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Response-shock delay as the controlling mechanism on avoidance behavior.

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RESPONSE-SHOCK DELAY AS THE CONTROLLING MECHANISM
IN AVOIDANCE BEHAVIOR

A Dissertation Presented

By

James Orel Benedict

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

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June, 1973

Major Subject: Psychology

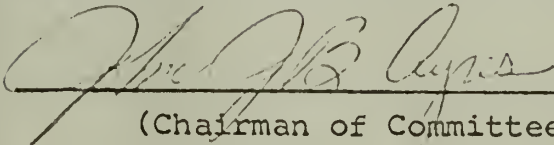
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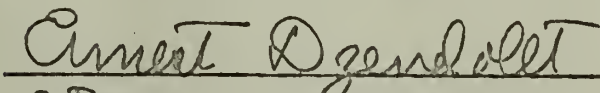
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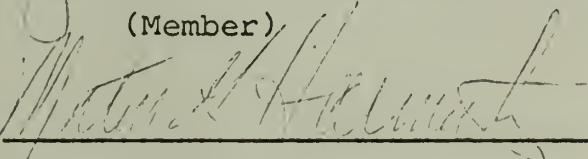
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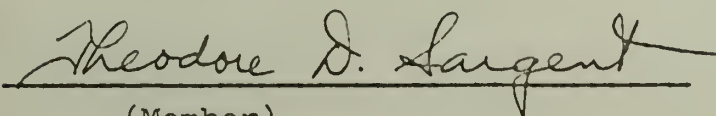
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Abstract

When rats were placed on procedures in which responses only delayed shock, they responded in such a way as to maximize the interval or delay between response and shock. Responding was not maintained by the termination of external stimuli or of internal temporal stimuli. Responding was also not maintained by maximizing the interval between trial onset and shock. When short latencies produced the longest response-shock delay, animals made short latency responses. When long latencies maximized the response-shock delay, animals made 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, animals primarily engaged in post-shock responding.

An avoidance procedure involves two contingencies for the animal. First, if the animal does not make the correct response, he receives an aversive event such as electric shock. The shock may be programmed to occur at regular or irregular intervals, and it may or may not be preceded by a signal. Second, if the animal does make the correct response, the shock which was scheduled will not occur.

When an animal responds on such a procedure, what maintains his behavior? It is possible to identify four potential sources of reinforcement and one source of eliciting stimuli. First, responses may be reinforced by the termination of some external conditioned aversive signal (Solomon and Wynne, 1953). Second, responding may be reinforced by the termination of some internal conditioned aversive temporal stimulus associated with shock onset (Anger, 1963). Third, responding may be reinforced by the reduction of the overall frequency of aversive stimulation (Sidman, 1962; Herrnstein and Hineline, 1966). Fourth, responses may be elicited by shock (Hutchinson, Renfrew, and Young, 1971). Or, fifth, responding may be reinforced by delaying the onset of aversive stimulation (Hineline, 1970). In this research it will be argued that a sufficient and perhaps a necessary condition for avoidance behavior is that the behavior delay the onset of aversive stimulation.

Delay of shock after a response is usually considered necessary for acquisition and maintenance of avoidance behavior (e.g., Bolles & Popp, 1964). Bolles and Popp (1964) ran a modified Sidman avoidance procedure. In a normal Sidman procedure, every response begins the response-shock (R-S) interval. Bolles and Popp changed the procedure

so that responses made during the shock-shock (S-S) interval did not begin the R-S interval until the S-S interval had delivered the next scheduled shock. They found that none of the animals placed on this procedure learned to avoid shock. This is evidence that delay of shock after a response may be a necessary condition for the acquisition of avoidance behavior.

Lambert, Bersh, Hineline, and Smith (1973) have recently presented some data that tend to demonstrate that delay may not be necessary for avoidance learning. They found that animals would respond to avoid scheduled pulse trains of five shocks even though each response was followed by one shock. Since shock immediately followed each response, it might be argued that shock delay is not necessary in avoidance. However, since the response-produced shock was probably less aversive than the series of five shocks, the results of Lambert et al do not refute the argument that delay of shock may be necessary. They may indicate only that under some conditions the reinforcing effects of delaying one aversive event may overpower the punishing effects of a less aversive event.

Hopefully, the results of the present research may help answer the question whether delay of shock is necessary and sufficient for the maintenance of avoidance behavior. Before the methods of the research are described, several experiments will be discussed to show how delay is a feature of every avoidance procedure. However, it is a feature whose importance is difficult to assess because it has always been completely confounded with several other possible sources of reinforcement.

Solomon and Wynne (1953) placed dogs on an avoidance procedure in which an external signal preceded shock. If the dogs crossed a hurdle during the signal, they would avoid the shock and the signal would terminate. Solomon and Wynne argued that, via classical conditioning, the signal came to elicit diffuse emotional responses in the dogs; these emotional reactions increased the drive level of the animals; the act of crossing the hurdle, which terminated the aversive signal, reduced the drive; and drive reduction reinforced the instrumental response. It should be noted, however, that when the dogs crossed the hurdle, they not only terminated the aversive signal, but also reduced shock density and delayed the onset of shock. In fact, in this experiment and many others like it, all four of the possible sources of reinforcement were confounded. It is impossible to determine which source of reinforcement maintained the behavior.

Bolles, Stokes and Younger (1966) in a series of five experiments tried to eliminate the confounding of the CS-termination contingency and the avoidance contingency. In one procedure responses terminated the CS but did not avoid shock; in another, responses avoided shock but did not terminate the CS; and, in another, the CS terminated before the response was made. They found that CS termination had some small effect on the strength of the avoidance response but that the major factor in avoidance learning appeared to be the avoidance of shock. In the discrete trial running-wheel procedures they used, the avoidance of shock (or shock frequency reduction) was always confounded with response-produced delay of shock. Delay of shock was present, but the procedures used made it impossible to assess the relative

importance of this source of reinforcement.

By using no external CS, Sidman (1962) eliminated the CS-termination contingency completely. He provided animals with two response levers, each associated with a different schedule of shock presentation. For instance, shocks associated with lever A were presented every 20 sec and shocks associated with lever B were presented every 40 sec. He found that animals did not respond on both levers but chose to respond on only one. Moreover, the animals usually chose the lever that afforded the greatest reduction in shock frequency. Sidman therefore concluded, that the source of reinforcement for avoidance behavior was the reduction of shock frequency.

This type of procedure does eliminate the confounding of external stimulus termination with the other three sources of reinforcement. It may also eliminate the confounding of any internal temporal stimulus termination. Since shocks were delivered by either the timer associated with lever A or with lever B, it was probably very difficult for an animal to form any temporal discrimination about the onset of shock. However, Sidman's procedure still left three variables confounded: Shock frequency reduction, response-produced delay of shock and shock elicited behavior. Not only did responses reduce the frequency of shocks, but they also increased the average delay between shocks; it is also possible that the responding was simply shock elicited.

Hennstein and Hineline (1966) devised a very clever procedure in which shocks occurred randomly in time so that the rat could not use any exteroceptive or internal temporal cue to guide his responding. After each short shock, a response could reduce the probability

of the next shock from 0.3 to 0.1 per 2 sec. This reduced probability of shock was in effect until the next shock, at which time the higher probability of shock was again programmed. Responses between shocks were not effective in reducing the probability of shock. After extended training, Herrnstein and Hineline found stable responding in 17 of 18 animals placed on the procedure. They therefore contended that their results showed that reduction in shock frequency was sufficient to maintain avoidance behavior and that neither internal nor external CS termination was necessary.

Herrnstein and Hineline's procedure again confounded two other variables with shock frequency reduction. First, responses increased the delay of shock. Without responding, shocks were programmed to occur every 6.7 sec on the average. With responding, shocks were programmed to occur every 20 sec on the average. Second, all responses may have been shock elicited. Hutchinson, Renfrew and Young (1971) and Hake and Campbell (1972) have reported that animals will respond to shock onset without any avoidance contingency.

Hineline (1970), realizing the possible importance of delay as a source of reinforcement in avoidance procedures, ran three experiments that bear directly on the position that delay may be the sufficient condition for avoidance behavior. The procedure in his Experiment 1 enabled a response to delay a shock without changing the overall shock frequency. At the beginning of each 20-sec cycle, a loud buzzer was initiated and a retractable bar was quickly extended into the chamber. If a response on the bar did not occur, a shock was delivered at Sec 8; 2 sec later the bar was retracted and the buzzer

terminated. If a response did occur the bar was quickly retracted, the noise terminated, and the shock delayed until Sec 18 of the cycle. Hineline found quite stable responding from the three rats placed on the procedure 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 delivered per cycle.

In his second experiment responses delayed shock, but also increased shock density. Specifically, if no response was made, the procedure was identical to that used in his Experiment 1 with a new cycle initiating every 20 sec. If the animal did respond, the bar retracted and the shock was delivered 8 sec after the response. Two sec after the shock, the bar was extended again into the chamber. A response, therefore, produced both a delay of 8 sec and a short cycle. These shorter cycles served to increase the frequency of shocks the animal received in a session. Hineline found that his subjects responded initially and then stopped responding. He argued that responding failed to be maintained in this experiment because it produced an increase in shock frequency.

Hineline's discrete trial procedure is by far the best procedure that has been developed for the study of avoidance behavior. It allows one to control for and/or manipulate each of the five possible controlling variables which may account for avoidance responding. This type of procedure also allows one to specify what delay the animal is maximizing, if in fact the animal is maximizing some delay. This brings our attention to the major problems in Hineline's (1970) experiments which this research will study.

First, in Experiment 1 it is difficult to evaluate the importance of the delay between the response and shock because of the fact that the duration of this delay was variable. Since the response-delayed shock was always given at Sec 18 of the cycle, the duration of the delay could vary from a maximum of 18 sec to a minimum of 10 sec.

Second, responding in Experiment 1 may have been maintained by the termination of an external warning signal, e.g., retraction of the lever, or by the termination of internal conditioned aversive temporal stimuli. In Hineline's procedures, response-produced delay of shock was always confounded with the termination of possible internal conditioned aversive temporal stimuli. According to Anger (1963), rats will make long latency responses because responding just before shock will lead to the greatest reduction in conditioned aversiveness.

Third, responding in Experiment 2 may have ceased because the response-produced delay of shock was reduced to 8 sec and not because the shock density increased as Hineline suggested.

Several questions arise from these problems. First, is the rat sensitive to the delay of shock? And if so, will it respond to maximize that delay? Second, is the delay between response and shock (R-S delay) more important than the delay between the onset of the trial and shock (O-S)? This might be determined by seeing which delay the animal maximizes. Third, will an animal respond merely to terminate the stimulus compound of bar retraction and noise offset? The results of Bolles, Stokes and Younger (1966) would suggest not. And fourth, will an animal respond to terminate the conditioned aversive

temporal stimuli associated with the time period just before shock?

The present research attempted to answer these questions by using a retractable lever procedure similar to that of Hineline. For the experimental groups a response on a cycle changed only the location of the shock on that cycle, but did not change the frequency of shock. The procedure also minimized the effect of shock elicited responding, because responses immediately after shock, when the bar was extended, had no effect on the location of the next shock and because response-delayed shocks occurred when the bar was retracted and not available. These shocks always occurred at least 2 sec before the next cycle in which the bar was reinserted.

Experiment 1

Five different groups were run. The delay produced by responding will be defined in terms of the R-S delay. In the three experimental groups each response delayed the onset of the shock for some specific length of time. In the first group the length of the delay or length of the R-S interval was independent of the response latency and was a constant 19 sec from the response. The second group received a procedure in which the shorter the response latency from the onset of the retractable bar, the longer the delay until shock. A third group received a procedure in which the longer the response latency, the longer the delay until shock.

Two control groups were run. In one of the control groups, each response terminated the warning signal and retracted the lever but did not change the location of shock. This control was included in the

study to determine if responding would be maintained by warning-signal termination. In the other control group each response functioned to avoid the shock on that cycle as well as to terminate the warning signal and retract the bar. This second group was included for purposes of comparing the different response latencies and response stabilities produced by these avoidance animals and the delay-of-shock animals.

Method

Subjects

The subjects were 31 naive albino rats 90-120 days old at the start of experimentation. Nine were males which were acquired from the Animal Research Center of Massachusetts, Inc., New Braintree, Massachusetts. Twenty-two were females which were acquired from the Holtzman Company, Madison, Wisconsin. All subjects were given at least a week to adapt to the colony and were frequently handled before the experiment. During the course of the experiment, they always had free access to food and water in their home cages but neither food nor water was available in the experimental chambers.

Apparatus

Two Gerbrand 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 and was lined with 5 cm styrofoam.

The front wall of the chamber containing the Standard Gerbrands

box and dipper receptable was covered with a piece of tin that fully extended to the sides and top and bottom of the chamber. A cue light was placed 6 cm above the retractable lever. 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. The lever in each chamber was modified so that the time for full extension to occur 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. Hineline (1970) also used a very fast lever to eliminate the opportunity of more than one response per cycle.

White noise of 87-dB was begun 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 were provided by two Grason Stadler shock sources (Model E1064GS). A Lehigh Valley Interact Computer System in a near-by room controlled all of the events and recorded all responses made in the experimental chambers.

