

RESPONSE-SHOCK DELAY AS A REINFORCER IN AVOIDANCE BEHAVIOR¹

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After rats received preliminary training to avoid shock on a discrete-trial retractable-bar avoidance procedure, the procedure was changed such that responses retracted the lever but did not affect the rate of shock. Responses only delayed the onset of shock. About half of the animals under these procedures responded consistently on almost 100% of the discrete-trial cycles over days. When short latencies maximized the response-shock delay, animals tended to make short-latency responses. When long latencies maximized the response-shock delay, animals tended to make long-latency responses. When all response latencies produced the same response-shock delay, animals made differing average-latency responses. And, when responses did not delay shock, most of the animals primarily engaged in shock-elicited responding while the other animals engaged in preshock responding.

Key words: response-shock delay, discrete-trial avoidance, unsignalled shock, retractable lever, rats

Herrnstein (1969), Herrnstein and Hineline (1966), and Sidman (1962) have argued that responding on an avoidance procedure is maintained because responses reduce shock density or shock probability. Herrnstein and Hineline's (1966) experiment is often used to support the shock-density reduction theory. They used a procedure in which responses could not avoid all shock. Responses could only reduce the probability of shock on the average from three every 10 sec to only one every 10 sec. Most animals responded on the procedure. They demonstrated that avoidance behavior could be acquired in a situation where temporal consistencies did not exist either between exteroceptive stimuli and shock or between covert stimuli and shock. But temporal consistencies generally did occur in their procedure between response and shock. On average, responses caused a longer delay between shocks. While they argued that shock-density reduction alone was sufficient to

maintain avoidance, Hineline (1970) demonstrated that a delay of shock may be a sufficient condition for avoidance. He used the following discrete-trial procedure: at the beginning of each 20-sec cycle, a loud buzzer sounded and a retractable bar was quickly extended into the chamber. If the rat did not press the bar, a shock was delivered 8 sec into the cycle; 2 sec later, the bar was retracted and the buzzer was terminated. If a bar press did occur, the bar was quickly retracted, the noise was terminated, and the shock was delayed until sec 18 of the cycle. Stable responding resulted, even though responses served only to delay the onset of shock from sec 8 to sec 18 of the cycle and had no effect on the frequency of shocks per cycle.

Hineline's procedure did not allow responding to vary systematically the duration of the delay, because the delayed shock always occurred 18 sec into the cycle. Also, the procedure did not specify which delay maintained responding. Specifically, responding could have maximized the delay between trial onset and shock (termed the O-S delay), and/or the delay between response and shock (termed the R-S delay). Also, the procedure did not specify whether responding was maintained by delaying the shock or was maintained by termination of conditioned aversive temporal stimuli (Anger, 1963). The present research attempted to control for these problems as well as to

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show that if a delay of shock is a reinforcer in avoidance behavior, then animals should respond to maximize the delay. Himeline's general discrete-trial procedure was used, except the temporal location of the delayed shock could vary and was dependent on the animal's response latency. This procedure allowed animals to adjust their response latencies to produce an increase in the delay of shock.

METHOD

Subjects

Thirty one naive albino rats, 90 to 120 days old at the start of experimentation, served. Nine were males acquired from the Animal Research Center of Massachusetts, Inc., New Braintree, Massachusetts. Twenty two were females acquired from the Holtzman Company, Madison, Wisconsin. All subjects were given at least a week to adapt to the animal colony and were frequently handled before the experiment. Subjects were randomly assigned to groups so that each group contained an equal proportion of males and females. During the experiment, they had free access to food and water in their home cages, but neither food nor water was available in the experimental chambers.

Apparatus

Two Gerbrands Model B operant-conditioning chambers with left-side dipper feeders were housed in ventilated sound-attenuated enclosures. One enclosure was a 0.62-m cube made of 12.7-mm plywood lined with acoustical tile. The other was 0.75 m long, 0.52 m high, and 0.62 m wide, made of 12.7-mm plywood and lined with 5-cm styrofoam.

The front wall of the chamber, containing the Standard Gerbrands lever and dipper receptacle, was covered with a piece of tin that fully extended to the sides and top and bottom of the chamber. A Lehigh Valley retractable bar (Model 1405M) was located on the right side wall of each chamber 8 cm from the grid floor and centered in the middle of the wall 6.5 cm from the back wall of the chamber. A cue light was placed 6 cm above the retractable lever. The lever in each chamber was modified so that the time required for full extension was reduced. The 15-rpm ac motor, which moved the lever in and out, was

replaced with a 75-rpm dc Barber-Coleman motor. The cam connected to the lever was modified to accommodate the faster motor. The duration of the extension or retraction of the lever was reduced from 1.9 sec with the 15-rpm motor to 0.5 sec with the 75-rpm motor. Himeline (1970) also used a fast lever to eliminate the opportunity of more than one response per cycle.

