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NEGATIVE REINFORCEMENT WITH SHOCK-FREQUENCY INCREASE[1]

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Two avoidance-conditioning experiments in which responding delayed shocks are reported. Rats receiving an average of two shocks per minute (imposed condition) could produce, by pressing a bar, a 3-min alternate condition. Six (Experiment I) or more (Experiment II) shocks occurred in the alternate condition. All shocks in the alternate condition were delayed and delivered at 1-sec intervals. With long delays, all subjects produced the alternate condition and spent a large percentage of each session in the alternate condition. The first experiment demonstrated that the longer the delay from onset of the alternate condition to onset of the shocks, the more session time spent in the alternate condition. The second experiment indicated that despite increased shock frequency, behavior is acquired and maintained when responding leads to sufficient delay. Individual subjects produced the alternate condition by bar pressing in essentially one of two patterns. One pattern, termed postshock, involved bar pressing immediately after shock; the other, termed posttransition, involved responding immediately after the transition from the alternate to the imposed condition. These results indicate that shock-frequency reduction is not necessary for avoidance conditioning; delay to shock onset is sufficient.

Key words: aversive control, avoidance, delayed shock, shock frequency, rats

Many avoidance-conditioning procedures involve both delay to shock and shock-frequency reduction. In free-operant avoidance (Sidman, 1953), for example, a response interrupts a series of shocks for several seconds. A response produces both an overall reduction in the number of shocks and an increased delay to the next shock. Herrnstein and Hineline (1966) manipulated the probability of shock following a response. During random shocks to rats, a response terminated a high-probability shock schedule and introduced a low-probability shock schedule. Just as in the free-operant avoidance procedure, however, Herrnstein and Hineline's procedure involves changes in both frequency and average delay to shock.

Several experimenters have tried to separate frequency reduction from increased delay. Lambert, Bersh, Hineline, and Smith (1973) examined the role of shock-frequency reduction with decreased delay to shock. Rats could respond and produce one shock immediately, and simultaneously prevent a series of five shocks later. By responding, the animal could reduce the overall number of shocks per trial (shock-frequency reduction) but only by receiving an immediate shock (reduced delay). This procedure was studied when an escape response was possible and when no escape was possible. Of the four subjects receiving the no-escape procedure, two subjects showed clear acquisition when a shuttle response was required, but two other animals failed to acquire when a bar-press response was required.

In an investigation of the role of delay to shock, Hineline (1970) employed a discrete trial bar-press procedure in which a response delayed the onset of a single shock for 10 sec, without changing the overall shock frequency. When shock frequency did not change, rats responded. In a further manipulation, Hineline (1970) found that responding was eliminated when responding led to a 10-sec delay and to an increase in the shock frequency.

The present investigations examined response-contingent delays longer than 10 sec and employed a free-operant procedure. In the first experiment, a response produced either a 10-, 88-, or 165-sec delay to shock and

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no change in the total number of shocks received. In the second experiment, a response produced over a 150-sec delay and an increase in the total number of shocks received by factors of 1.5x, 2.0x, or 3.0x.

EXPERIMENT I
RESPONSE-PRODUCED DELAY WITH CONSTANT SHOCK FREQUENCY

This experiment tested the hypothesis that increasing the amount of delay to shock onset increases responding. Responses for different subjects produced either a 10-, an 88-, or a 165-sec delay, but did not reduce the overall number of shocks.

Subjects

Nine female albino rats, obtained from the Holtzman company, were 90 to 120 days old when introduced into the experiments. Each was naive and was individually caged with free access to both food and water.

Apparatus

All subjects were tested in one of two operant-conditioning chambers 23.3 cm long, 20.4 cm wide, and 20 cm high. The chambers were modified so that the bars in the grid floor were parallel with the 23.3-cm wall. Inner Plexiglas ceilings were mounted 11.5 cm above the grid floor. A Gerbrands rat lever required approximately 20 g (0.196 N) to depress and was mounted 7.1 cm from the side along the 20.4-cm wall, 6.3 cm above the grid floor. A response activated a clicker (85 dB, 10 clicks per second) and illuminated two 24-V bulbs mounted 2.5 cm on either side of the response lever. A continuous 75-dB white noise was on throughout all sessions. Onset of the white noise and two houselights mounted on the back of the 20.4-cm wall signalled the beginning of the experimental session; offset of the noise and lights signalled termination. Each chamber was enclosed within a larger wooden acoustical chamber.

A constant-current shock source (BRS Inc.—SGS003, 10% duty cycle) delivered 3-mA shock for 0.3 sec to grids, front and rear walls, and response bar. Grid bars were 0.15 cm stainless steel spaced 1.3 cm apart center to center. Solid-state switching circuits housed in an adjacent room controlled all events.

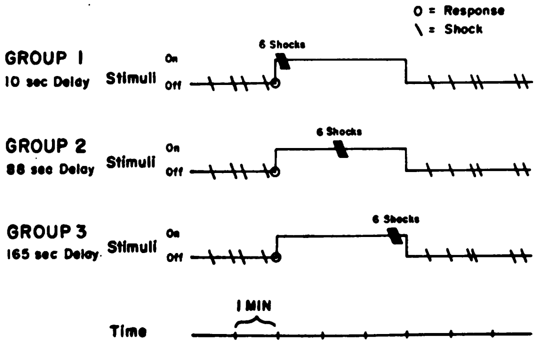

Fig. 1. Schema for the procedures employed in Experiment I. Time is represented from left to right on the bottom line. The remaining three lines represent sequence of events for Groups 1, 2, and 3. Upward displacement of a line marks the onset of the alternate condition with correlated stimuli. Downward displacement of a line marks return to the imposed, VT 30-sec shock condition. A "/" marks a shock and a "O" marks a response. Overall shock density is constant for all three groups.