Procedure

Preliminary Training. Two phases of preliminary training were run to enable the subjects to develop stable discrete trial bar pressing. During the first phase, which continued for two 2-hour sessions,

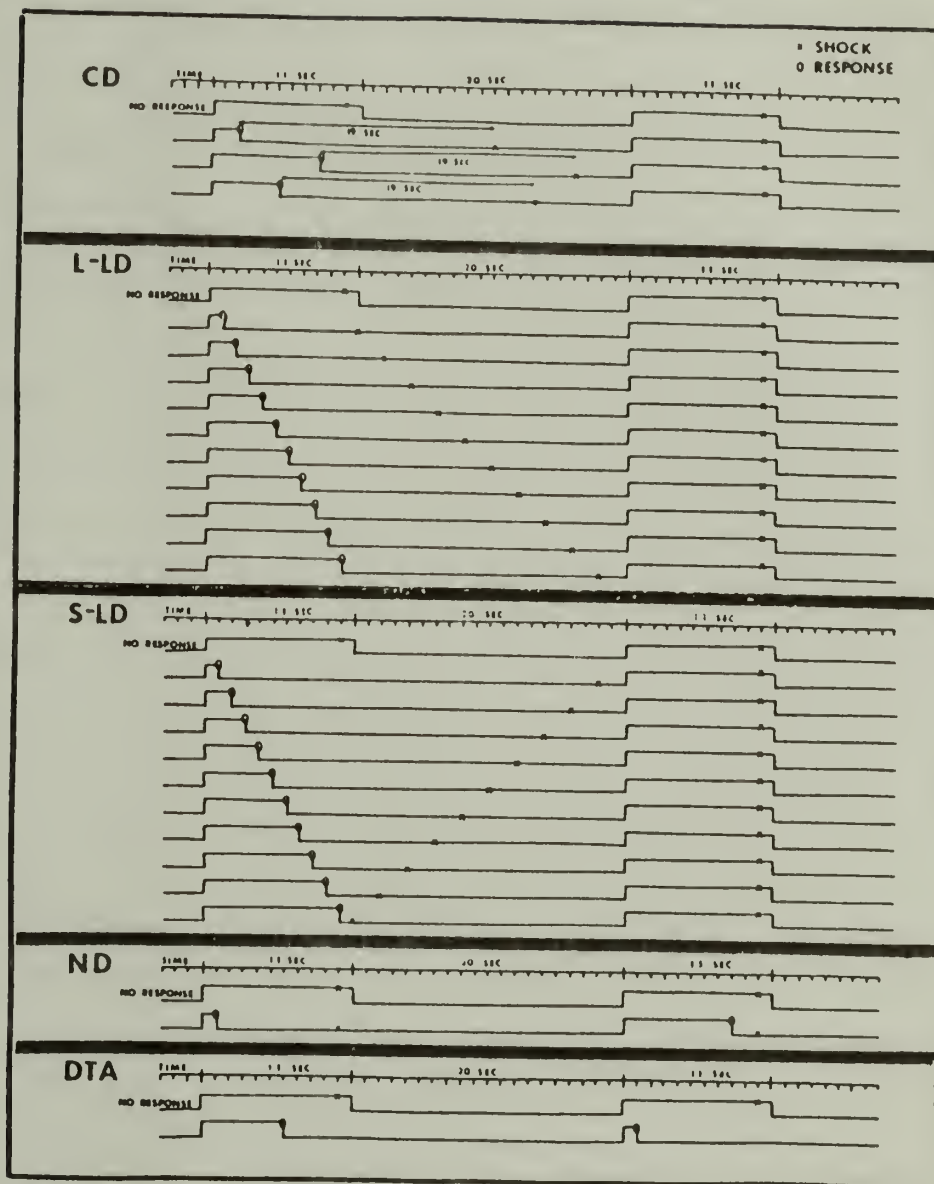
all subjects were placed in a discrete-trial avoidance procedure. Bar extension and white noise initiated each session. If a response did not occur within 10 sec, a .5 sec, 0.8-ma shock was delivered to the grid floor every 3 sec until a bar press occurred. When a response occurred the bar retracted, 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 immediately followed the first and continued for three consecutive sessions. Four of the five groups were placed on the Constant Delay procedure diagrammed in Figure 1, panel CD. 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 .5-sec, .8-ma shock was delivered in the 10th sec, and the bar was retracted at the 11th sec. If a response did occur, the bar retracted, the white noise terminated, and the shock was delayed for 19 sec from the response. Subjects always received one shock per cycle, but the response delayed the shock from Sec 10 to a point between Sec 19 and Sec 29 of the cycle.

The fifth group was placed on a discrete trial avoidance procedure in which only one shock was given per cycle if no response occurred. The procedure is diagrammed in Figure 1, panel DTA. A bar press retracted the bar, terminated the noise, and avoided the shock programmed for that cycle. Group DTA received this procedure for the duration of the study.

Figure 1 Schema for the procedures in Experiment 1.

Upward displacement of a line indicates insertion of the lever and onset of the white noise. Downward displacement indicates retraction of the lever and offset of the white noise. The cycle length in each condition was 31 sec long.



Since the purpose of the study was to determine whether response latencies were sensitive to the duration of the delay of shock, only those subjects that were responding on more than 50% of the cycles during the last session of phase 2 of preliminary training were used in the main part of the study.

Delay Training. After preliminary training, the four delay-of-shock 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 would delay 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. The Short-Latency-Long-Delay (S-LD) Group received a procedure outlined in Figure 1, panel S-LD. A short response latency delayed shock for a longer duration than a long one did. For example, a response latency of 1 sec delayed shock for 28 sec, while a latency of 8 sec delayed shock for only 4 sec. The Long-Latency-Long-Delay (L-LD) Group received a procedure outlined in Figure 1, panel L-LD. In this procedure a long response latency delayed shock for a longer duration than a short one did. For example, a response with a latency of 1 sec delayed shock for only 10 sec while a response with a latency of 8 sec delayed shock for 17 sec.

The No-Delay (ND) Group, diagrammed in Figure 1, panel ND, was a control group in which a response did not delay shock but served only to terminate the white noise and retract the lever. Shocks were always delivered at Sec 10.

After preliminary training, any animal that responded on less than

10% of the cycles for 5 consecutive days was dropped from the study. The delay training was continued for 20 days for the remaining animals, and the entire procedure was replicated two additional times so that a total of six animals was run in each of the five conditions.

Table 1 shows four possible response schemes the animals might use to determine their response latencies. The entries in the table predict for each response scheme what the average response latency should be under each of the five different experimental procedures. A "short latency" might be one less than 2 sec, and a "long latency" might be one greater than 2 sec. A "variable latency" prediction might indicate that different animals would choose different latencies and also that the particular response scheme really makes no a priori prediction about the average latency. A "no-response" entry indicates that animals placed on a given procedure should stop responding.

Results and Discussion

Preliminary Training

Phase 1, Discrete Trial Avoidance. Table 2 shows the response rate per minute and shock rate per min for each animal in the study on the second day of the discrete trial avoidance procedure. Most of the animals emitted about 2.5 responses per min with most of these responses occurring within the first 2-3 sec of bar extension. Since animals could respond only after the 21-sec R-S interval when the bar was again extended, the absolute maximum response rate was 2.85 responses per min. The actual response rates were very close to the maximum, reflecting short latencies.

Table 1

Average Latency Predictions For Each Condition

Schemes	Groups				
	CD	S-LD	L-LD	ND	DTA
Maximize:					
Response-Shock (R-S) Interval	variable	short	long	no resp.	variable
CS onset and shock (O-S) Interval	long	short	long	no resp.	variable
Terminate:					
CS onset	short	short	short	short	short
Conditioned Aversive Temporal Stimuli	long	long	long	no resp.	long

Table 2

Response Rate and Shock Rate Per Minute for Session Two
of Discrete Trial Avoidance Preliminary Training

Animal	Response Rate	Shock Rate
33	2.8	0.03
34	2.4	0.72
N1	2.5	0.06
N2	2.2	0.54
N3	2.6	0.05
N4	2.5	0.12
31	2.6	0.43
32	2.7	0.14
A1	2.1	1.12
A2	2.6	0.33
A3	m.d.	m.d.
A4	m.d.	m.d.
36	2.6	0.30
C1	2.4	0.11
C2	2.5	0.16
C3	2.6	0.30
C4	2.5	0.03
39	2.3	0.75
40	2.4	0.27
L1	2.5	0.08
L2	2.6	0.08
L3	2.5	0.12
L4	2.6	0.04
37	2.6	0.21
38	2.7	0.21
F1	2.4	0.31
F2	2.4	0.47
S1	2.2	1.15
S2	2.4	0.10
S3	2.6	0.07
S4	2.6	0.05

m.d. A printer malfunction led to the loss of part of the data for these two animals on the second day of phase 1.

Shock rates also reflected good avoidance behavior. The overall average was about 1 shock every four minutes. Most of these shocks were delivered in the early portion of the avoidance session during a warmup period (see Hoffman, 1966). Every animal was responding consistently to avoid shock by the second day of avoidance pretraining.

Phase 2, Constant Delay Training. Four of the five groups received three days of constant delay training, i.e., each response produced a constant R-S delay of 19 sec until shock. The fifth group, Group DTA, was continued on a Discrete Trial Avoidance procedure that delivered only one shock per cycle if no response occurred (Figure 1, panel DTA).

Of the 31 subjects that received constant delay training, 28 met the 50% criterion on the third day. The three animals that did not meet the criterion 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 the remainder in the 90% range. Their average latencies ranged from 0.02 to 5.20 sec.

Experimental Treatments

On the day following preliminary training, the DTA Group continued to receive the discrete trial avoidance procedure. The remaining animals that had met the 50% criterion on the third day of CD preliminary training were assigned to groups in such a way that after the three replications there would be five or six subjects in each group.

Table 3 shows the sequence of procedures for each animal in the experiment.

Constant Delay Condition. In this treatment, a high percentage of responses were predicted and Table 1 shows there were three possible average latency predictions. The left panel of Figure 2 shows the percent response plotted as a function of days for each animal. The solid lines are plots of all responses before and after shock. However, only response latencies less than 10 sec produced a delay of shock. The dotted lines on the figure plot the percent responses before shock. Responding occurred on approximately 100% of the cycles for three animals. Very few of these responses occurred after shock.

The response rate of C2 and C4, plotted on the bottom of the figure, decreased over days. During each successive session these two subjects did not begin responding until later and later in the session, but by the last 30 cycles both usually responded on at least 90% of the cycles. After day 15 C2 did not respond on more than 67% of the cycles during any 30-cycle block; however, the highest percent always occurred during the last block.

The average response latencies for each animal are plotted in the right panel of Figure 2. Remember that every response latency less than 10 sec produced a 19-sec delay until shock. A response latency after shock did not affect the location of shock. It only terminated white noise and retracted the lever. Response latencies varied greatly between subjects, but each subject displayed a fairly consistent average latency over days. Three animals had average latencies greater than 4 sec and two had average latencies less than 2 sec.

Table 3

Sequence of Procedures for Each Animal in Experiment 1
Preliminary Training

Group	Animal ¹	Avoidance	Constant Delay	Experimental Treatment
N D	33	2	3*	0
	34	2	3	5**
	N1	2	3	20
	N2	2	3	20
	N3	2	3	20
	N4	2	3	20
DTA	31	2	0	23
	32	2	0	23
	A1	2	0	23
	A2	2	0	23
	A3	2	0	23
	A4	2	0	23
C D	36	2	3	20
	C1	2	3	20
	C2	2	3	20
	C3	2	3	20
	C4	2	3	20
L-LD	39	2	3	20
	40	2	3	20
	L1	2	3	20
	L2	2	3	20
	L3	2	3	20
	L4	2	3	20
S-LD	37	2	3*	0
	38	2	3*	0
	F1	2	3	20
	F2	2	3	14**
	S1	2	3	20
	S2	2	3	20
	S3	2	3	20
	S4***	2	3	20

* These animals were terminated from the study after the third day of CD preliminary training because their response probability was less than 50%.