White noise of 87-dB sounded when the bar was extended into the chamber and terminated when the bar was retracted. The speaker was located on the left side wall, that is, the wall opposite the lever. Scrambled shocks of 0.8-mA intensity and 0.5-sec duration were provided by two Grason Stadler shock sources (Model E1064GS). A Lehigh Valley Interact Computer System in a nearby room controlled all events and recorded all responses.

Procedure

Preliminary training. Two phases of preliminary training enabled the subjects to develop stable discrete-trial bar pressing. During the first phase, which continued for two 2-hr sessions, all subjects were placed in a discrete-trial avoidance procedure. Bar extension and white noise initiated each session. If a response did not occur within 20 sec, a 0.5-sec 0.8-mA shock was delivered to the grid floor every 3 sec until a bar press occurred. When a response was made, the bar retracted, the white noise was terminated, and all remaining shocks were avoided until the next trial, which began 21 sec after the response.

The second phase was begun after the second session and continued for three consecutive sessions. Four of the five groups were placed on the constant-delay procedure. Each session was divided into 240, 31-sec cycles. At the beginning of each cycle, the bar was extended into the chamber and the white noise turned on. If a response did not occur within 10 sec, a 0.5-sec 0.8-mA shock was delivered in the tenth second, and the bar was retracted at the eleventh second. If a response did occur before 10 sec, the bar retracted, the white noise terminated, and the shock was delayed for 19 sec from the response. Response latencies between 10 and 11 sec retracted the bar but did not affect the duration or location of the shock. Subjects always received one shock per cycle, but a preshock response delayed the shock from sec 10 to a point between sec 19

and sec 29 of the cycle, depending on the latency of the response.

The fifth group was placed on a discrete-trial avoidance procedure in which one shock during sec 10 was given per cycle if no response occurred. A bar press before shock retracted the bar, terminated the noise, and avoided the shock scheduled for that cycle.

Experimental treatment. After preliminary training, the five groups continued to receive 240, 31-sec cycles with one shock per cycle. However, the groups differed with respect to how long a given response delayed shock. The constant-delay (CD) group continued to receive the same procedure it received during the second phase of preliminary training, *i.e.*, each response delayed the shock for 19 sec after the response. Long latencies maximized the O-S delay but did not affect the R-S delay of 19 sec. The short-latency-long-delay (S-LD) group received a procedure in which a short response latency delayed shock for a longer duration than a long one did. A response latency between 0 and 1 sec produced an R-S delay of 18 sec, and an O-S delay of 29 sec. Each second added to the response latency decreased the R-S delay by 3 sec and the O-S delay by 2 sec. A response latency between 9 and 10 sec produced an R-S delay of 1 sec and an O-S delay of 11 sec. The long-latency-long-delay (L-LD) group received a procedure in which a long response latency delayed shock for a longer duration than a short one did. A response with a latency between 0 and 1 sec produced an R-S delay of 10 sec and an O-S delay of 11 sec. Each second added to the response latency increased the R-S delay by 1 sec and the O-S delay by 2 sec. A response with a latency between 9 and 10 sec produced an R-S delay of 19 sec and an O-S delay of 29 sec.

The no-delay (ND) group was a control group for which a response did not delay shock but served only to terminate the white noise and retract the lever. Shocks were always delivered 10 sec after the onset of the cycle. The discrete-trial avoidance group (DTA) continued to receive the discrete-trial avoidance procedure it had received during preliminary training.

The delay training was continued for 20 days for all animals except those that failed to respond to at least 10% of the cycles on five consecutive days.

RESULTS

Since the focus of the experiment was on the latency behavior of those animals that delayed shock, only the data from those subjects that responded on at least 50% of the 240, 31-sec cycles during each session throughout the study are discussed in detail.

Preliminary Training

In Phase 1 of preliminary training, all subjects were under a discrete-trial avoidance procedure, and all learned and maintained avoidance behavior during the two sessions. Average response rate in Session 2 was about 2.5 responses per minute, reflecting short response latencies; the overall shock rate was about one shock every 4 min. Most of these shocks were received in the early portion of the avoidance session during a warmup period (see Hoffman, 1966).