Procedure

Subjects were tested for 6 hr every other day. All variable-shock tapes were generated by means of Fleshler and Hoffman (1962) tables. The procedure is schematized in Figure 1. If the rat failed to respond, shocks were delivered at irregular intervals averaging one every 30 sec. This procedure is called a variable-time (VT) 30-sec shock schedule. The VT 30-sec shock schedule, which was in effect throughout each session if no response occurred, is called the imposed condition. A lever response changed the imposed condition to an alternate condition for 3 min. Further responses during the alternate condition were recorded but had no effect. During the alternate condition, the clicker and lights (correlated stimuli) on either side of the bar were on, and the rat received a train of six shocks. These shocks occurred 1 sec apart as measured from onset to onset. This train of shocks began 10, 88, or 165 sec into the alternate condition for Group 1 (S-8, S-17, and S-33), Group 2 (S-10, S-11, S-31), and Group 3 (S-12, S-13, S-32), respectively. After the end of the 3 min, the alternate condition (with correlated stimuli) terminated, and the VT 30-sec shock schedule (imposed condition) was re-instated. Subjects, at this time, could produce the alternate condition or remain in the imposed condition.

RESULTS

Figure 2 shows for all animals the percentage of time in the alternate condition across sessions. Rats S-8, S-17, and S-33, receiving the 10-sec delay condition, spent the lowest amount of time in the delayed-shock alternate condition.

In contrast, the six subjects receiving the 88-sec or 165-sec delay spent a large percentage of each session in the alternate condition. By the sixth session, each subject in the 88-sec delay group was spending over 70% of the session in the alternate condition, and by the twelfth and thirteenth sessions, between 80% and 85% of the session in the delayed-shock condition. The three subjects receiving 165-sec delay showed the highest per cent of time in the alternate condition. From Sessions 5 to 13, all three rats spent more than 92% of each session in the delayed-shock condition. During the first two sessions, Rat S-32 showed a considerable drop in responding, but recovered to over 85% by the fourth session. From the first session, the other two 165-sec delay subjects, S-12 and S-13, spent the largest per cent time in the alternate condition.

Among subjects within each group, similar performances were observed. Figure 3 presents cumulative records for three subjects. The records are representative of both the indicated subject's terminal performance and of the other subjects in the same condition. The 10-sec delay subject, S-8, responded little; Subjects S-31 (88-sec delay) and S-32 (165-sec delay) spent a large percentage of each session with the alternate condition in effect. In addition, the 88-sec delay and 165-sec delay produced different patterns of responding.

The enlarged portions of the cumulative records in Figure 3 show the typical response patterns at the end of the alternate condition.

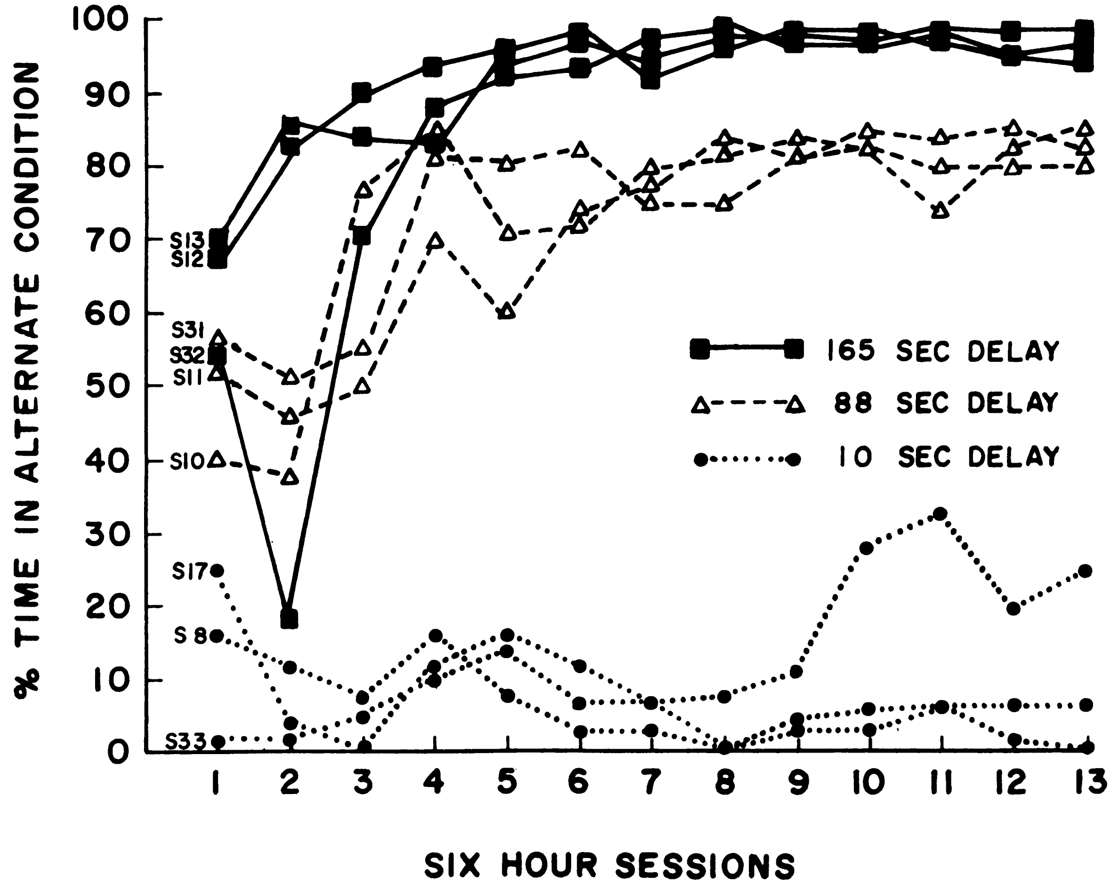

Fig. 2. Per cent of time in the alternate condition as a function of 6-hr sessions for subjects in Group 1 (10-sec delay), Group 2 (88-sec delay), and Group 3 (165-sec delay).