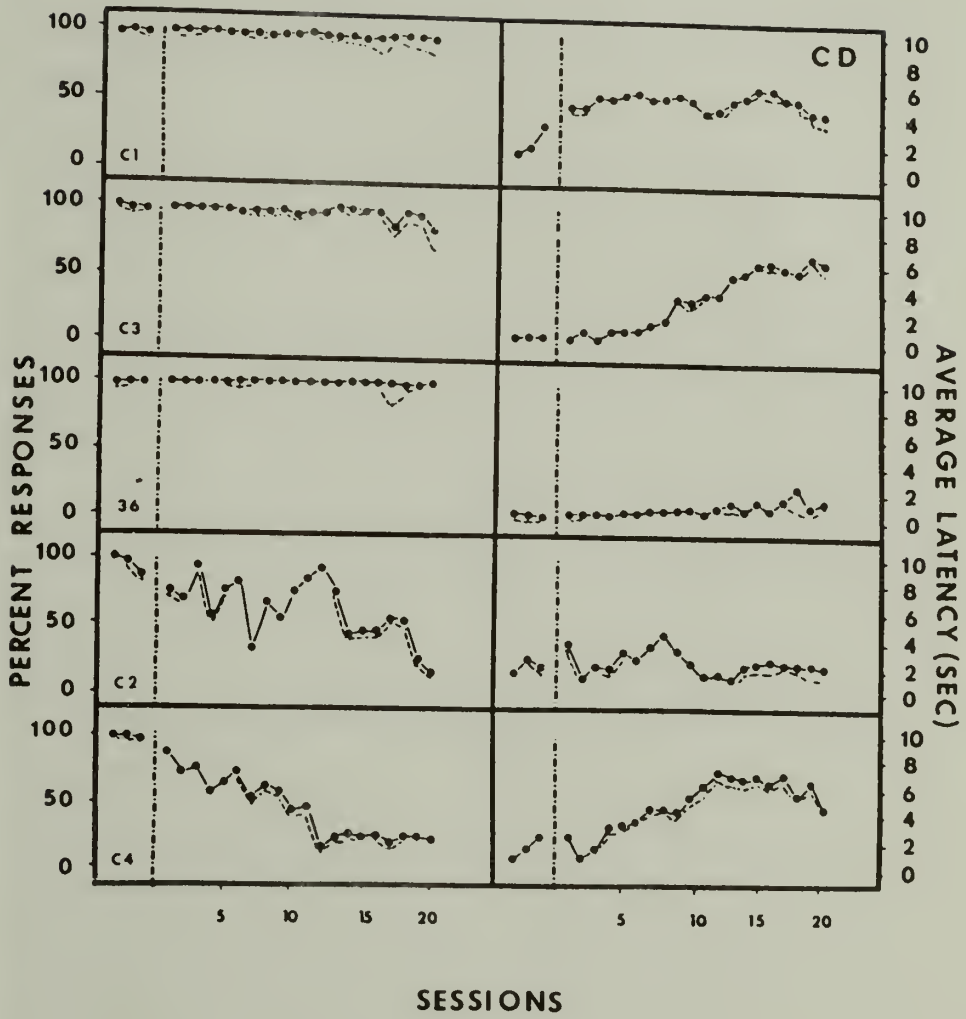
** These animals were terminated from the study after they responded on less than 10% of the cycles on 5 consecutive days.

Table 3 (cont'd)

*** This subject met the criterion for being dropped from the study after 9 days on the S-LD procedure; however, it was then placed on the L-LD procedure for 4 sessions and on the DTA procedure for 8 sessions.

1 Animals designated by a two digit number were males. Animals designated by a letter and a number were females.

Figure 2 The percent response and average latencies for five 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.



The latency-distribution data for Day 15 are plotted in Figure 3. The data are plotted in terms of two measures. The dotted line represents the conditional probabilities of any given latency. This measure (LA/OP) is the probability of a given latency conditional on the number of times at least that latency is reached. The solid line connecting the circles represents the relative frequencies of any given latency. The former measure is analogous to "interresponse times per opportunity" in free operant situations (see Anger, 1963). The figure shows that subjects varied greatly in terms of their latency distributions. For those subjects who responded on more than 94% of the cycles, conditional probabilities showed a distinct rise near the middle of the interval. Hineline (1970) also reported a similar rise from the delay procedures he used. However, Hineline also reported a steep descent from the peak just before shock. Figure 3 shows that this was not always the case for these animals.

Long-Latency-Long-Delay Condition. In this treatment long latencies produced longer delays of shock than short latencies did. In accordance with Hineline's results, consistent responding was expected; and, unique to this procedure, long latencies were generally predicted (see Table 1).

The left panel of Figure 4 shows the percent responses for each of the six subjects. Only three of the six maintained a high response probability during the 20 days of the treatment. The poor responders did not show increasingly longer periods of warm-up as did the poor responders in the CD condition. For example, L2, a poor responder, usually made fewer responses during the last 30-cycle block than it

did during earlier blocks. The right panel of Figure 4 shows the average latencies for each subject plotted over sessions. Rat L2, a poor responder, initially made very short latencies (approximately 1 sec). On the L-LD procedure this latency produced a delay of 11 sec, only 1 sec more delay than if no response had occurred. This short delay might account for the within-session and between-session response decrement. There was some warm-up for Rats 39 and L1 but it was minimal.

Notice that the three rats that stopped responding before shock responded after shock to a much greater extent than did those rats that maintained a high response probability. This can be seen by comparing the before shock response, represented by the dotted line in Figure 4, and the total response curve, represented by the solid line. This observation also is evident in the latency distribution data in Figure 5. The poor responders placed over 70% of their responses after shock while the high responders placed less than 10% after shock. The high responders all showed a gradual increasing LA/OP curve and a small decrease after the peak just before shock. The peak was between 8 and 9 sec for all three of the responders. The LA/OP curve increased after shock, which shows that if the subjects did not respond before shock, they took every opportunity to respond after shock. This finding is again in disagreement with Hineline's results. He found a decreased LA/OP curve after shock for his subjects, even though subjects had 2 sec after shock in which to respond.

Figure 3 The latency distributions for the five animals in the Constant-Delay condition on Day 15 of the treatment. The vertical solid line at Sec 10 delineates the location of shock if no response occurred. The percent response for each animal on Day 15 is found under the animal number.

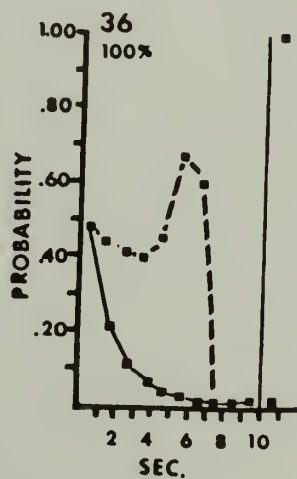
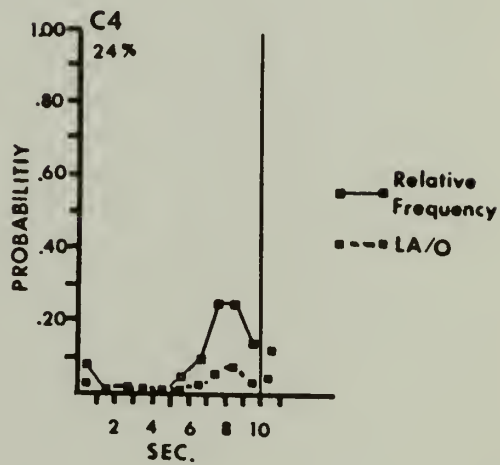
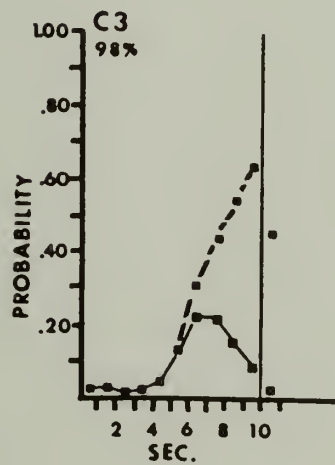
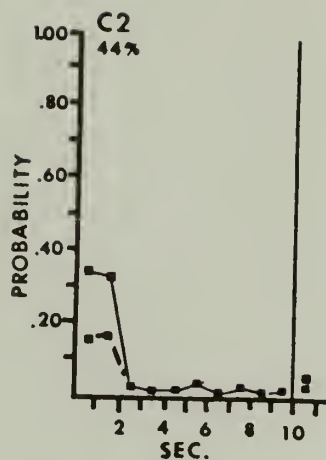
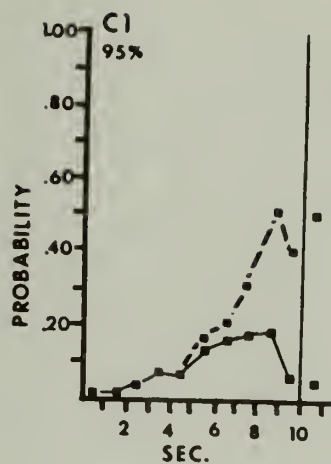


Figure 4 The percent response and average latencies for six animals in the Long-Latency-Long-Delay condition. The data plotted to the left of the vertical dotted lines are from the three sessions of the Constant-Delay Preliminary Training. Solid lines connecting solid circles plot all responses. Dotted lines connecting open circles plot responses made before shock.