The second phase of preliminary training for four of the five groups consisted of three days of constant training, *i.e.*, each response produced a constant R-S delay of 19 sec until shock. Three animals on the constant-delay training did not meet a 50% criterion and responded on 0, 0, and 48% of the cycles on the third day. Of those animals that did meet the criterion, one animal responded in the 50% range, one in the 70% range, three in the 80% range, and 17 in the 90% range. Their average latencies ranged from 0.02 to 5.20 sec.

The fifth group, Group DTA, was continued on a discrete-trial avoidance procedure that delivered only one shock per cycle if no response occurred. Of the six animals placed on this procedure, all six met the 50% response criterion after three days.

Experimental Treatments

Only 18 subjects continued to respond on more than half of the cycles throughout the 20 days of experimental treatment. These animals, henceforth identified as good responders, responded on almost 100% of the cycles; the poor responders responded on much fewer than 50% of the cycles. The two poor responders in the CD condition responded on an average of 31% of the trials. The two poor responders in the S-LD condition responded on an average of 7% of the trials. The L-LD condition produced three poor responders with an average terminal performance of 25%. The

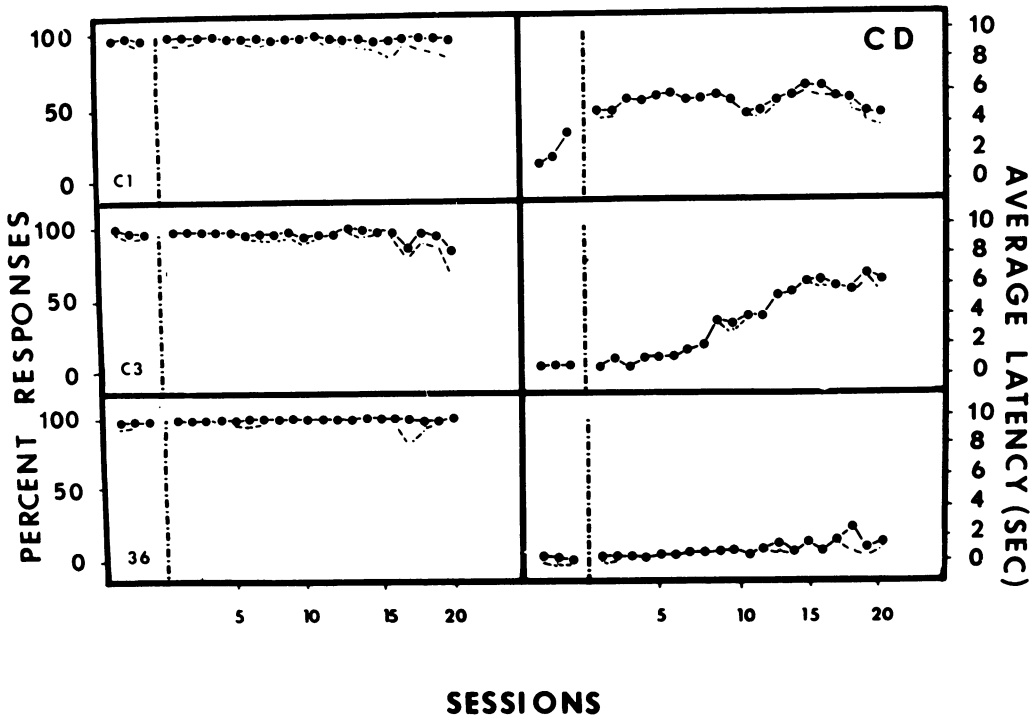


Fig. 1. The per cent response and average latencies for three animals in the constant-delay condition. The data plotted to the left of the vertical dotted lines are from the three sessions of constant-delay preliminary training. Solid lines connecting solid circles plot all responses. Dotted lines connecting open circles plot responses made before shock.

ND condition produced two poor responders with an average terminal performance of 6% and the DTA condition produced one poor responder that responded on only 13% of the trials. Only the results of the good responders are discussed from this point.

Constant-delay condition. The left panel of Figure 1 shows the percentage of trials in which a response occurred. The solid lines plot the percentage of trials in which responses occurred before and after shock. However, only response latencies shorter than 10 sec produced a delay of shock. The dotted lines on the figure plot the percentage of trials in which responses were made before shock. Responding occurred on approximately 100% of the cycles for the three responders. Very few of these responses occurred after shock.