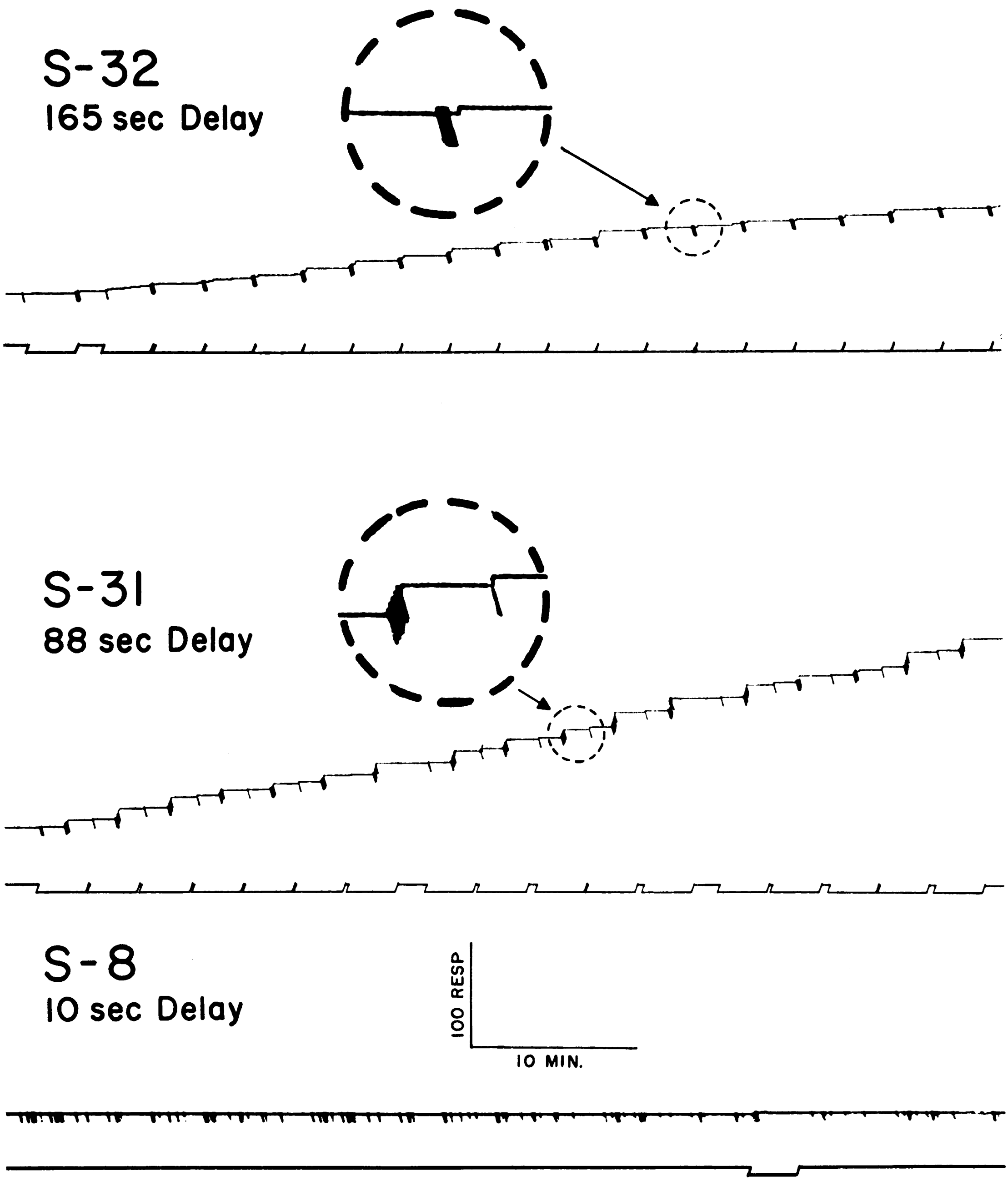

Fig. 3. Sample cumulative records from Session 10 of subjects in Groups 1, 2, and 3 receiving delays of 10, 88, and 165 sec, respectively. Downward displacements of the response marker indicate shocks and downward displacements of the event pen along the bottom of the record indicate onset of the alternate condition.

Rats often responded during and briefly after the train of shocks in both the 165-sec and 88-sec delay conditions. In the 88-sec delay condition (middle record), subjects typically did not respond again until after a shock in the imposed condition. In the 165-sec delay condition (top record), subjects typically did not respond again until immediately after the imposed condition was re-introduced. The lack of variability evident in Figure 2 is related to the pattern of responding produced by the three delay conditions. Subjects responding immediately after and only after the first shock would receive 30 sec in the imposed condition following each alternate condition. Such a pattern leads to approximately 51 min (or 14% of the session) in the imposed condition during each 6-hr session. Subjects responding after shock, and not at any other time, will spend approximately 86% of a session in the alternate condition. Figure 2 shows that the terminal performance of each subject in the 88-sec delay was close to 86% in the alternate condition.