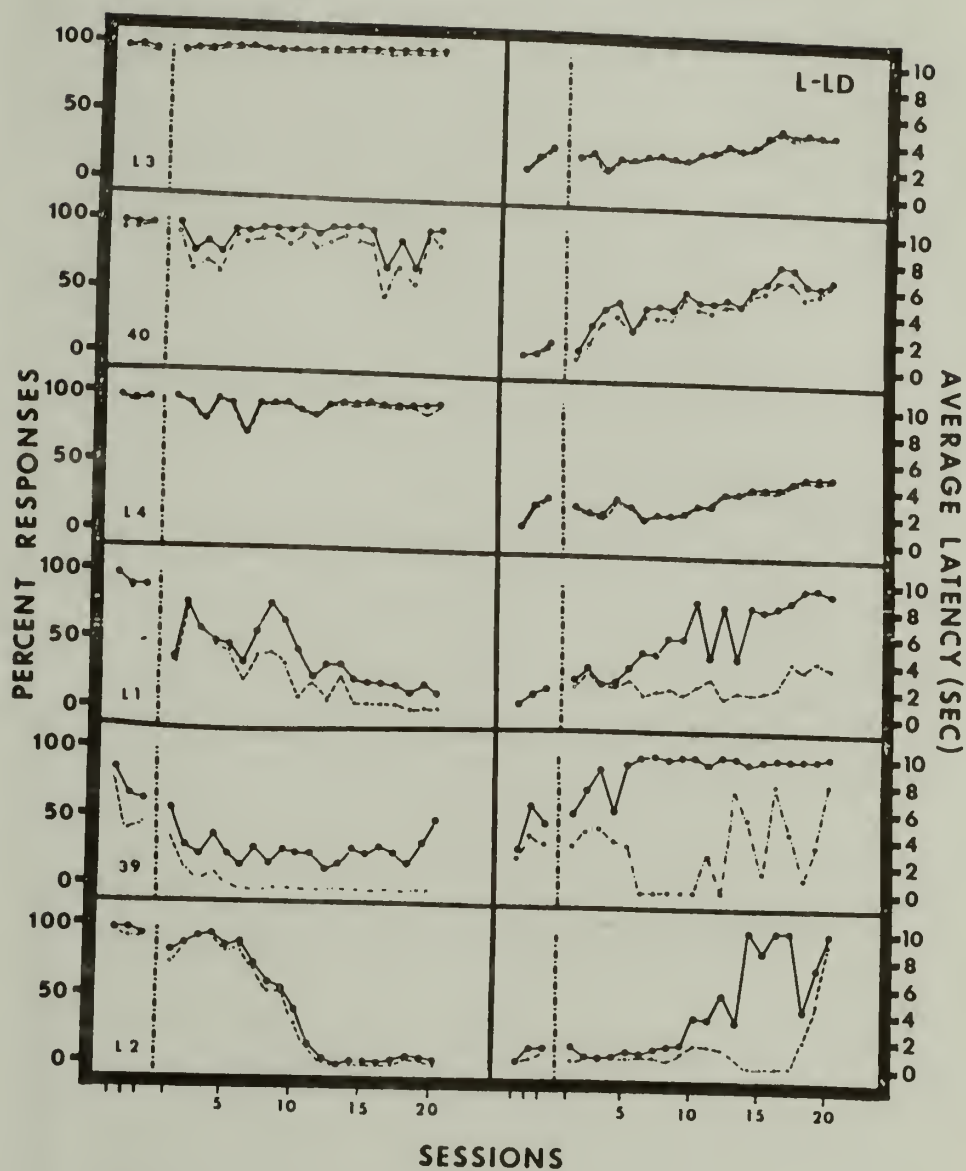
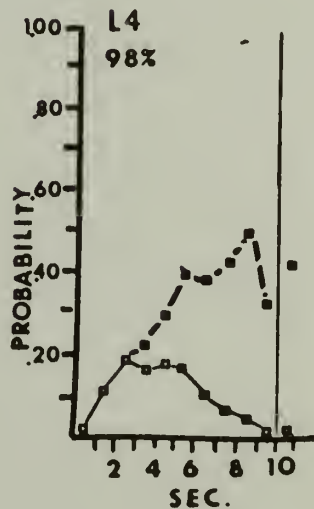
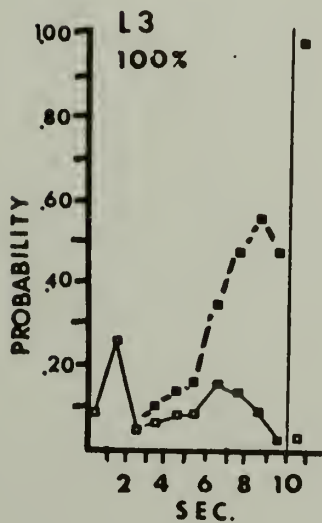
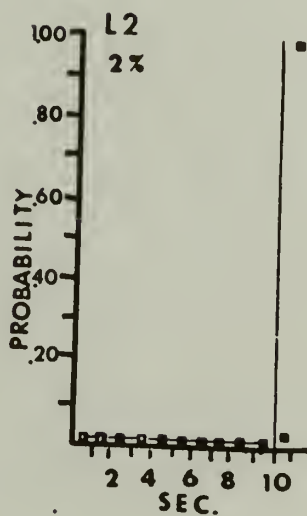
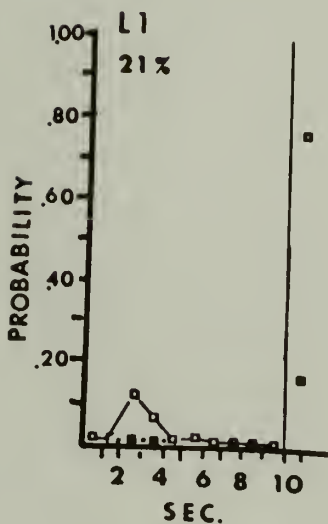
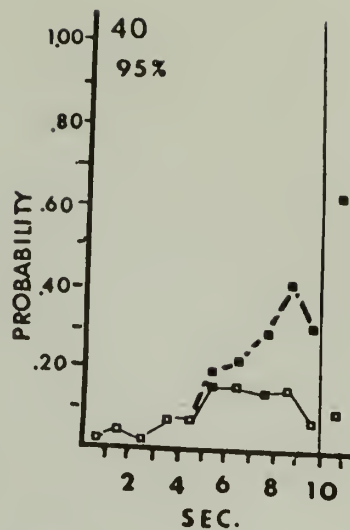
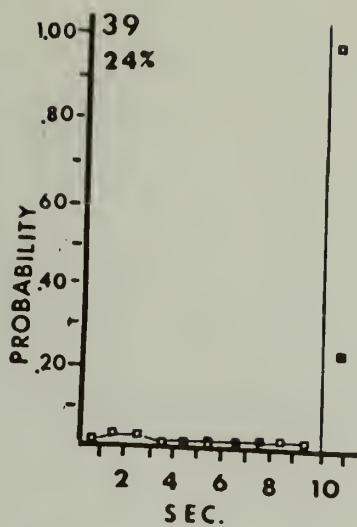
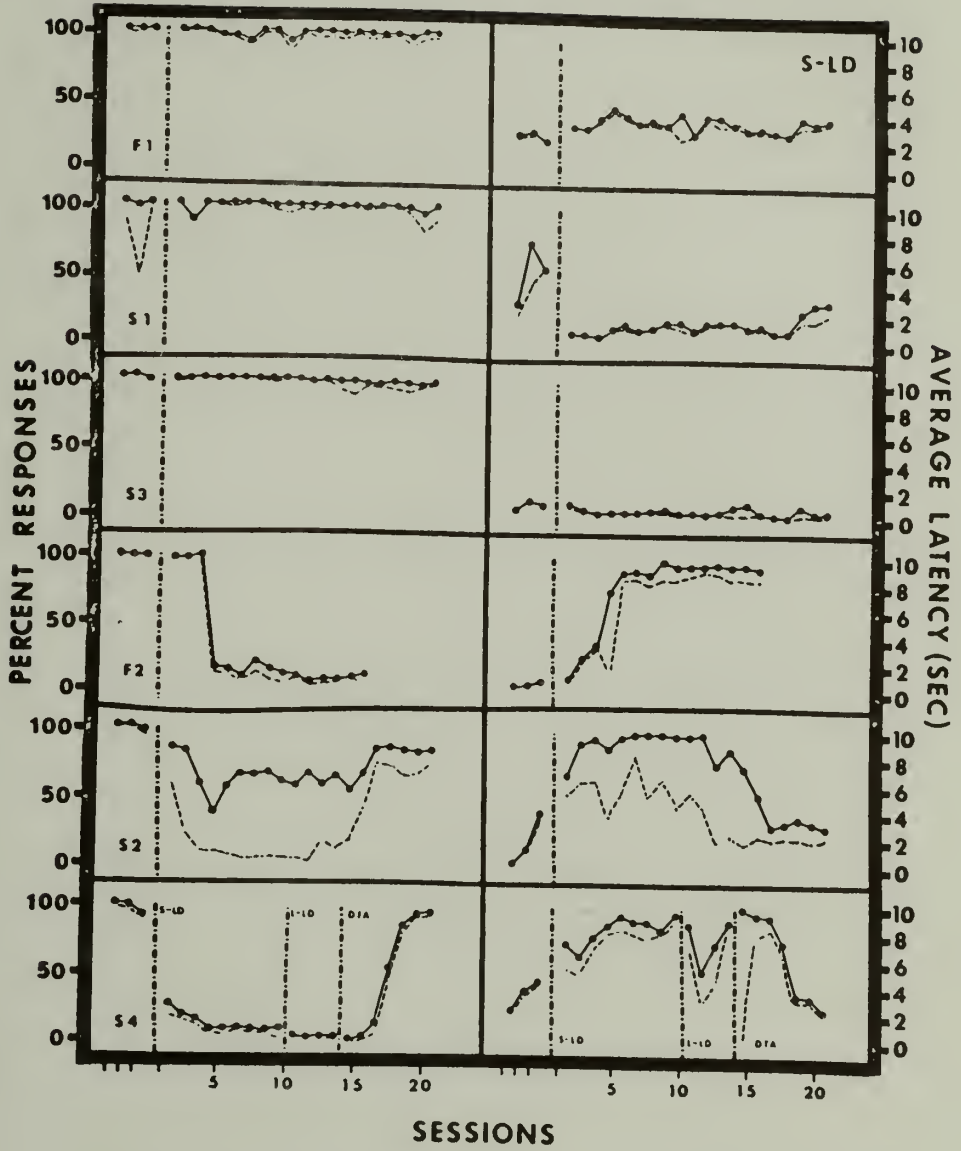


Figure 5 The latency distributions for the six animals in the Long-Latency-Long-Delay condition on Day 15 of the treatment. The vertical solid line depicts the location of shock if no response occurred. The percent response for each animal on Day 15 is located under the animal number.



—■— Relative Frequency
- - - ■ - - - LA/O

Figure 6 The percent response and average latencies for six 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.



The average response latencies before shock for responders reached asymptote consistently at a value between 4-5 sec. This specific latency with this procedure produced a delay of 15 sec between response and shock and 20 sec between the beginning of the cycle and shock. The average response latency for poor responders was close to 10 sec.

Short-Latency-Long-Delay Condition. In this treatment, short latencies produced longer R-S delays of shock than did long latencies. Consistently high response probability was expected and unique to this procedure, short latencies were generally predicted (see Table 1). The left panel of Figure 6 shows the percent responses for each of the six subjects in the condition. Three animals maintained a very high response probability. Of these three subjects, S1 and S3 had average latencies less than 2 sec 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 (see Figure 1). The third animal that maintained responding, F1, had an asymptotic average latency between 3 and 4 sec. This latency produced a delay of 19 sec after the response. This was the same delay that the CD animals always received after a response and that this animal had received under the CD condition during preliminary training.

The three poor and the three good responders responded differently on the first session of the S-LD procedure. The poor responders initially made long latency responses that produced short delays of shock while the good responders initially made short latency responses which produced long delays. This difference can be seen by looking

at the median delay produced by the first ten responses made by each subject on the first session of the S-LD procedure. The three good responders, F1, S1, and S3, responded to produce a median R-S delay of 22, 28, and 28 sec respectively. The three poor responders, S2, S4, and F2, responded to produce a median R-S delay of 14.5, 13, and 28 sec respectively. F2, which responded initially to produce a 28-sec delay, maintained a near perfect response probability until Day 4 of the S-LD procedure at which time it almost stopped responding. On this day the median delay produced by its first ten responses was 5.5 sec. This short delay reflected the fact that most of its latencies were very long.

One might conjecture that an animal would continue to respond if its initial responses produced long delays and that an animal would cease responding if its initial responses produced short delays. However, since the poor responders initially had long latencies, it can not be determined if the controlling factor leading these animals not to respond was the latency of the response or the duration of the delay of shock.

When the poor responders stopped responding they also shifted their few responses from before shock to after shock. Good responders seldom responded after shock. For instance, S2 stopped responding before shock on the second day of the procedure and shifted its response latency almost exclusively after shock. This change in response latency was accompanied by an increase in response probability up to 85%. Rat S2 was the only animal in the experiment that changed its response strategy after extended exposure to a condition. Usually

after the first few days on a procedure, it was possible to predict the general asymptotic behavior of each animal. S4 also quickly stopped responding when placed on the S-LD procedure. It was terminated from the condition when it had met the termination criterion of five consecutive days of a response probability of less than 10%. S4 was then placed on the L-LD procedure for four sessions, but it still did not respond. Finally it was placed on the DTA procedure and its response probability quickly recovered and its average latencies decreased. Shock delay appeared not to be sufficient.

The latency distribution data for the S-LD condition was plotted in Figure 7. It can be seen that the good responders placed over 95% of their responses before shock while the two poor responders placed 60% of their responses before shock. The remaining 40% of their responses occurred in the 1 sec after shock while the lever was still available. The plots of the S-LD responders are very different from the plots of the L-LD responders. The S-LD peaks occurred much earlier. In fact the LA/OP curves and relative frequencies curves show peaks between 0 and 1 sec for rats S1 and S3. The two poor responders who had not been terminated by Day 15 had their peak LA/OP curves between 10 and 11 sec, i.e., after shock. Again, as in the other conditions, poor responders responded mainly after shock.

Analysis of Poor Responders

Approximately half of the animals that were placed on the delay procedures failed to maintain responding. A careful analysis of their latency data during the two phases of preliminary training was made to determine if the poor responder could be identified at a point

before the different delay procedures were begun. Several measures were studied to determine if poor and good responders could be discriminated.

During the first session of the Discrete Trial Avoidance preliminary training, it was not possible to separate the asymptotic good responders from the asymptotic poor responders. For example, the median number of avoidances was 240 for the poor responders and 242 for the good responders. The median number of shocks received was 70 for the poor responders and 75 for the good responders. The median latency for the first ten trials was 13.11 sec for the poor responders and 14.58 sec for the good responders. The differences between the medians did not approach significance in any of the comparisons. On Day 2 of the Discrete Trial Avoidance preliminary training, these measures again did not differentiate the good and poor responders.

A difference did appear, however, between these two types of responders during the second phase of preliminary training, the Constant Delay training. In short, those animals that became poor responders took more trials to begin responding than did the good responders. This was observed on each of the three days of CD training and on the first day of the experimental-delay training. Table 4 shows the number of trials each animal received until it made at least two responses. The second and not the first response was used as a cut off because occasionally animals would accidentally hit the lever on the very first trial but would not begin to consistently respond until much later. Comparisons of the means at the bottom of each column show that the good responders on the average, started

responding much sooner than the poor responders did. The t -values and two-tailed probabilities associated with each t -value can also be found at the bottom of the table.

Control Conditions

The two remaining conditions were designed to be control treatments. The first was a discrete trial avoidance condition (DTA). Since responses produced shock avoidance in this condition, a high response probability was expected. The second condition was a No-Delay (ND) condition in which responding, maintained during the CD preliminary training, was expected to extinguish.

Discrete Trial Avoidance Condition (DTA). Figure 8 shows that five of the six animals placed on the DTA procedure responded on approximately 100% of the cycles on each of the 23 treatment days. The one rat that did not respond, Rat 31, was a male and showed a great deal of day to day and within-a-day variability. Extended warm-up was not a factor because this rat would often respond on 20 consecutive trials and then fail to respond on the next 30.

Average latencies, shown in the right panel of Figure 8, were consistent within subjects over days and varied among subjects between 2 and 5 sec. When four of these animals were placed on a conventional extinction procedure of removing the shock, their response probabilities quickly decreased. This demonstrated that the white noise and bar extension were probably not unconditioned aversive stimuli and that this termination was not sufficient to maintain responding.

Table 4

The Number of Trials before each Subject made its Second Response during the Constant Delay Preliminary Training and the first Session of the Experimental Delay Treatment

Type of Responder	<u>S</u>	CD Preliminary Training			Experimental Delay	Asymptotic * Percent Response
		1	2	<u>Days</u> 3	1	
Good	L3	0	0	0	1	100
	L4	1	0	0	0	95
	40	2	2	0	0	88
	F1	2	0	0	3	98
	S1	3	2	0	1	99
	S3	1	0	0	0	97
	C3	0	0	4	4	85
	C1	1	0	0	0	98
	36	1	0	0	0	100
Means		1.22	0.44	0.44	0.89	95.6
Poor	L1	1	1	11	15	19
	L2	0	0	1	4	4
	39	23	36	43	27	30
	F2	8	8	8	11	7
	S2	0	0	0	0	85
	S4	1	0	1	5	7
	C4	1	0	0	0	26
	C2	1	0	20	0	46
Means		4.37	5.63	10.5	7.75	28.0
t-values		1.18	1.24	2.04	2.14	7.36
Probabilities (2-tailed)		0.26	0.23	0.06	0.05	.00002

* The asymptotic percent response was found by taking the median percent response for the last five days of the experimental treatment for each subject.