The average response latencies for each animal are plotted in the right panel of Figure 1. The computation of average response latencies was based only on those latencies shorter than 11 sec. Response latencies varied greatly among subjects, but each subject displayed a fairly consistent average latency over days. Two ani-

mals had a preshock average latency longer than 4 sec and one had an average latency shorter than 2 sec.

Long-latency-long-delay condition. The left panel of Figure 2 shows the per cent responses for each of the three criterion responders. Over the last five days, their terminal preshock per cent response averaged about 93%. The right panel of Figure 2 shows the average latencies for each subject plotted over sessions. The response latencies before shock were typically between 4 and 6 sec for the last five sessions. These specific response latencies on this procedure produced a 14- to 15-sec R-S delay and an 18- to 20-sec O-S delay.

The right panel of Figure 2 also shows a trend in all three rats of an increasing average response latency over days. A trend analysis of the average preshock response latencies of the three subjects was performed to determine if this linear trend was significant over the 20 experimental sessions (see Keppel, 1973, p. 416).

The trend was found to be significant in the L-LD condition ($F = 31.52$, $df = \frac{1}{2}$, $p < 0.05$).

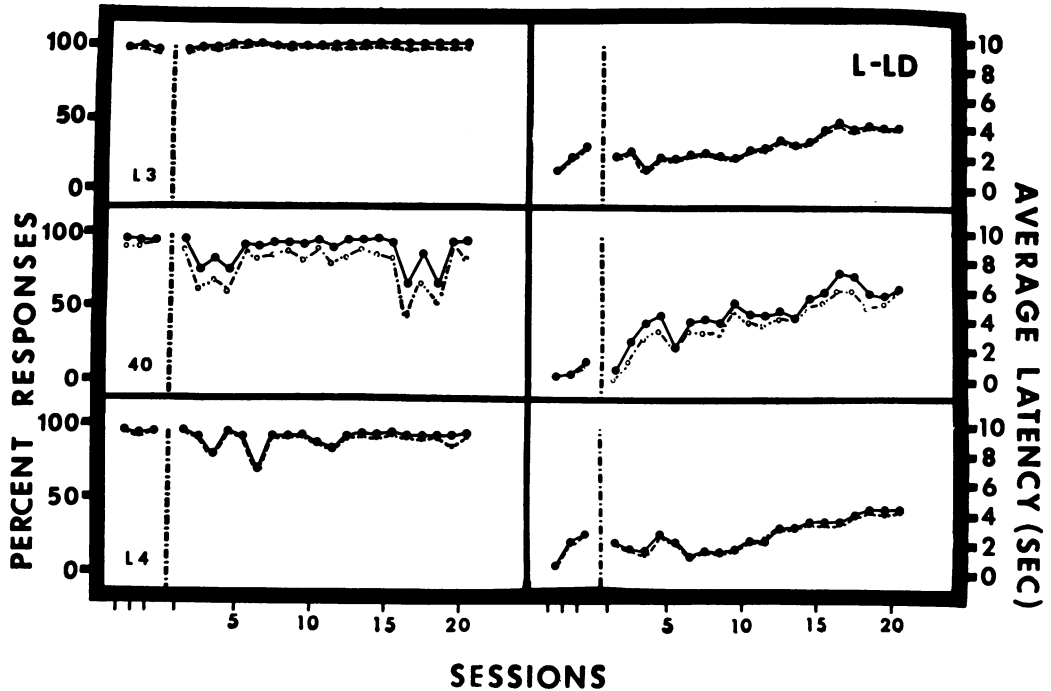


Fig. 2. The per cent response and average latencies for three animals in the long-latency-long-delay condition. The data plotted to the left of the vertical dotted lines are from the three sessions of the constant-delay preliminary training. Solid lines connecting solid circles plot all responses. Dotted lines connecting open circles plot responses made before shock.

None of the other conditions demonstrated a significant linear trend ($F_s < 2$).

Short-latency-long-delay condition. The left panel of Figure 3 shows the per cent responses for each of the four good responders in the condition. Three animals maintained a very high response probability; one did not. Three subjects, S1, S2, and S3 had preshock average latencies of 2 sec or less for the last five sessions, which are shown in the right panel. This specific latency produced a shock delay of 24 sec from the onset of the cycle and 22 sec from the response. The fourth animal that maintained good responding, Subject F1, had a terminal average latency of about 4 sec. This latency produced an R-S delay of 19 sec. This was the same R-S delay that the CD animals always received and that this animal had received under the CD condition during preliminary training.