Figure 4 shows the extent to which each subject engaged in posttransition, postshock, and "other" response patterns. These data were obtained from cumulative records. If an alternate condition was preceded by a single shock, the response producing the alternate condition was considered a postshock response. If an alternate condition was produced by a response, and no shocks had occurred since the prior alternate condition, the response was identified as a posttransition response. Alternate conditions produced by responses preceded by more than one shock were termed "other" responses. For each subject, Figure 4 shows the number of alternate conditions produced by each type of response during Session 12. Of the alternate conditions produced by the subjects in Session 12, 86% were produced by either postshock or posttransition responses. Subjects receiving 88-sec delay all show predominately postshock responding and those receiving 165-sec delay all show predominately posttransition responses. The 10-sec delay led to few alternate conditions produced mainly by responses falling in the "other" category.

The terms postshock and posttransition are intended to tell when the responses were observed to occur. As is clear from Figure 4 and Figure 2, both types or responses, postshock and posttransition, were, in different subjects, negatively reinforced. That is, they increased in probability when effective in delaying shock.

Discussion

These results support Hineline's (1970) demonstration that, with shock frequency held constant, delay is sufficient to produce and maintain responding. While Hineline's (1970) discrete-trial procedure maintained responding with a 10-sec delay, the present procedure required longer delays (88 and 165 sec) to support behavior. The present results extend Hineline's (1970) findings by demonstrating that different delay durations affect the probability of a response as well as the pattern of

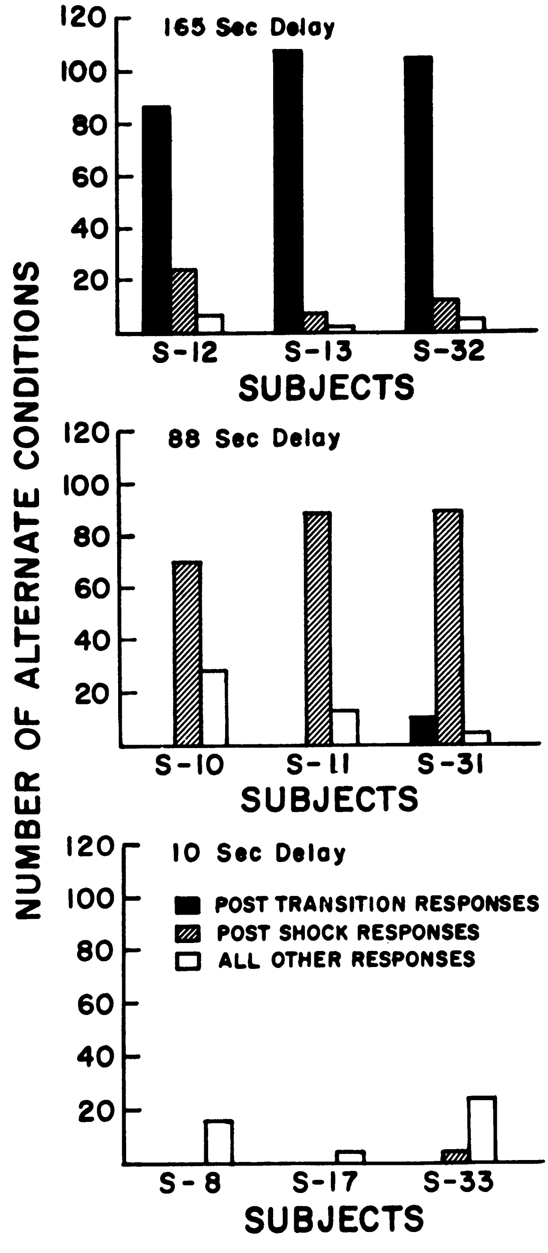

Fig. 4. Number of alternate conditions produced by posttransition (solid bar), postshock (stripped bar), and "other" (open bar) responses for each subject during Session 12. Subjects receiving delay-to-shock onset of 165, 88, and 10-sec are displayed in the top, middle, and lower graphs, respectively.

responding. Finally, the results of this first experiment demonstrate the feasibility of studying delay to shock and shock frequency independently with a free-operant avoidance procedure.

EXPERIMENT II
SHOCK-FREQUENCY INCREASE

The first experiment held shock frequency constant between the imposed and alternate conditions. The second experiment investigated the possibility that rats will delay shock even when responding increases the overall shock frequency. Hineline (1970) found that not one of 11 naive rats would delay shock 10 sec when responding increased overall shock frequency. The present experiment employed substantially longer delays and several values of shock-frequency increase.

Subjects

Twenty-one female albino rats, obtained from the Holtzman company at 90 to 120 days old, were individually caged with free access to food and water.

Apparatus

Same as Experiment I.

Procedure

All subjects received shocks on the average every 30 sec according to the same VT 30-sec schedule used in Experiment I. This imposed condition was in effect throughout each session unless the animal responded. The first response in the imposed condition produced the alternate condition for 3 min. Correlated with the alternate condition were the clicker and illuminated bulbs on each side of the response lever. The distribution and number of shocks occurring during the alternate condition varied among groups. Shocks during the alternate condition were 1 sec apart, measured from onset to onset.

For one group, D-1.5 (S-22, S-35, and S-39), the alternate condition consisted of 161 sec of shock-free time followed by nine shocks, and, finally a 10-sec period of shock-free time before the imposed condition was re-introduced. A second group, C-1.5 (S-1, S-3, and S-5), served as controls for the D-1.5 group. A response from an animal in Group C-1.5 activated a 3-min alternate condition, during which the subject received shocks an average of every 20-sec, (VT 20-sec). Upon completing 10 sessions under this no-delay, control condition, the C-1.5 group was tested for 10 days under a delayed-shock condition identical to that of Group D-1.5. The alternate condition under no-delay (C-1.5, Sessions 1 to 10) and delay (D-1.5, Sessions 1 to 10; C-1.5, Sessions 11 to 20) conditions contained 1.5 times the total number of shocks received during a 3-min period in the imposed condition.