Figure 7 The latency distributions for six animals in the Short-Latency-Long-Delay condition on Day 15 of the treatment. The vertical line at Sec 10 depicts the location of shock if no response occurred. The percent response for each animal on Day 15 is located under the animal number.

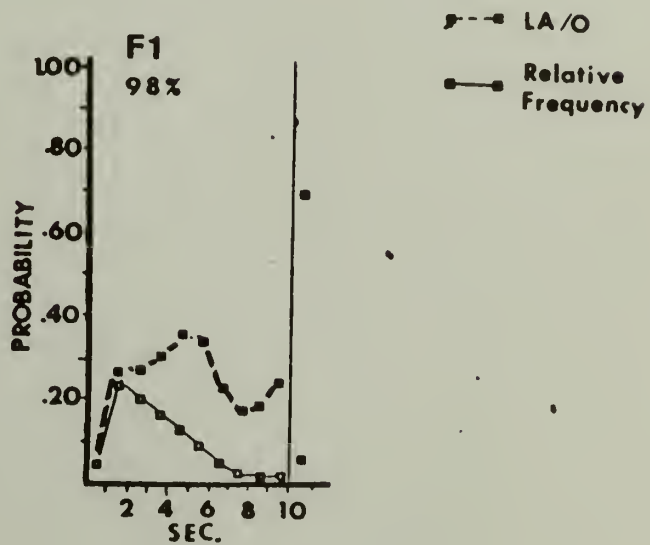
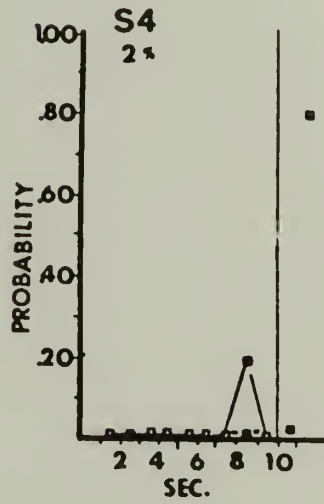
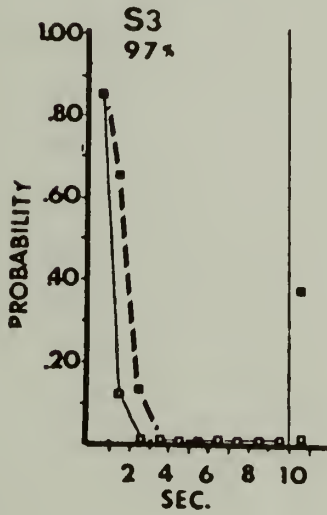
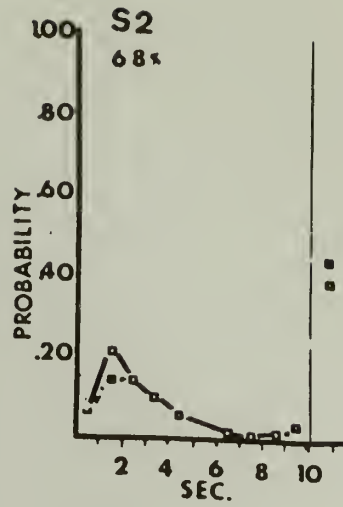
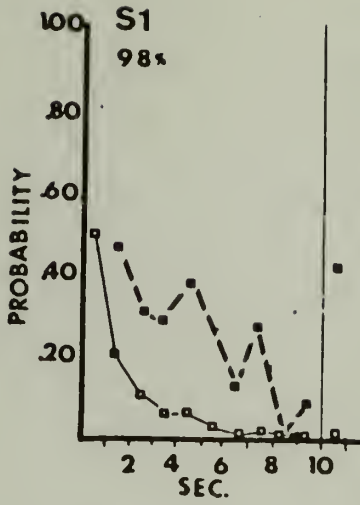


Figure 8 The percent response and average latencies for six animals in the Discrete-Trial-Avoidance condition. Solid lines connecting solid circles plot all responses. Dotted lines connecting open circles plot responses made before shock.

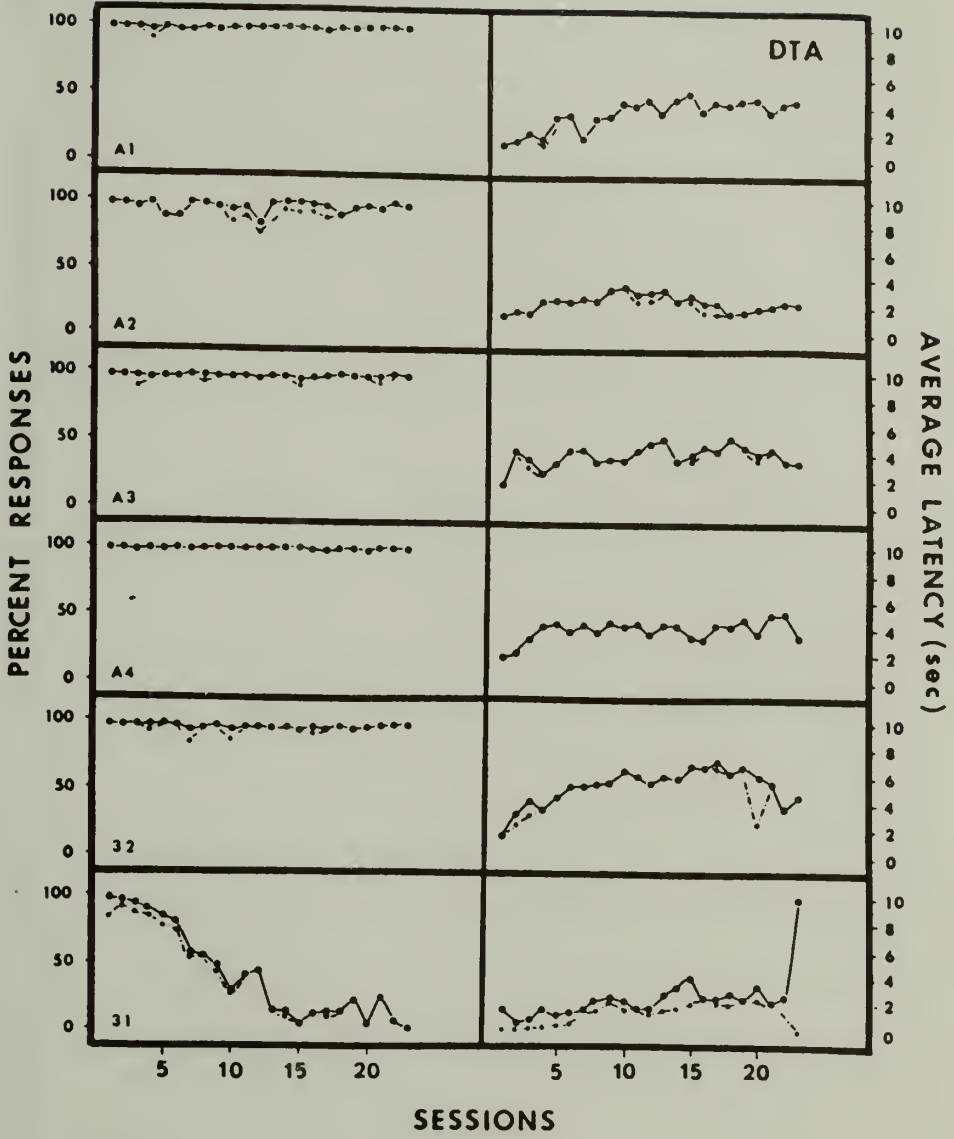


Figure 9 The latency distributions for six animals in the Discrete-Trial-Avoidance condition on Day 15 of the treatment. The vertical line at Sec 10 depicts the location of shock if no response occurred. The percent response for each animal on Day 15 is located under the animal number.

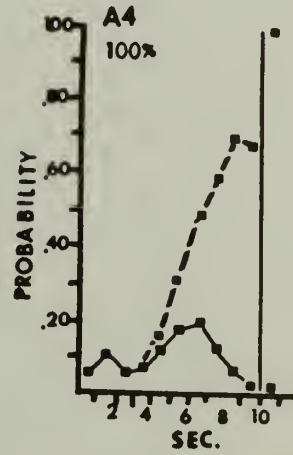
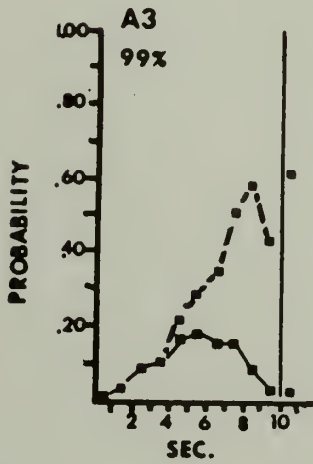
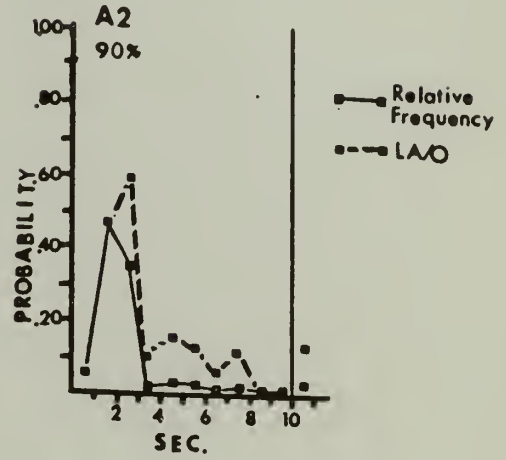
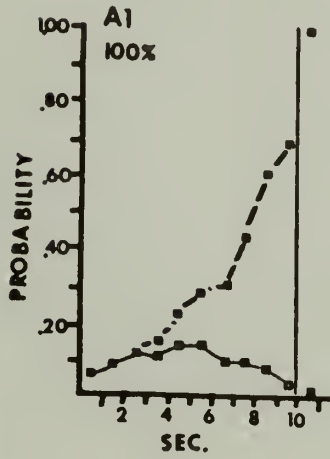
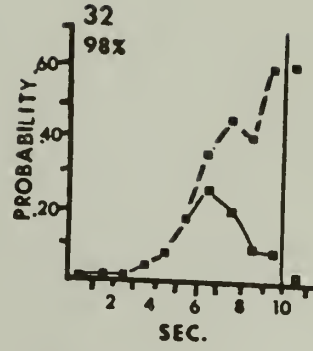
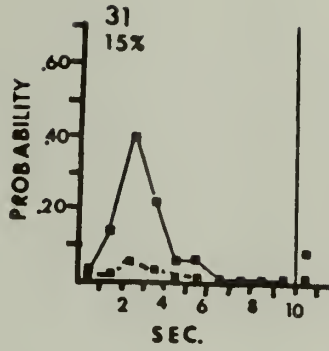
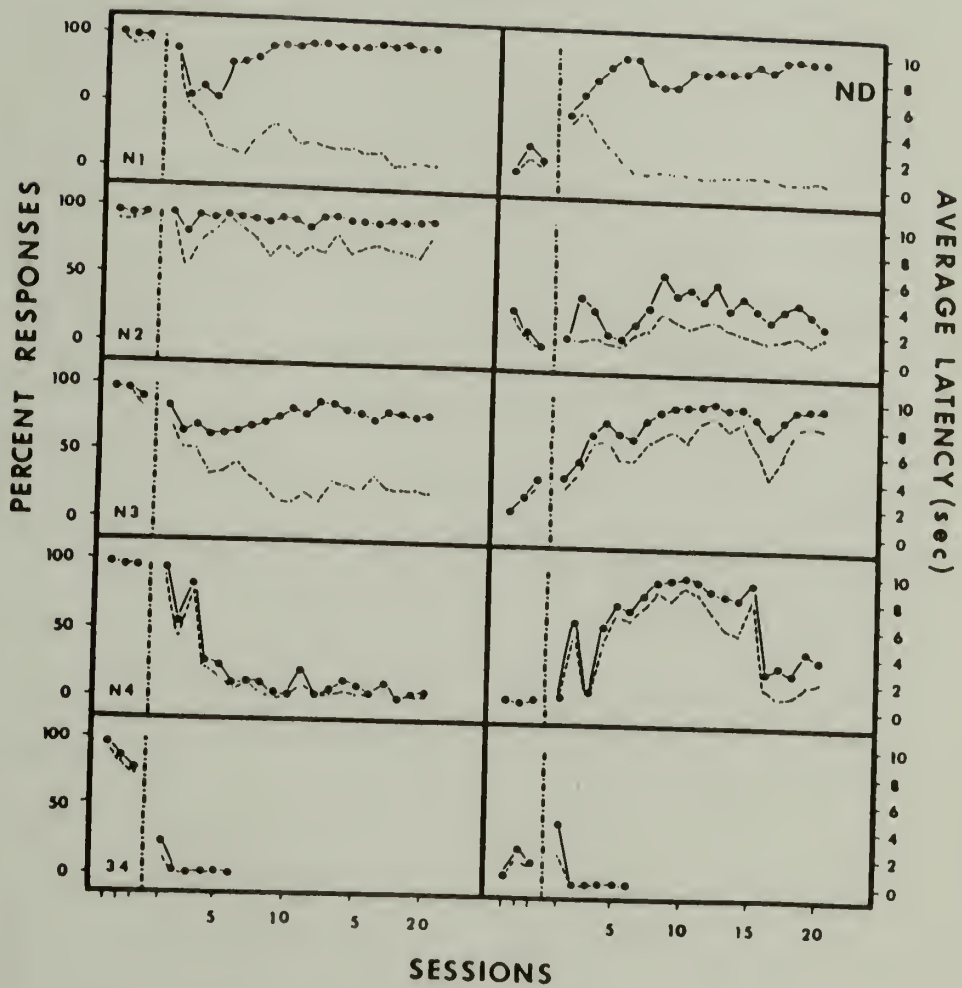


Figure 10 The percent response and average latencies for five animals in the No-Delay condition. The data plotted to the left of the vertical dotted lines are from the three sessions of the Constant-Delay Preliminary Training. Solid lines connecting solid circles plot all responses. Dotted lines connecting open circles plot responses made before shock.