Subject S2 was not as consistent a responder as the remaining three. Unlike the others, Subject S2 stopped responding before shock on the second day on the S-LD procedure and responded almost exclusively after shock. The

per cent of cycles it responded to with a latency shorter than 10 sec decreased to 5% as shown by the dotted line. However, during the last five experimental sessions, preshock response probability increased to 75%, with a preshock average latency shorter than 2 sec.

Discrete-trial avoidance condition (DTA). Figure 4 shows the five good responders on the DTA procedure. They responded on approximately 100% of the cycles on each of their treatment days. Average latencies, shown in the right panel of Figure 4, were consistent within subjects over days and varied among subjects between 2 and 5 sec.

No-delay condition (ND). Figure 5 shows the three animals that continued to respond on more than half of the trials. These three rats consistently responded on more than 80% of the cycles during each of the 20 sessions. The responding of two rats appeared to be shock elicited, because it occurred after shock and just before bar retraction. Subject N1 responded almost exclusively after shock, with only approximately 10% of the cycles responded to before shock. Subject N3 responded

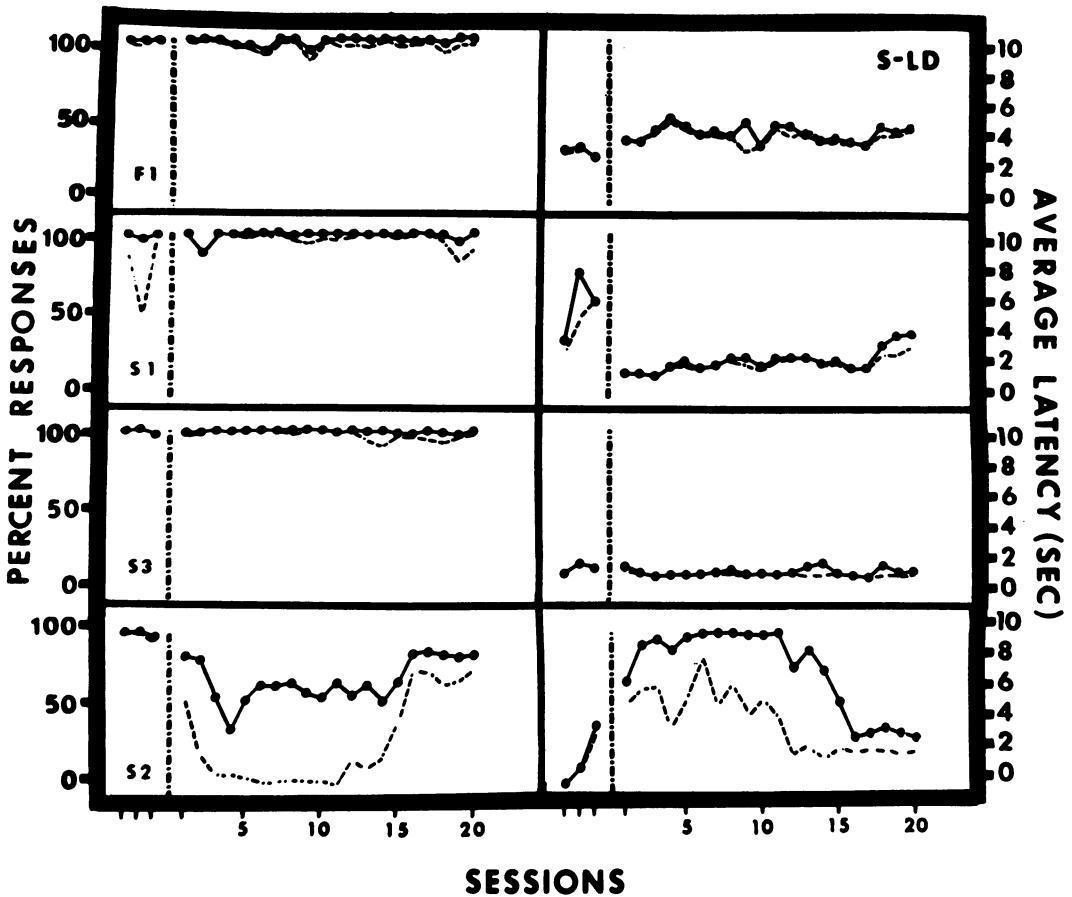


Fig. 3. The per cent response and average latencies for four animals in the short-latency-long-delay condition. The data plotted to the left of the vertical dotted lines are from the three sessions of the constant-delay preliminary training. Solid lines connecting solid circles plot all responses. Dotted lines connecting open circles plot responses made before shock.

on approximately 30% of the cycles before shock, with an average latency of approximately 7 sec, and responded on 50% of the cycles after shock. Subject N2 responded on 70% of the cycles before shock and 20% of the cycles after shock, with a before-shock latency of 1 to 2 sec. During a session, Subject N2 responded after shock during the first part of the session and then before shock during the latter part. For instance, on Day 15, its average latency during the first 30-cycle block was 5.14 sec; during the last 30-cycle block its average latency was 1.79 sec.

