 s was added to each interval of a VT 210-s schedule.

Baseline. Each subject received the two signaled-shock conditions for several sessions (Baseline phase) and then was given the opportunity to choose between the two (Changeover phase). During the Baseline phase subjects spent the first 3 hr of each session in the 20-s signal condition and the last 3 hr in the 5-s signal condition. In these sessions responding on the levers had no scheduled consequences, but responses and the time that would have been spent in the alternate condition had these responses been effective were recorded. These measures provided the baseline for assessing subsequent changeover responding. Subjects remained in the Baseline phase until responding stabilized. Responding was considered stable when the percentage of time that would have been spent in the alternative condition

varied by 10% or less over three successive sessions.

Changeover. During the Changeover phase subjects chose between the two signaled-shock schedules. Subjects were placed on one signaled schedule (imposed condition) and were given the opportunity to change to the other (alternative condition). A single response on either lever produced the alternative condition for 1 min (the changeover period); further responses during the changeover period had no scheduled consequences. When the changeover period terminated, the imposed condition was reinstated, and a response on either lever could again produce the alternative condition. To reduce the number of shock-elicited changeovers, responses during and for 2 s following a shock had no scheduled consequences. This Changeover phase continued until the percentage of time spent in the alternative condition stabilized (see above).

Order of conditions. All subjects first received the Baseline phase. When responding stabilized, the Changeover phase was initiated. Four subjects of Group 1 were placed in the 20-s signal condition and were given the opportunity to change to the 5-s signal condition (CO-5 option). The remaining subjects were placed in the 5-s signal condition and were given the opportunity to change to the 20-s signal condition (CO-20 option). When performance stabilized, the Baseline and Changeover phases were repeated. Subjects then were exposed to Baseline for the third time. They were then given an opportunity to change in the opposite direction—that is, subjects previously receiving CO-5 now received CO-20 and vice versa. Finally, Baseline and the Changeover options were repeated.

RESULTS AND DISCUSSION

Despite differences in mean and minimum intershock intervals, subjects in the three groups performed similarly, as shown in Figure 1, which presents data for individual subjects. Each bar indicates the

percentage of time spent in changeover by a given subject, averaged over the final three sessions of a phase.

Although some intersubject variability occurred during the changeover phases, a consistent pattern emerged. When given the CO-20 changeover option (black bars), 15 of 18 subjects changed from the 5-s to the 20-s condition at rates above baseline levels (white bars). These levels were replicated on second exposure to the CO-20 option for all subjects except Subject S-56 (see Figure 1). This subject therefore received a third exposure to the CO-20 option. Unfortunately, this animal died of a respiratory infection before receiving the CO-5 changeover option. The remaining subjects each received two exposures to the CO-5 option (striped bars), but none changed from the 20-s to the 5-s signal condition at rates above baseline levels during either opportunity.

Although most subjects changed to the 20-s signal condition, the level of changeover varied considerably from subject to subject. Differences in responding due to the different intershock intervals may have been obscured by this variability. Previous research has shown that preference for signaled-shock schedules increases with intershock intervals over the 120-s to 240-s range, but this effect is weak (Harsh & Badia, 1976). Additional research using a broader range of intershock intervals is necessary to clarify whether intershock interval and signal length interact to determine preference.

Although preference for the 20-s signal condition is clear, it is not obvious how the longer signal induces this preference. Evidence suggests that responding maintained by change from unsignaled- to signaled-shock schedules is controlled by stimuli correlated with safe periods (Badia et al., 1979; Badia, Harsh, Coker, & Abbott, 1976). However, given that in the present case the intershock intervals of the two schedules were identical, the 20-s signal condition necessarily offered safe-period stimuli averaging 15 s *shorter* than those of the 5-s

Fig. 1. Experiment 1. Mean percentage of time spent in changeover during criterion sessions in each condition. Top row: VT 120-s schedule with a 23-s minimum ISI. Middle row: VT 120-s schedule with a 43-s minimum ISI. Bottom row: VT 240-s schedule with a 43-s minimum ISI.

signal condition. This should have led to at least a weak preference for the 5-s signal condition if the length of safe periods were the only factor determining choice (Harsh & Badia, 1976; Safarjan & D'Amato, 1978). What, then, could account for the observed preference?