Most of the responders showed typical avoidance timing with long latencies (see Figure 9). The relative frequency curves for Rats 32, A3, and A4 peaked at 5-6 sec and the LA/OP curves increased throughout the 11 sec interval with a slight drop just before shock. A2, which had the shortest average latency (see Figure 8) placed most of its responses during the first 2 sec of the white noise signal. The relative frequency and LA/OP curves both peaked very early for this animal. It should be mentioned that the good responders seldom placed their responses after shock.

No-Delay Condition (ND). The second control treatment was expected to extinguish responding. Decreased responding was expected because responses had no effect on the location of shock. Responses merely terminated the white noise and retracted the lever. As Figure 10 shows, only two of the five animals placed on the condition decreased their responding. The other three rats consistently responded on more than 80% of the cycles during each of the 20 sessions. Rat N1 responded almost exclusively after shock. Rat N3 responded on approximately 30% of the cycles before shock with an average latency of 8 sec and responded on 50% of the cycles after shock. Rat N2 responded on 70% of the cycles before shock and 20% of the cycles after shock. During a session, N2 would respond after shock during the first part of the session and then respond before shock on the later part of the session. For instance, on Day 15, its average latency during the first 30-cycle block was 5.14 and during the last 30-cycle block its average latency was 1.79. Latency-distribution data plotted in Figure 11 reflects this predominance of post-shock responding except for Rat N2

who also responded a great deal very early in the cycle.

Summary Data

Figure 12 summarizes the asymptotic percent response data for each of the five treatments. In graphing the data, each group was divided into two kinds of responders: Those who responded on more than 50% of the cycles and those who responded on fewer than 50%. The ranges for each subdivision of data for each group were plotted and the median for each range was identified with a closed circle (good responders) or an X (poor responders). The plots show that animals responded at the extreme values. For instance in the S-LD condition the four good responders had a range between 85 and 99 percent, while the two poor responders responded on as few as 7 percent of the cycles during the last five days of the treatment. These dichotomous results occurred in every group. Those animals that responded, responded on almost every cycle and those animals that were poor responders responded on almost every occasion on much fewer than 50% of the cycles. This observation was less true for the CD Group but remember those two animals that were poor responders had extended warm-up periods, while the poor responders in other groups did not. If the percent response from the later part of each session had been plotted instead of the overall percent response, perhaps the data points for the two CD poor responders would have been much closer to 90%.

Figure 13 is a summary of the asymptotic average latency data for each of the five treatments. Only animals that responded on at least 50% of the cycles at the end of treatment were included in the

Figure 11 The latency distributions for four animals in the No-Delay condition on Day 15 of the treatment. The vertical line at Sec 10 depicts the location of shock if no response occurred. The percent response for each animal on Day 15 is located under the animal number.

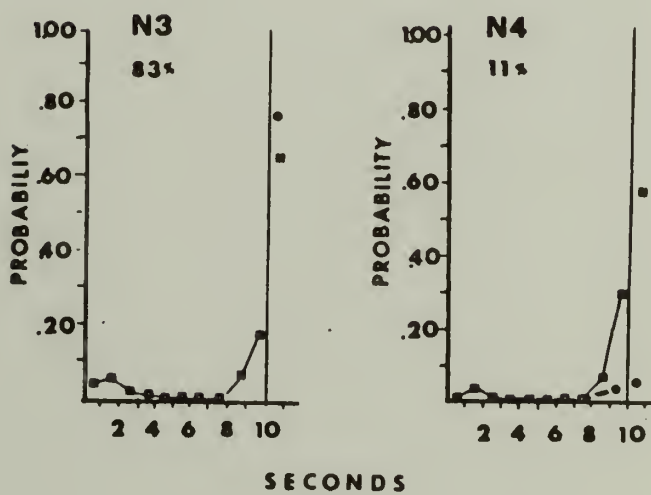
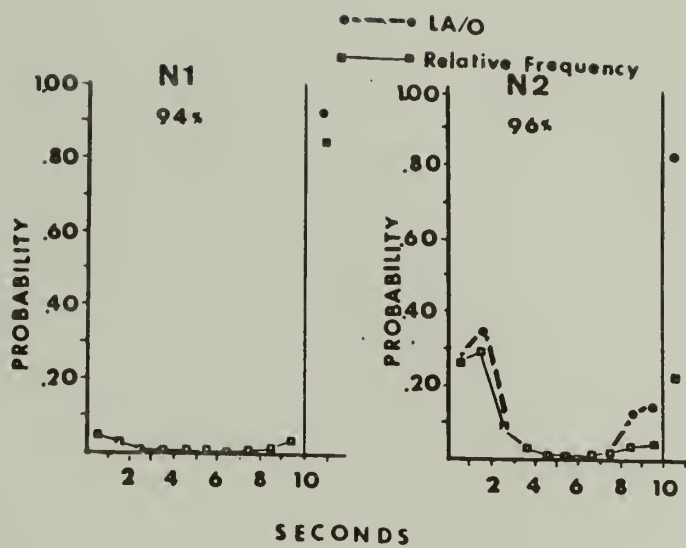


Figure 12 The range of percent response for each condition. The solid bars depict the range of percent response for animals that responded on more than 50% of the cycles during the last 5 sessions. The solid circles represent the median percent response. The number of animals in each range are shown in parenthesis. The dotted bars and X's represent the same data for those animals that responded on less than 50% of the cycles during the last 5 sessions.

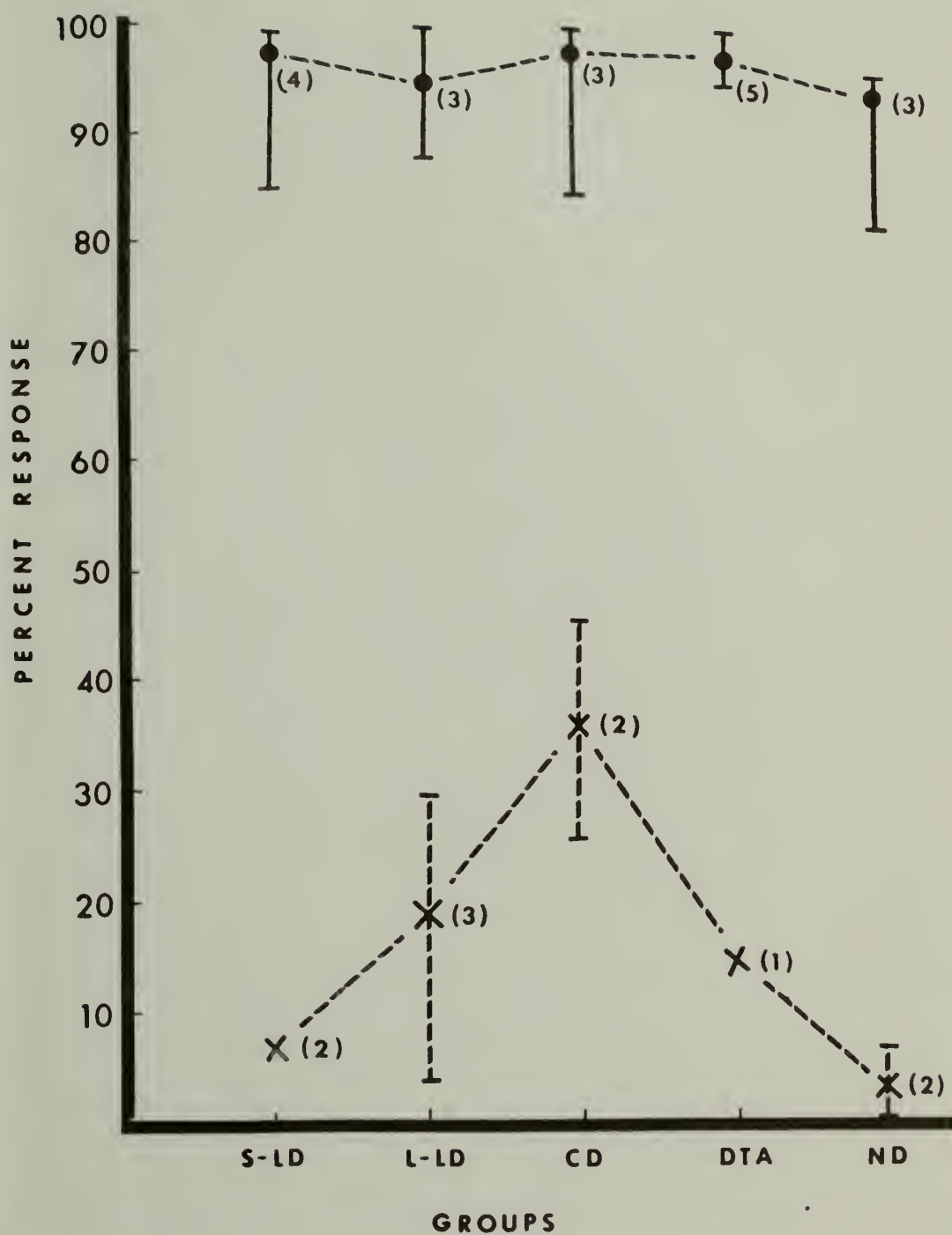


Figure 13 The range of median latencies for each condition for those animals that responded on more than 50% of the cycles during the last 5 sessions. The solid bars represent the range of latencies for the subjects in each condition during the last 5 sessions, and the solid circles represent the medians for each range.

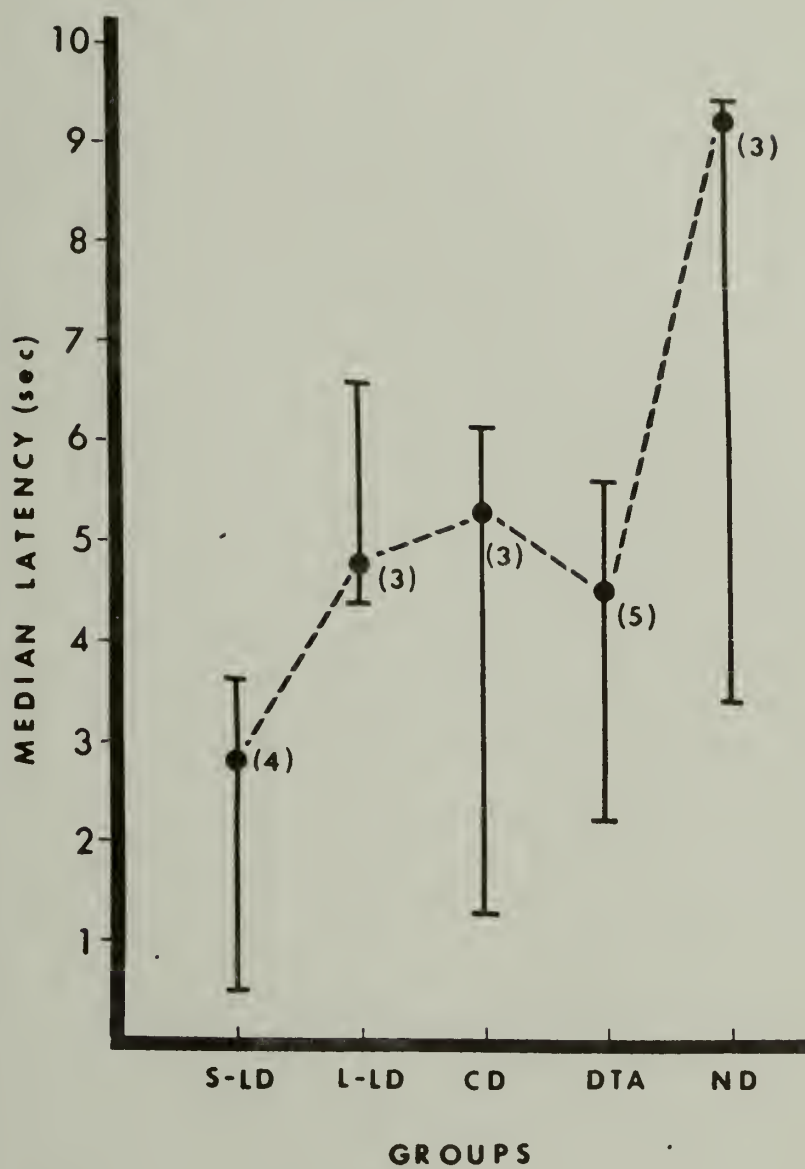


figure. The range of latencies among subjects in each group are shown. The solid circle on each bar designates the median latency for each group over the last five days of training.