DISCUSSION

The present results support Hineline's (1970) finding that responding can be maintained by response-produced delay of shock without

shock-frequency reduction. The animals that consistently delayed shock responded on almost 100% of the cycles over 20 sessions, and they responded in much the same way as animals placed on a discrete-trial avoidance procedure. However, only half of the animals placed on the delay procedures maintained their responding. The nonresponders responded on less than 30% of the cycles.

In addition to supporting Hineline's (1970) results, this experiment suggested that the latency of responses was affected by the duration of the shock delay. Animals that consistently delayed shock tended to make response latencies that maximized the R-S interval. By the end of the experimental treatment, the two of the four subjects in the short-latency-long-delay group made short latencies of 2 sec or less, which produced long delays of shock. The

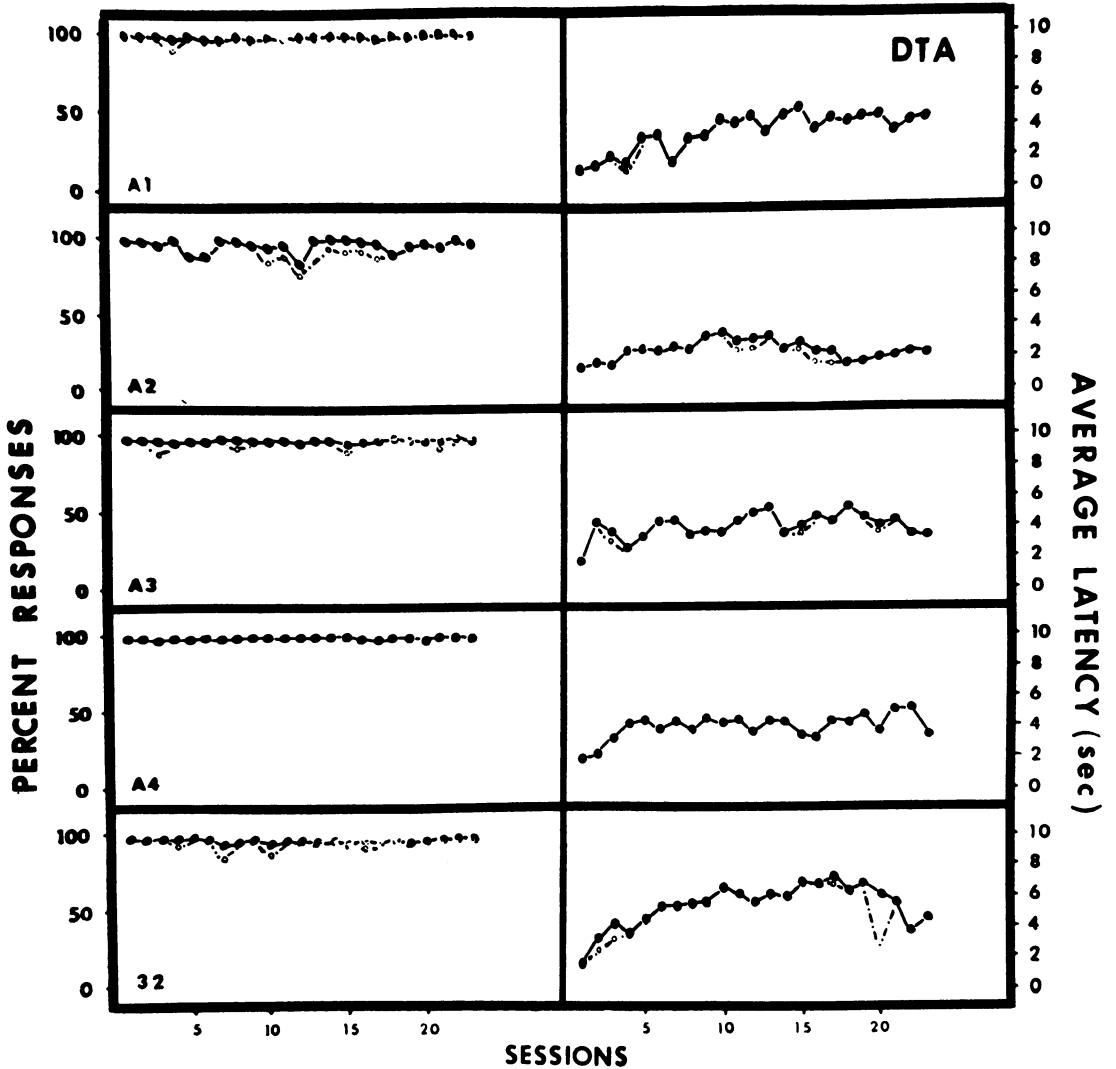


Fig. 4. The per cent response and average latencies for five animals in the discrete-trial-avoidance condition. Solid lines connecting solid circles plot all responses. Dotted lines connecting open circles plot responses made before shock.

long-latency-long-delay group ended the treatment with relatively long latencies, longer than the S-LD group had. Also, while the S-LD group showed no tendency to increase latencies over days, the L-LD group significantly increased their response latencies during the 20 treatment sessions.