The only other obvious difference between the 5-s and 20-s signal conditions is the length of the signals. It is possible that 20-s signals are simply less aversive than 5-s signals under these conditions, but there is no independent evidence of that. To determine the source of reinforcement for the changeover response it is necessary to assess directly the relative aversiveness of the two signals identifying shock periods and of the two stimuli identifying the shock-free periods. Experiment 2 performed this assessment.

EXPERIMENT 2

Subjects were first exposed in an operant chamber to the two signaled schedules. As in

Experiment 1, the two schedules were identified by different correlated stimuli (light versus darkness). Unlike Experiment 1, however, the 5-s and 20-s signals were also identified by different stimuli (continuous versus pulsed tone). Following conditioning, subjects were transferred to a shuttlebox for preference testing. In one phase, the two compartments of the shuttlebox were differentially correlated with the two signals identifying shock periods and in another phase with the two stimuli identifying shock-free periods.

Subjects

Four female Sprague-Dawley rats (Holtzman Co.) 90 to 120 days old at the start of the experiment served. Conditions in the colony room were the same as those described for Experiment 1.

Apparatus

Conditioning sessions were conducted in one of the operant chambers used in Experiment 1; preference testing was conducted in

a two-compartment shuttlebox. Enclosed within a sound-attenuating chamber, the shuttlebox was constructed from clear acrylic sheets and measured 47.5 cm long, 17.0 cm wide, and 20.5 cm high. Its floor consisted of 0.4-cm stainless steel rods spaced 1.5 cm center to center. Tones (1000 Hz, 82 dB, C-scale) were delivered by a 7.6-cm speaker mounted at the center of the ceiling midway between the two compartments. Correlated stimuli were provided by two houselights (#509K 28-V dc bulbs covered by 2.5-cm white jeweled lens caps), one mounted over the center of each compartment on the ceiling. The shuttlebox was pivoted at its center and tilted slightly downward on the side occupied by the subject, closing one or the other of two microswitches located at opposite ends of the box. One switch operated a clock, which recorded the amount of session time the subject spent in the left compartment. The other switch functioned only to balance auditory cues produced by switch operation on the two sides.

Procedure

Subjects received one 330-min experimental session every other day. During each session, subjects spent the first 300 min in the operant chamber, where they were exposed for 150 consecutive min to a 5-s signal condition and for the other 150 min to a 20-s signal condition. The order of the latter two conditions was counterbalanced across sessions. Signals in one condition were provided by continuous tones; signals in the other condition were provided by pulsed tones (1 s on, 1 s off). In addition, a different correlated stimulus (houselight-on or houselight-off) identified each condition. The particular stimuli used to identify the different periods were counterbalanced across subjects.

Shock (0.5 s, 75 mW) was presented immediately at the termination of each signal. Throughout the conditioning session, shocks were delivered according to the same VT 120-s (23-s minimum intershock interval) schedule as that described for Group 1 in Experiment 1.

The last 30 min of each session were used to assess preference. Subjects were removed from the operant chamber and placed in the shuttlebox, where one of three preference tests was conducted as described below.

Baseline preference test. This condition assessed whether a side preference was evident in the shuttlebox prior to stimulus preference tests. Subjects were placed in the center of the shuttlebox following each conditioning session. A blinking light (1 s on, 1 s off) was in effect during the test so that visual stimuli in the shuttlebox did not correspond to either of the stimuli identifying shock-free periods presented in the operant chamber. The amount of time that was spent on each side of the apparatus was recorded, although choosing a particular side did not result in any stimulus change. Subjects received baseline preference testing until the time spent on either side of the shuttlebox did not vary more than 5 min across three consecutive sessions.

Signal-duration preference test. Following baseline preference testing, subjects received signal preference testing. This situation provided an off-baseline examination of the relative aversiveness of long and short signals. Signals were scheduled according to the same VT 120-s schedule used in conditioning, but shocks were omitted. Subjects received the 5-s signal experienced during training when they stood on one side of the shuttlebox and the 20-s signal when they stood on the other side. The blinking light was presented in both sides of the shuttlebox as in baseline testing to eliminate the influence of stimuli that identified shock-free periods correlated with different signal lengths in the operant chamber.