The ND subjects had the longest latencies ($MD = 9.33$). This reflects the large percentage of post-shock responding. The L-LD subjects had long latencies, and every L-LD subject had longer average latencies than every S-LD subject. The CD subjects displayed the largest range of latencies for delaying shock. The figure also shows that the subjects in Group DTA displayed response latencies which were very similar to those displayed by subjects that could only delay shock. It can be concluded, therefore, that response latencies and response stabilities are similar on avoidance and delay-of-shock procedures.

The results of Experiment 1 are best accounted for by the hypothesis that responding is controlled by the duration of the R-S delay, (see Table 1). Animals did not always respond to maximize the CS onset and shock (O-S) interval because this hypothesis falsely predicted that the response latencies from the CD condition would always be long. However, two of the six animals in this condition had very short latencies. The CS termination hypothesis can also be disregarded because first, it falsely predicted that the response latencies would be short for all delay groups and second, it falsely predicted that animals in the ND condition would make short latency responses. These animals mainly responded after the shock. The termination of conditioned aversive temporal stimuli can also be rejected as a hypothesis because it falsely predicted that the latencies for all

the delay groups would be long. This was not the case because the S-LD subjects had very short latencies. The one hypothesis that is supported by the data is that responding was controlled by the duration of the R-S delay.

Experiment 2

Experiment 1 found that if an animal will respond to delay shock, it will place its responses in such a way as to maximize that delay. Experiment 2 was run to answer two questions: First, could an avoidance-type procedure be devised that would develop responding in the poor responder? Second, could the average latency be changed by a different avoidance procedure?

A modified delay-avoidance procedure was used in which certain response latencies delayed shock and other latencies avoided shock: For some animals a short latency of less than 4 seconds avoided shock, and a latency greater than or equal to 4 seconds merely delayed shock for 19 sec. For other animals the opposite was true. Thus short latencies, less than 4 sec, delayed shock and latencies greater than or equal to 4 sec avoided it. This partial avoidance procedure is similar to one that Sidman (1966) used and termed "interval avoidance."

Method

Subjects

Ten subjects from Experiment 1 were used. They were C1, C2, C3, C4, S1, S2, S3, S4, L1, and L2. They were all responding on at least 10% of the cycles by the end of their training.

Apparatus

The apparatus was the same as used in Experiment 1.

Procedure

With the partial avoidance or the limited interval avoidance procedure, one of two contingencies occurred. Either short latencies less than 4 sec avoided shock and long latencies equal to or greater than 4 sec delayed shock for 19 sec, or latencies less than 4 sec merely delayed shock and longer latencies avoided it. All other aspects of the procedure were identical with that used in the Constant Delay condition of Experiment 1. Animals that tended to have short latencies from Experiment 1 (i.e., S1, S3, C2) were placed on the late avoidance procedure. Animals that tended to have long latencies in Experiment 1 (i.e., C1, C3, S4) were placed on the early avoidance procedure. Animals that had low response probabilities were arbitrarily placed on one of the two procedures. Seven or eight sessions were run, depending upon the animal.

Results and Discussion

Early Avoidance procedure. Those animals on the early avoidance procedure shortened their average latencies almost immediately and maintained or developed a high response probability. L2 was a typical animal in the condition. As Figure 14 shows, its average latency decreased from near 10 sec to 1 sec and its response probability steadily increased from 7% to 99%.

Late Avoidance procedure. The animals placed on the late avoidance procedure did not change their response rate nor did they change

their average response latency. For instance, L1 who was a poor responder during Experiment 1 did not change its response probability or its average latency during the partial avoidance procedure. After a long latency which avoided shock, L1 would often follow on the next trial with a short latency which only delayed shock. L1 would then fail to respond on the next few trials.

These results differ from those that Sidman (1966) reported for his limited interval avoidance. He found the best responding in a procedure very similar to the late avoidance procedure in which long response latencies just before shock avoided it. The experimental conditions in his study, however, were quite different. He used a fixed bar, and a cycle length of 15 sec and no ITI. Also short response latencies in his procedure had no effect on the location of shock; while in this procedure they delayed it. From the results of this experiment it appears that animals favor avoidance of shock to delay of shock and that they quickly learn to make the avoidance response if avoidance follows short latencies.

Experiment 3

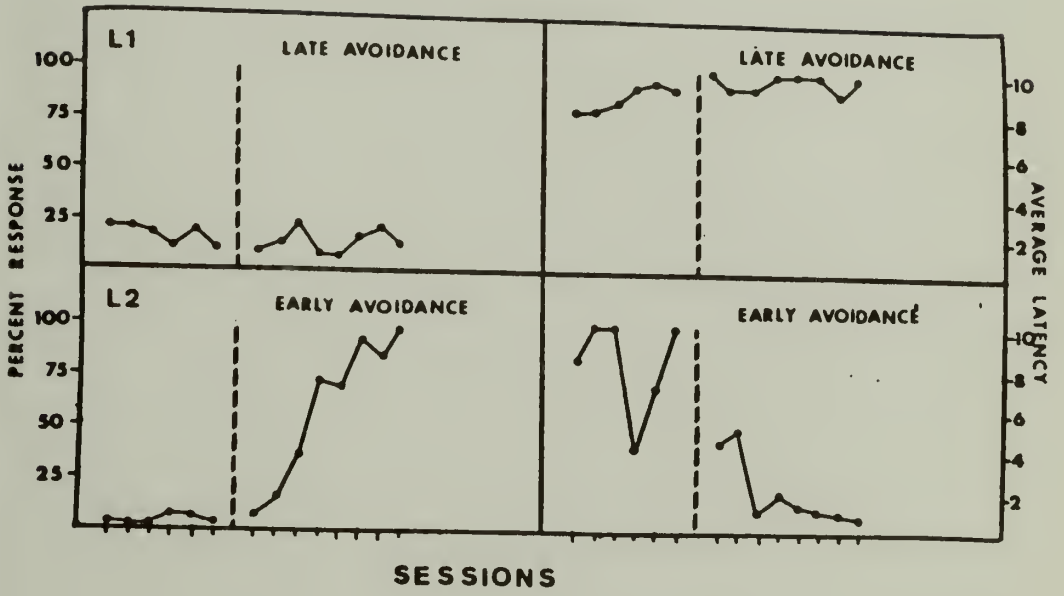
The purpose of this experiment was to see if the No-Delay procedure would eliminate the responding maintained on the partial avoidance schedules.

Method

Subjects

Subjects C3, C4, S3, and S4 from Experiments 1 and 2 were used.

Figure 14 The percent response and average latencies for two subjects that received either a late or early avoidance treatment. The data plotted to the left of the vertical dotted lines are from the last six sessions of Experiment 1 for each animal. Both animals were in the Long-Latency-Long-Delay condition in Experiment 1.



Apparatus

The apparatus was that used in Experiment 1.

Procedure

After the last day of partial avoidance, subjects were placed on the No-Delay procedure exactly as it was run in Experiment 1. During each session 240 31-sec cycles were given. Responses did not effect the location of shock but retracted the lever and terminated the white noise. Subjects were run for 5 days.

Results

The No-Delay procedure decreased the response probability for three of four rats and increased their average latencies. This increase in average latencies reflected the larger number of responses after shock. Figure 15 shows the effect of the No-Delay procedure on the probability of response and on the average latencies for each of the four animals. The No-Delay procedure may be more effective at eliminating responding after extended exposure to a response-avoidance procedure than after a brief exposure to a response-delay procedure. A parametric study with more animals would varify this point.

Experiment 4

During observations of animals placed on the L-LD delay procedure, it was noticed that animals appeared to freeze during the period after the response and before the delayed shock. After the shock the animals again engaged in normal exploratory activity. Perhaps the time interval between the delayed shock and the next lever extension was important. Animals may maximize the R-S delay better if there is a

relatively long time between the shock and the onset of the next trial. In Experiment 4 two animals from the L-LD condition of Experiment 1 who were good responders were placed on 41-sec cycles, each, 10 sec longer than the cycle used in Experiment 1. The extra 10 sec were attached to the end of the cycle after the delayed shock and 10 sec before the onset of the next trial.

Method

Subjects

Two subjects L3 and L4 from the L-LD condition who responded on approximately 100% of the trials of Experiment 1 were used.

Apparatus

The apparatus was the same as used in Experiment 1.

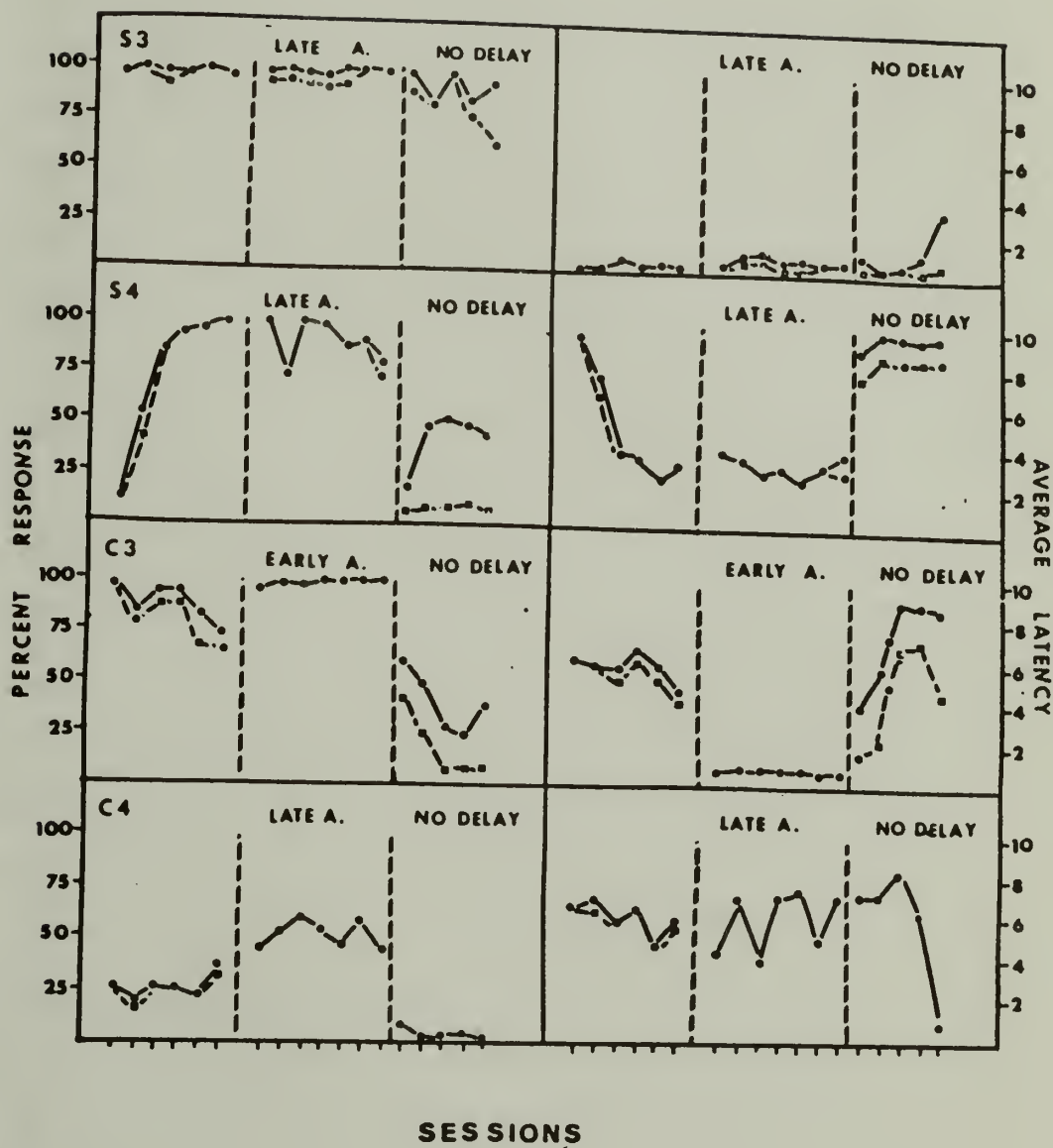
Procedure

Procedure was identical to the L-LD condition of Experiment 1 but the cycle length was 41 sec instead of 31 sec. Latencies produced delays as shown in the panel L-LD in Figure 1, but 10 sec were added to the end of each cycle. Because of the increased cycle length, only 176 cycles were given in each of the 12 sessions.

Results

The two rats continued to respond on the longer cycles. Also each animal increased its average response latency. Figure 16 shows the relative frequencies for each latency before and after the change in the cycle length. On Day 15 of Experiment 1 the modal relative-

Figure 15 The percent response and average latencies for four animals that received No-Delay training after receiving either late or early avoidance training. Each section is divided into three panels. The left panel is the data from Experiment 1. The middle panel is the data from Experiment 2. And the right panel is the data from the No-Delay treatment of Experiment 3. The solid lines connecting solid circles plot all responses. Dotted lines connecting open circles plot responses made before shock.



frequencies for both animals were between 1 and 3 sec. However, after 9 sessions on the longer cycle length, their modal relative-frequencies had shifted to longer latencies between 7 and 9 sec.