Results from the constant-delay condition demonstrated that animals were not sensitive to the O-S delay and did not respond to maximize it. The CD procedure was designed so that long-latency responses would produce long O-S delays while maintaining the R-S delay at 19 sec. The data showed (see Figure 1)

that the average response latency varied from 1 to 6 sec among subjects and was not consistently long.

Anger (1963) argued that an important reinforcer in an avoidance situation is the reduction of conditioned aversiveness of temporal stimuli. The temporal stimuli that elicit the most conditioned aversiveness are those just preceding shock. Animals should, therefore, respond just before shock, because responses at this time lead to the greatest reduction in conditioned aversiveness and are highly reinforced. Although Anger might predict that response latencies would be long in the present

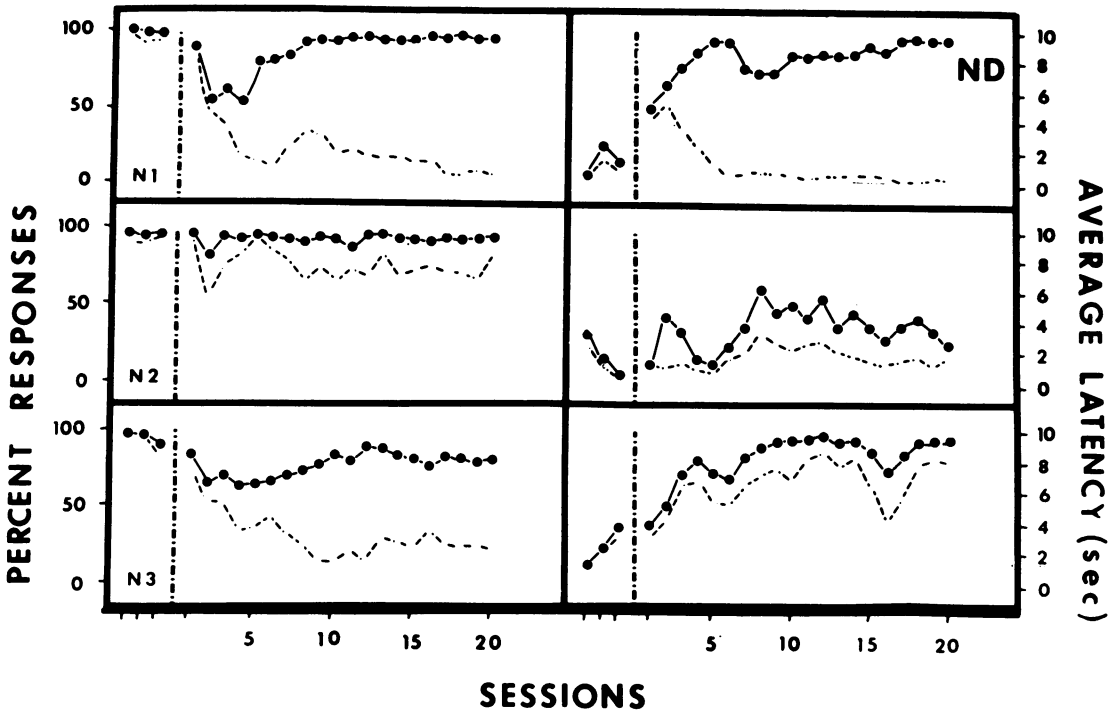


Fig. 5. The per cent response and average latencies for three animals in the no-delay condition. The data plotted to the left of the vertical dotted lines are from the three sessions of the constant-delay preliminary training. Solid lines connecting solid circles plot all responses. Dotted lines connecting open circles plot responses made before shock.

experiment, the response latencies, in fact, were not long in all of the delay groups. Specifically, the S-LD group made very short response latencies and showed no tendency to increase them over sessions.