Preference testing of signals continued until the time spent on either side of the shuttlebox did not vary across three consecutive sessions by more than 5 min. The positions of the two signals were then reversed and signal preference testing continued until the stability criterion was again met (reversal). A second reversal was then conducted. Two subjects received 20-s signals and two received 5-s signals on the left side during

initial signal preference testing.

Safety-duration preference test (correlated stimulus). After the last preference test for signal duration, subjects were given preference tests with stimuli previously correlated with different shock-free periods (referred to in Figure 2 as the correlated stimulus). In this situation, neither shocks nor signals were ever presented, but each side of the shuttlebox contained one of the stimuli that identified shock-free periods (light-on or light-off) during conditioning. By choosing a particular side, subjects could remain in the presence of the stimulus that was correlated with shock-free periods of the 5-s signal condition or those of the 20-s signal condition. Preference tests continued until performances stabilized. The positions of the two safe stimuli were then reversed and preference testing continued until stability was achieved a second time (reversal).

RESULTS

Baseline and Signal Preference Tests

Data from baseline and signal preference tests are shown in Figure 2. Each point represents the time in minutes spent by a given subject on the left side of the shuttlebox. Only the last three (criterion) sessions of each testing phase are displayed. During baseline preference tests (first column), Subjects S1 and S4 spent most of the final three sessions (25 min or more of the 30-min sessions) on the left side of the shuttlebox, but Subjects S2 and S3 spent little time (8 min or less) on the left side. Following baseline assessments, subjects were given signal preference tests. Subjects S1 and S4 initially received the 20-s signal on the left side of the shuttlebox (second column); Subjects S2 and S3 initially received the 5-s signal there. All four subjects developed a strong preference for the side with the 5-s signal, whether it was presented on the left or right, although doing so contradicted the side preferences exhibited in baseline testing. Reversing the locations of the 5- and 20-s signals (third column) changed the side preferred so that each subject once again

spent most of each session on the side with the 5-s signal. A second reversal (fourth column) again changed the side preferred so that subjects again spent the majority of session time on the side offering the 5-s signal.

Safe-Stimulus Preference Tests (correlated stimulus)

Figure 2 also displays data for individual subjects on the final three sessions of preference tests for stimuli identifying the shock-free periods correlated with the different signal conditions. Subjects S1, S2, and S4 received initial testing with the correlated stimulus from the 20-s signal condition on the left side (fifth column). All three subjects developed a strong preference for the left side. Subject S3 received its initial testing with the correlated stimulus of the 5-s signal condition on the left side (fifth column). This subject developed a strong preference for the right side. Thus, all subjects strongly preferred the correlated (safe) stimulus of the 20-s signal condition, whether this stimulus appeared on the left or right side of the shuttlebox. Furthermore, in the subsequent reversal phase (sixth column) each subject reversed its preferred side, thus continuing to show a strong preference for the correlated stimulus of the 20-s signal condition.

GENERAL DISCUSSION

For 15 of 18 subjects in the first experiment, responding was maintained by changes from a condition with a 5-s preshock signal to one with a 20-s preshock signal; responding was not maintained by changes from a condition with a 20-s preshock signal to one with a 5-s signal. The second experiment evaluated separately the importance of the two preshock signals and the importance of the stimuli identifying the shock-free (safe) periods correlated with them. Subjects preferred the 5-s preshock signals over the 20-s preshock signals in off-baseline testing, but chose the stimulus identifying the shock-free period correlated with the 20-s signal condition over that of the 5-s signal. Because signals of 20 s were more aversive than those

Sessions

Fig. 2. Experiment 2. Time spent on left side of shuttlebox during criterion sessions when either long or short signals (columns 2 through 4) and long or short safe periods (columns 5 and 6) were presented on the left side. The alternative stimuli were presented on the right side of the shuttlebox. The preshock stimulus duration correlated with the left side of the shuttlebox is indicated at the top of each column in the figure.

of 5 s, choice of the 20-s signal condition in Experiment 1 cannot be explained by a preference for the longer signal. Instead, preference for the condition was apparently strengthened by the stimuli identifying the shock-free (safe) periods. However, it is difficult to understand how the shock-free stimulus correlated with the 20-s signal condition acquired greater reinforcing value (or less

aversiveness) than the shock-free stimulus correlated with the 5-s signal condition. We discuss two possible reasons below.