For a second delay group, D-2.0 (S-37, S-40, and S-41) a response in the imposed condition produced a 3-min alternate condition composed of 158 sec of shock-free time followed by a train of 12 shocks, and, finally, a 10-sec shock-free period before onset of the imposed condition. Serving as controls for the D-2.0 group, Group C-2.0 (S-2, S-4, and S-6) received 10 session of no delay, during which shocks in the alternate condition were delivered on a VT 15-sec schedule. For an additional 10 sessions, Group C-2.0 was tested under delay conditions identical to those of Group D-2.0. Throughout no-delay and delay procedures, the 3-min alternate condition contained twice the number of shocks received during a comparable 3-min period in the imposed condition.

For a third delay group, D-3.0, of three naive rats (S-42, S-51, and S-52), a response in the imposed condition activated the alternate condition and resulted in a 152-sec shock-free period followed by a train of 18 shocks, and, finally, a 10-sec shock-free period before the imposed condition was re-introduced. Serving as controls (C-3.0) for the previous group, three naive rats (S-7, S-9, and S-19) received shocks an average of every 10 sec (VT 10-sec) during the alternate condition. After completing 10 sessions under the no-delay condition, Group C-3.0 was tested an additional 10 days under delay conditions identical to those of Group D-3.0. Subjects in Groups D-3.0 and C-3.0 received in the alternate condition three times the number of shocks in 3 min of the imposed conditions.

Finally, a fourth control group, C-0 (S-14, S-16, and S-18), received VT 30-sec shock in both the imposed and alternate conditions. A response for this group activated the correlated stimulus for 3 min, but had no effect on delivery of shocks.

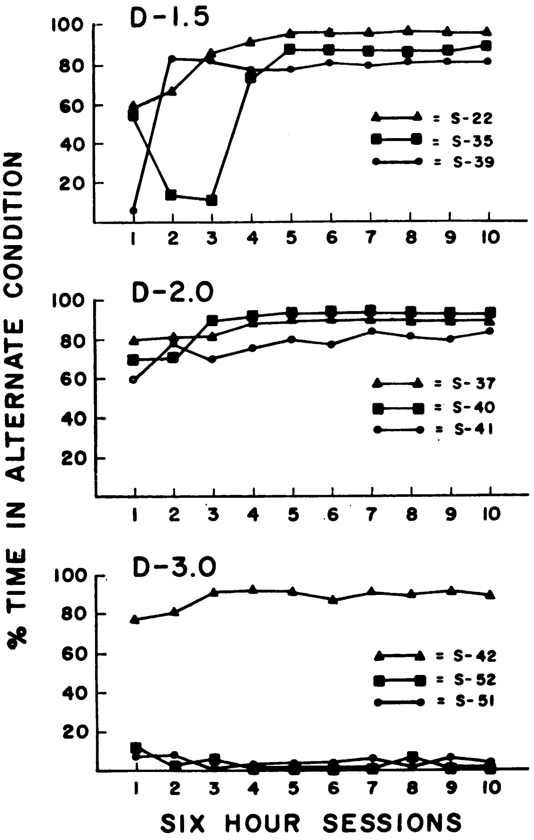

Fig. 5. Per cent of time in the alternate condition as a function of 6-hr sessions for subjects in Groups D-1.5, D-2.0, and D-3.0. Responding for Groups D-1.5, D-2.0, and D-3.0 resulted in scheduled delay-to-shock onset of 161, 158, and 152 sec, respectively, and shock frequency increases of 1.5x, 2.0x, and 3.0x, respectively.

RESULTS

Figure 5 shows percentage of total session time spent in the alternate condition across sessions for Groups D-1.5, D-2.0, and D-3.0. Responding produced shock-frequency increases of 1.5, 2.0, and 3.0 times respectively. All subjects in Groups D-1.5 and D-2.0 produced the alternate condition frequently. By the fourth session, subjects in Groups D-1.5 and D-2.0 were producing the delayed-shock condition more than 70% of the session time. One subject, S-35, in Group D-1.5 showed a declining function up to Session 3, but from Session 3 to Session 4, percentage of time in the delayed-shock condition increased from 11% to 72%. From the first session, all subjects in Group D-2.0 spent greater than 60% of the total session time in the delayed-shock alternate condition. As Figure 5 indicates, the performance was stable for subjects in these groups and shows maintained responding for at least seven sessions (42 hr) despite the response-produced increase in shock frequency.