Several researchers have suggested that animals prefer signalled to unsignalled shock (Badia, Culbertson, and Lewis, 1971; Lockard, 1963; Perkins, Seymann, Levis, and Spencer, 1966). The present results, however, tend to show that unsignalled delayed shock is preferred to signalled shock that is not delayed. Not only was the delayed shock unsignalled, but also its temporal location was variable. For example, in the S-LD procedure, a response latency of 1 sec delivered the delayed shock at sec 29 of the cycle, but a response latency of 3 sec delivered the shock at sec 25 of the cycle. The R-S delay as well as the O-S delay was variable but dependent upon the response latency. The signalled shock did not appear to be as important for the subject as a delay of shock.

The findings from the no-delay condition were rather unexpected, because the predic-

tion had been made that responding would cease under this procedure. However, responding was maintained in three of five animals. Gibbon and O'Connell reported at the 1973 meetings of the Eastern Psychological Association on a procedure very similar to the no-delay procedure, and their data were very similar to mine. They used a retractable bar procedure with an intertrial interval of 100 msec. The comparable interval in the present research was 20 sec. Responses on their procedure retracted the bar but did not change the location of shock. Gibbon and O'Connell found that three of their five animals acquired and maintained responding on this procedure, and their responding was almost exclusively after shock or shock elicited. This postshock responding also characterized the behavior that animals showed on the no-delay condition in the present research. These results support the conclusion of Hake and Campbell (1972) and others that animals will mainly respond after shock when they have no control over its occurrence. In the delay procedures used in this research, on the other hand, animals did

control the location of shock and their responses occurred almost exclusively before shock. The left panels of Figures 1, 2, and 3 show that the good responders in the delay conditions made almost no responses after shock. But the good responders in the no-delay condition shown in Figure 5 placed most of their responses after shock.

This research also bears on the issue of whether animals respond to changes in the relative frequency of events (Herrnstein, 1969; Rescorla, 1967), or whether they respond to changes in temporal contiguities of events (Benedict and Ayers, 1972; Hineline, 1970). It has been conventional for experimenters to talk about programming differences in the relative frequencies of events. However, an experimenter's verbalizations of what he has programmed may not necessarily be equated with what is controlling the animal's behavior. Specifically, there would seem to be two mechanisms through which animals could discriminate programmed differences. First, the animal may "count" shocks during some unit of time (*i.e.*, come under the control of number of such shocks). If the number of shocks before a response is greater than the number of shocks after a response, and if the two numbers are discrepant enough, the animal may form the discrimination that responses are effective at reducing relative frequencies of shock. This mechanism would probably require a great deal of counting by the animal and it is unclear how long before and after a response an animal must count to discriminate the relative frequencies. The second mechanism is based on a temporal discrimination. The animal may "time" the intervals between shocks before and after a response. If the shock-response-shock interval is greater than the shock-shock interval, the animal may form a discrimination that responding decreased the temporal contiguity of shocks and increased the interval between shocks. It could form this discrimination after one comparison.

The responding found in the present research could not be maintained by the first discrimination process because the number of shocks before and after a response always remained the same. Animals always received one shock during every 31-sec cycle. Responding, however, could have been maintained by the second discrimination process. For example,

in the S-LD procedure, animals could have formed a discrimination to respond after comparison of intervals between shocks with and without responses. In this procedure, when an animal never responded, it received a shock every 31 sec. However, if the animal made a short-latency response on a cycle, this would increase the time interval to the next shock by about 20 sec, extending the interval between successive shocks to 51 sec. And, if the animal did not respond on the very next trial, the interval between successive shocks could be as short as 12 sec. The response-delayed shock would occur at sec 28 of cycle n and the no-response shock would occur at sec 10 of cycle $n + 1$. Thus, the animal might form the discrimination after only two trials that responding increased the duration between shocks. Gibbon (1972) presented a mathematical model of avoidance behavior based on this second discrimination process, the process of comparing different temporal intervals. The present research supports Gibbon's model in showing that animals appear to make discriminations to respond based on a comparison of temporal intervals or temporal contiguities.

In conclusion, the present results cannot be explained by shock-density reduction, but can be explained via a shock-delay mechanism. This mechanism is based on the delay of shock produced by a response and is demonstrated by the maximization of the R-S interval.

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