One reason may relate to stimulus compounding within the Rescorla and Wagner (1972) model of classical conditioning. In brief, the model states that, on each trial, the compound formed by the CS and the continuously present background stimuli receives

an increment in associative strength on the strength of shock. In the interval between CS-shock pairings, the continued presence of background stimuli in the absence of shock extinguishes some of the associative strength gained by the background during pairing. Because the CS does not occur between shocks, it does not lose associative strength. Across succeeding trials the CS acquires an ever larger share of the total strength accumulating to the compound. Rescorla and Wagner (1972) note that during conditioning, the strength of conditioning to the background will be inversely proportional to the strength of conditioning to the CS.

In the present study, the stimuli identifying the shock-free period may have functioned as background stimuli so that as the signal gained more of the available strength, less remained for the background stimuli. Thus, the lower aversiveness of the shock-free stimulus associated with the 20-s signal condition may be a direct consequence of the greater aversiveness of the 20-s shock signal (Experiment 2).

Although the Rescorla-Wagner model accounts for the inverse relationship between the CS (shock signal) and the background (shock-free signal), there are several shortcomings. The most important is that the model ignores signal duration as a parameter. Thus it does not account for greater aversive conditioning to the 20-s shock signal over the 5-s one. Second, differences in conditioning between the two shock signals and the two safe signals are expected only during acquisition. Eventually shock signals are expected to absorb all the excitatory conditioning and the safe signals are expected to become neutral. However, preference for the 20-s signal in Experiment 1 was stable over weeks. There was no indication that the strengths of the safe stimuli were moderating. Finally, for Experiment 1, the model offers no explanation for why the relatively aversive 20-s signal did not counteract the effects of the safe stimulus.

A second possible reason for the shock-free stimulus correlated with the 20-s signal condition to have greater value relates to the

contrast between the shock and shock-free (safe) periods. Safety is a contrast phenomenon. It would seem that the value of a safe period would be positively related to the aversiveness of the situation. This assumption is supported by studies showing that preference for signaled over unsignaled shock increases with shock intensity (Harsh & Badia, 1975; Perkins, Seymann, Levis, & Spencer, 1966).

Additional evidence that contrast can alter the values of stimuli identifying shock and safety has been provided by Weisman and Litner (1969). Subjects that received conditioning trials in which both CS + and CS - were presented showed greater facilitation of avoidance responding when S + was presented, and greater suppression when CS - was presented, than subjects that received comparable numbers of trials with CS + or CS - alone.

Experiment 2 supports a contrast view of safety. Given a choice only between pre-shock signals, subjects chose the 5-s signal, which indicates that it was less aversive. However, given a choice between stimuli identifying the shock-free periods, subjects ought to choose, which they did, the stimulus contrasted with the more aversive 20-s signal.

To be viable, the contrast view of safety must explain why the increment in aversiveness of the shock stimulus does not simply cancel the decrement in the aversiveness of the safe stimulus. The problem is a familiar one to students of observing behavior. Both Wyckoff (1952) and Bower, McLean, and Meacham (1966) have attempted to solve it by postulating a nonlinear averaging process in which the more attractive stimulus is assigned greater weight in the equation governing choice, but this approach lacks explanatory power. Alternative approaches are needed.

A related problem is encountered by the contrast notion when one assumes that aversiveness of the signal is related to its duration. Without limiting assumptions, the contrast notion implies that the optimal signal duration for aversiveness would nearly span

the interval between shocks. Also, the use of different signal durations to assess aversiveness confounds signal-present and signal-absent durations. An empirical test of the contrast notion that avoids such confounding is possible, however. Such a test would vary signal aversiveness by using different shock intensities.

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