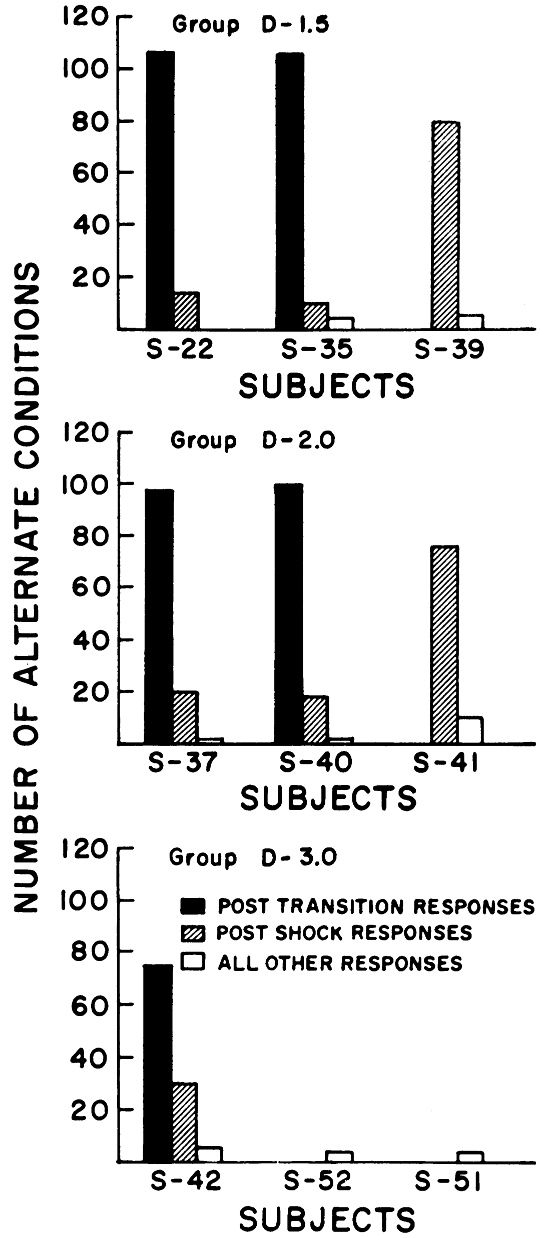

Fig. 6. Number of alternate conditions produced by posttransition (solid bar), postshock (stripped bar), and "other" (open bar) responses for each subject during Session 10. Subjects in Groups D-1.5, D-2.0, and D-3.0 are displayed in the upper, middle, and lower graphs, respectively.

Figure 6 shows the number of alternate

conditions classified as postshock, posttransition, and "other" for each of the subjects in Groups D-1.5, D-2.0, and D-3.0 in Session 10. Two animals (S-37 and S-40) in the D-2.0 group showed predominately posttransition response patterns. In contrast, one animal in each of these groups (S-39 in D-1.5 and S-41 in D-2.0) showed predominately postshock response patterns.

Bar pressing for only one of the three animals (S-42) in the D-3.0 group was clearly reinforced by the alternate condition. From the first session, S-42 produced the delayed condition (Figure 5) and responded in the posttransition pattern (Figure 6). The other two subjects, S-51 and S-52, showed little responding.

Figure 7 presents the results for Groups C-1.5, C-2.0, and C-3.0. Bar pressing resulted in shock-frequency increases of 1.5, 2.0, and 3.0 times respectively. During the first 10 sessions for all animals, responding led to no delay. Upon completion of 10 sessions with no delay, Groups C-1.5, C-2.0, and C-3.0 received an additional 10 sessions with delays of 161, 158, and 152 sec, and trains of 9, 12, and 18 shocks, respectively; hence, for each subject, overall shock frequency remained the same across all 20 sessions. Under the delay conditions (Figure 7), bar pressing for one subject (S-1) only was reinforced by the delay condition in Group C-1.5; all three (S-2, S-4, and S-6) subjects produced the alternate condition in

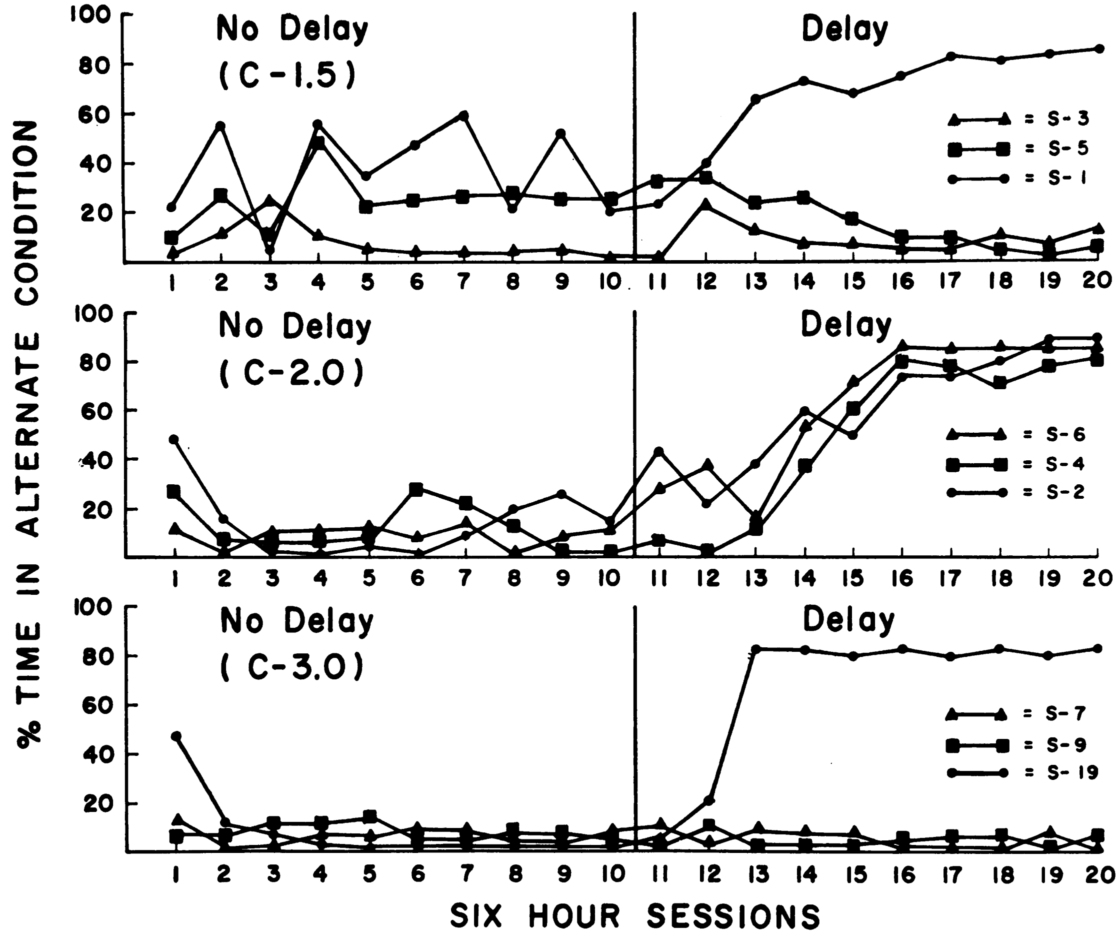

Fig. 7. Per cent of time in the alternate condition as a function of 6-hr sessions for subjects in Groups C-1.5, C-2.0, and C-3.0. (Subjects in Groups C-1.5, C-2.0, and C-3.0 received response-contingent shock-frequency increases in all 20 sessions of 1.5x, 2.0x, and 3.0x, respectively.) During the first 10 sessions, Groups C-1.5, C-2.0, and C-3.0 received no delay, but during Sessions 11 to 20, subjects in these groups received response-contingent delays of 161, 158, and 152 sec, respectively.

Group C-2.0; and one (S-19) of the three subjects in Group C-3.0 exhibited significant bar pressing. Each of the five animals (S-1, S-2, S-4, S-6, and S-19) that did respond under delay conditions developed the postshock response pattern previously described.

For the first 10 sessions, Groups C-1.5, C-2.0, and C-3.0 received shock according to a VT 30-sec schedule in the imposed condition and according to a VT 20-, VT 15-, and VT 10-sec schedule in the alternate condition, respectively. The results of these three conditions together with the C-O group are summarized in Figure 8. Figure 8 shows the mean and range of the per cent of time in the alternate condition for Sessions 6 to 10. It is clear from Figure 8 that the performance of these subjects shows an orderly relation between per cent time in the alternate condition and shock frequency. Subjects in the C-O group, in which responding had no effect on shock frequency, spent a mean of 50% of the total session time in the alternate condition. In contrast, subjects in Groups C-1.5, C-2.0, and C-3.0 showed smaller alternate condition times. As seen in Figure 8, the greater the shock frequency increase from the imposed to the alternate condition the less the alternate condition time.

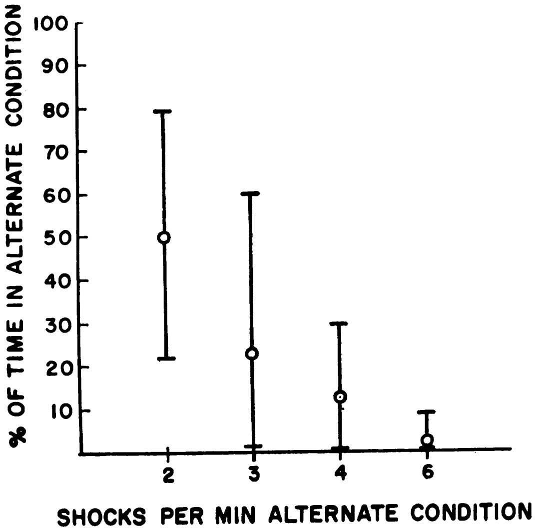

Fig. 8. Mean and range of the per cent of time in the alternate condition as a function of shock density in the alternate condition averaged over Sessions 6 to 10. The mean is indicated with an open circle; the range, with the vertical line passing through the open circle.

GENERAL DISCUSSION

The first experiment demonstrated an orderly relationship between responding and delay to the onset of a series of shocks with overall shock density held constant—the greater the delay, the higher the probability of a response in the imposed condition. This result supports and extends Hineline's (1970) finding that delayed-shock onset is a sufficient basis for avoidance conditioning. In addition, the second experiment demonstrated the reinforcing effectiveness of delayed shock even when responding results in a 100% increase in shock frequency.

It is necessary to consider whether responding was maintained by the delay or by some other aspect of the alternate condition. One possibility is that the first shock in the group of shocks acted as a signal identifying a brief high shock-density period. Badia and Culbertson (1972) showed that rats produce a condition in which stimuli identify the occurrence of shocks. This finding has been interpreted as supporting the view that subjects prefer situations in which shock and shock-free periods are identified (safety hypothesis). If, in the present experiment the first shock in every shock train acted as a signal, all subjects in grouped shock conditions received signalled shocks in the alternate condition and unsignalled shock in the imposed. Although this explanation cannot be ruled out, the fact that subjects in the 10-sec delay group in the first experiment showed little responding argues against it. Presumably, the signalling function of the first shock would be operating in the 10-sec group, just as in other conditions. There is the possibility that the occurrence of so many shocks so soon after a response overrides the benefit of any signalling effect.

The safety theory was extended by Badia, Harsh, and Coker (1975). In this experiment, rats received brief shocks on either fixed-time (*e.g.*, FT 60-sec) or variable-time (*e.g.*, VT 60-sec) schedules. When given a choice between FT or VT shock, subjects chose FT. This preference was found when unsignalled shocks were delivered and also when a 4.5-sec signal preceded all shocks. The safety concept explains the preference for FT over VT shock schedules by noting that safe and unsafe periods are more discriminable in FT schedules (because of the reliable temporal cues) than VT schedules. The finding that signalled shocks on an FT schedule were preferred to signalled shocks on a VT schedule is interpreted by hypothesizing that the combination of the signal plus the temporal cues provided by the FT schedule produce more discriminable safe periods than do the signals without the temporal cues (VT schedule).

In the present experiment, the safety analysis implies that the alternate condition would be preferred because the shock periods and safe periods are more discriminable than in the imposed condition. The safety notion alone is inadequate to explain the present findings, however. Because shocks were grouped in the alternate condition, shock and shock-free periods were, regardless of delay, equally discriminable. Delay to shock was clearly important.

While long delays appear to be a powerful reinforcer in the present procedure, the summary data (Figure 8) for the control conditions (C-0, C-1.5, C-2.0, and C-3.0) are orderly even in the absence of a scheduled delay—the higher the shock frequency in the alternate condition the less time spent in that condition. One may be surprised (see Figure 8) that any behavior occurred. Herrnstein and Hineline (1966) reported that when the probability of a shock following a response was equal to the probability of a shock in the absence of a response, bar pressing stopped. The C-0 group in the present study could not affect the delivery of shocks; yet, this group spent (on the average) 50% of the total session, averaged over the last five sessions, in the alternate condition. The C-1.5 group increased the shock frequency by 50%; yet, these subjects spent 22.5% in the alternate condition averaged over Sessions 6 to 10. Procedural differences may account for the apparent discrepancy between the present findings and those of Herrnstein and Hineline (1966). The relationship between shock frequency in the alternate condition and per cent time in the alternate condition shown in Figure 8 implies that shock-generated responding may be suppressed in proportion to the shock frequency or the postresponse reduction in the delay of shock onset.

The value of two-factor theories of avoidance (Anger, 1963; Rescorla and Solomon, 1967) to the sort of data presented here is limited. Perhaps most relevant is Anger's conditioned-aversive-temporal-stimuli (CATS) formulation. Postresponse time stimuli are held to acquire differential aversiveness, depending upon their closeness to shock. Time stimuli occurring near to the point in time of shock delivery are highly aversive, while time stimuli distant from shock are less aversive. When responses replace highly aversive time stimuli with less-aversive time stimuli, the responses are reinforced.

Anger's CATS theory correctly predicts responding in Experiment I. All time periods in the imposed condition maintain some uniform level of aversiveness because shocks are delivered on an unpredictable variable schedule. A response shifted the animal to a less-aversive, postresponse time interval. The postresponse interval at the beginning of the alternate condition is less aversive because it was never paired with shock (except perhaps in the 10-sec delay condition). While Anger's (1963) theory predicts some responding under conditions in which shock frequency is held constant, the CATS formulation offers no suggestion concerning the length of the delay necessary or the extent to which shock frequency can be increased before responding fails to be reinforced. Two-factor theory predicts no responding under the baseline control conditions in Groups C-0, C-1.5, C-2.0, and C-3.0. Like the shock-frequency reduction theory (Sidman, 1962), Anger's (1963) theory predicts no responding because postresponse time stimuli should be equally or more aversive than preresponse time stimuli (due to the frequent pairing with the greater shock density in the alternate condition).

Hake and Campbell (1972) studied primate behavior in a procedure similar to the present one. In the Hake and Campbell experiments, a shock occurred every 30 sec in the imposed condition; the first response after 3 min produced a 2-min shock-free alternate condition. Two patterns of responding were observed; one was described as preshock and the other as postshock responding. Several observations indicated the postshock responses were aggression-motivated and involved attacking the manipulandum.

Considerable responding was generated in the present experiment by presenting shock in the absence of any apparent negative reinforcement (Figure 8). It is necessary to show that the reinforcing effects of delaying shock strengthened responding over and above the generative effects of shock alone (Sessions 1 to 10). But when shocks in the alternate condition are delayed, increased time in the alternate condition results (Sessions 11 to 20).

Some investigators have chosen to eliminate or minimize postshock responding. Hineline (1970) eliminated postshock responding by removing the response bar. Badia *et al.* (1975) attempted to minimize the influence of postshock responding by imposing a 2.5-sec delay after shock, during which responses were ineffective. While it is important to distinguish between responses generated simply by shock presentation and responding produced by reinforcement, there are two arguments against the practice of routinely eliminating postshock responding from experiments on negative reinforcement. First, there may be important interactions between the two types of behaviors. For example, the negatively reinforced responses may not develop if postshock responses are prevented. Second, the shock-generated response may be modified by its consequences. That is, negative reinforcement may influence the frequency and form of shock-generated responses.

In the present research, no restrictions were placed on shock-generated responding. The results showed the reinforcing effect of delay to shock, with shock frequency held constant, in addition to the response-generating effects of shock presentation. Also, the probability of shock-generated responding was found to depend on the shock frequency produced by the responding (Figure 8).

The present findings (together with Hineline's, 1970) indicate that delay to shock onset is sufficient to support the acquisition and maintenance of responding, even when responding increases shock density. Whether or not delay to shock onset is a necessary condition requires further investigation. Bolles and Popp (1964) modified a free-operant avoidance schedule so that a response reduced overall shock frequency but did not delay shock. Rats failed to acquire a bar-pressing response under this procedure. Lambert *et al.'s* (1973) results in the no-escape, bar-press procedure also implied that delay is necessary. In contrast, Lambert *et al.'s* (1973) no-escape, shuttle-box procedure supported the view that delay is *not* necessary.

The question of whether shock-frequency reduction or shock delay reinforces avoidance behavior is in some sense a pseudo-question. In the absence of some specific time interval over which frequency is calculated, shock-frequency reduction and delay to shock variables cannot be placed in opposition. The reinforcing mechanism seems a combination of both notions. For example, consider two time periods following a response that is effective in activating the delayed-shock, alternate condition for animals in the D-2.0 condition. The first time period, S, is 2-min long; the second time period, L, is 3-min long. Both are initiated with the onset of the alternate condition. During the S period, the animal receives no shock; therefore, a shock-frequency reduction relative to the imposed, no-response condition. In contrast, if shock frequency is considered over the L period, the animal receives a 100% increase in the shock frequency. Perhaps the terms "avoidance", "escape", and "punishment", arbitrarily emphasize particular postresponse times on a continuum.

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