Discussion

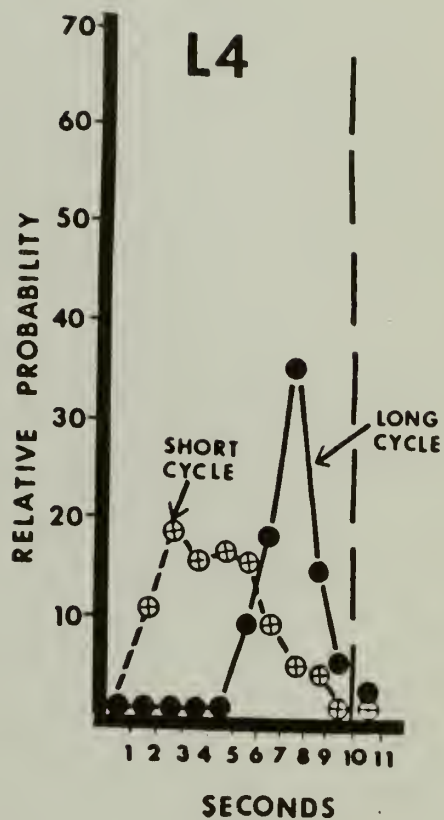
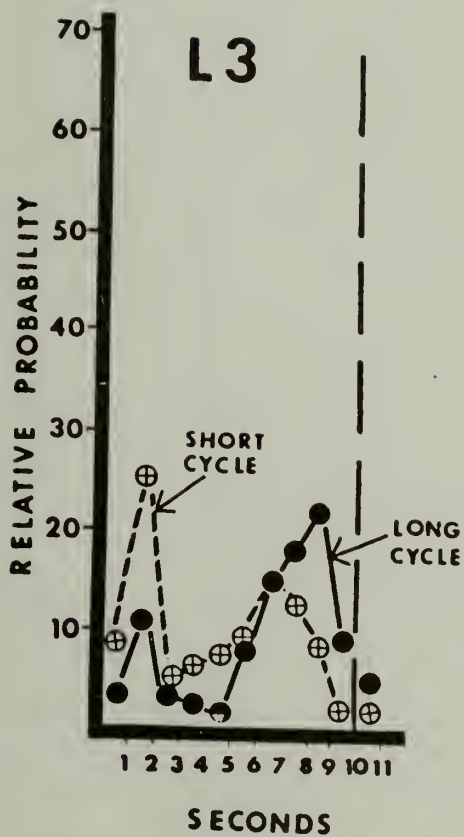
The longer cycle lengths allowed the two subjects to make longer response latencies. On the L-LD procedure these longer latencies produced longer R-S delays. Presumably the longer cycles enabled these rats to better maximize the R-S delay. However, it is not known whether the longer cycles produce longer latencies independent of the delay contingencies or whether longer cycles enable subjects to better maximize the R-S delay independent of the duration of the latency. For example, if the latter possibility is correct, the subjects on the S-LD procedure should shorten their latencies on the longer cycles. An experiment should be run comparing the latencies of S-LD and L-LD subjects on long cycles after they have received these same procedures on shorter cycles. This would eliminate the confounding of the two variables of R-S delay and duration of latency.

Even though these two variables were confounded, the results of Experiment 4 are still interesting and unpredicted. The period between shock and the next trial was not initially considered to be important but these data show that animals are sensitive to the duration of this interval and that animals will change their behavior when the interval is lengthened.

Experiment 5

It was expected in Experiment 1 that a procedure that programmed

Figure 16 Relative frequencies for L3 and L4 on a 31-sec cycle and on a 41-sec cycle, under the Long-Latency-Long-Delay treatment. The data for the short cycle is taken from Session 15 of Experiment 1. The data for the long cycle is from the ninth session under the 41-sec cycle.



no shock delay after a response would lead the animal to stop responding. The results, however, showed that three of five animals under this condition continued to respond. Experiment 5 attempted to eliminate this responding by titrating the delay of shock after each response, that is by moving the shock closer to the beginning of the cycle each time the animal responded and farther from the beginning of the cycle each time the animal failed to respond.

Method

Subjects

Four subjects from Group No-Delay in Experiment 1 who had maintained responding were used.

Apparatus

The apparatus was the same that was used in Experiment 1.

Procedure

The procedure was the same as that used in the No-Delay condition in Experiment 1 except that each response latency less than 10 sec, subtracted 0.25 sec from the potential location of shock on the next trial if a response occurred. If the animal did not respond, then 0.25 sec was added to the potential location of shock on the next trial if a response occurred. For example, if a response was made on Trial 1, the shock was delivered at Sec 10. If a response was made on Trial 2, a shock was delivered at Sec 9.75. However, if no response occurred on Trial 3 and a response occurred on Trial 4, then the shock was again delivered at Sec 10. If the shock delay had been reduced to 1 sec and a response occurred at the fourth sec, then the shock was

delivered immediately and the potential delay of shock on the next trial was set at 0.75 sec. Shock could not be programmed to occur after Sec 10 or before Sec 0 of the cycle. Responses after shock, that is, responses between Sec 10 and Sec 11, had no effect on the titration procedure. Two subjects were run for 7 sessions and the other two were run for 8 sessions.

Results

The titration procedure did not appreciably change or reduce the overall response probability of the four subjects. However, it did affect the distribution of pre- and post-shock responses for two of the rats as shown in Figure 17. N2, who had responded mainly before shock on the normal No-Delay procedure of Experiment 1, reduced its percentage of responses before shock to near zero. The titration procedure appeared to punish the pre-shock responding for this animal. The opposite results were found for N3. This animal had responded on approximately 25% of the cycles before shock during Experiment 1. During the titration procedure, this animal increased its percentage of before-shock responses to nearly 75%. Since every response before Sec 10 of the cycle decreased the delay of shock on the next trial, N3 was receiving over half of its shocks immediately after responses. During each of the last few sessions, N3 received about 90 shocks immediately after a response.

Discussion

The reasons for these results are very unclear. For one animal, the titration procedure decreased the probability of pre-shock

responding. For another animal it increased the probability of pre-shock responding. The pre-shock responder was seen to use the lever as a spring board to vault around the walls of the box when the response-produced shock was being given. This animal had complete control of when the shock would be given, and perhaps this jumping behavior was an effective "avoidance" response.

The No-Delay procedure might be modified so that the lever would retract just before or during shock. This would eliminate the post-shock responding and would allow for a better evaluation of the effect of the No-Delay procedure.

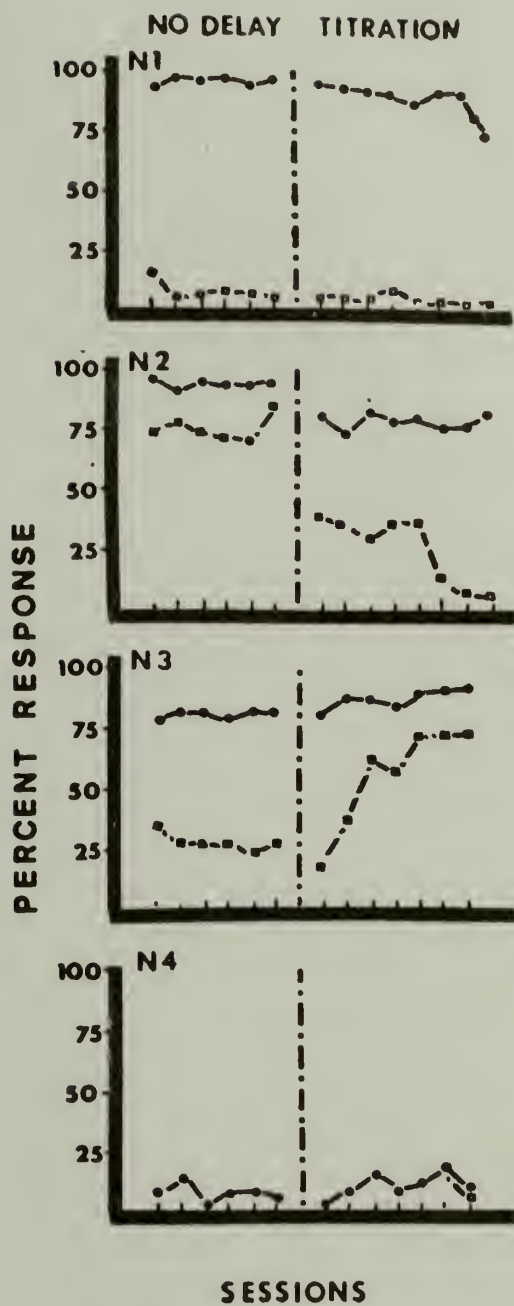
General Discussion

There are several major findings from this research. First, most animals initially responded to delay shock but only about half of these animals maintained this behavior over a period of days. Those animals that did maintain responding did so at a level that approximated 100%. Those animals that failed to maintain bar pressing usually responded on less than 30% of the cycles.

Second, if an animal consistently depressed the bar to delay shock and if the duration of the delay depended on the response latency, then the animal adjusted its latencies to maximize the R-S delay. The data show that the good responders in the Short-Latency-Long-Delay condition all had shorter latencies than the good responders in the Long-Latency-Long-Delay condition. The median response latencies did not overlap between the two conditions.

Third, if an animal consistently bar pressed to delay shock but its response latencies did not affect the duration of the R-S delay,

Figure 17 The percent response for the No-Delay subjects on a Titration-of-Delay procedure. The data to the left of each vertical dotted line is from Experiment 1. The solid lines, connecting solid circles, plot all responses. The dotted lines connecting open circles, plot response made before shock.



then the median response latencies were variable among subjects. The range of response latencies for the CD condition was larger than for either the S-LD or L-LD condition. In the CD condition in which every response latency produced 19 sec of R-S delay, the median latencies among subjects varied from approximately 1 sec to approximately 6 sec, a range of 5 sec. However, in the S-LD condition the latencies varied from approximately 0.5 sec to 3.5 sec, a range of only 3 sec; and in the L-LD condition the latencies varied from approximately 4 sec to 6.5 sec, a range of only 2.5 sec.

Fourth, a poor responder usually placed its few responses during the 1 sec after shock when the lever was still available. This result suggests that responses were shock elicited. Good responders, those that usually responded on almost 100% of the cycles, seldom made responses after shock. When post-shock latencies did occur, they were usually made in the very early portion of the session.

Fifth, most of the subjects in the discrete trial avoidance procedure maintained their responding during the training period. Their latencies and response probabilities were very similar to the latencies and response probabilities of the shock-delay animals.

Sixth, the No-Delay condition was not consistently effective in eliminating responding. Two animals stopped responding. Three did not. These three animals responded on more than 80% of the cycles; however; most of their responses were shock elicited and occurred immediately after shock. A titration-of-delay procedure did not eliminate responding either. However, it did change the response latency in two of four animals exposed to it. One animal that had

previously responded before shock before the titration procedure, responded mainly after shock following the titration procedure. The exact opposite was true of a second animal. The No-Delay procedure developed more shock-elicited responding than any other procedure.

Seventh, when two subjects from the L-LD condition were placed on the L-LD procedure with longer cycles, their modal relative frequencies shifted from between 1 and 3 sec on the short cycles to between 7 and 9 sec on the long cycles even though the R-S delays assigned to each latency remained the same.

Eighth, several animals were placed on a procedure in which some latencies avoided shock while others only delayed shock. Animals placed on a procedure in which very short latencies produced avoidance quickly shortened their average latencies by as much as 4 sec. However, animals placed on a procedure in which long latencies produced shock avoidance, did not increase their average latency to any great extent even though they made some responses that avoided shock, and thus were exposed to the contingency.

Hineline (1970) found that animals would respond to delay shock on approximately 80% of the trials even though responses did not reduce the overall frequency of shocks. The findings from this research support Hineline's data in that animals did respond to delay shock. In fact some animals in the present study had a higher response probability than Hineline had found. In addition the probability of response to delay shock was very similar to the probability of response to avoid shock.

However, where Hineline found that all of his subjects would respond to delay shock, this research found that only about half of the subjects placed on the delay procedures would continue to respond to delay shock. The discrepancies in the two results may be due to the procedural differences in the two studies, or to the strains of rats used as subjects. Hineline used Lashley brown rats; the present study used albinos. Hineline used a cycle length of 20 sec; this research used a cycle length of 31 sec. On no-response trials Hineline delivered a shock at Sec 8 in the 10-sec bar extension period; this research delivered the shock during Sec 10 in the 11-sec bar extension period. Hineline always scheduled the response-delayed shock at Sec 18 of the 20-sec cycle. However, in this research the location of the shock was variable and depended upon the response latency. For example, in the Constant Delay procedure the shock always occurred 19 sec after a response and therefore, depending on the latency, could occur between Sec 19 and Sec 29 of the cycle.

It was observed in Experiment 1 that during the CD preliminary training all poor responders started to respond much later than the good responders did. Because of the nature of the CD delay procedure, this period of warm-up shown by the poor responders may have affected the strength of the lever-press response vis-a-vis other responses made by these animals. During the Discrete Trial Avoidance phase of preliminary training, the lever retracted and the white noise terminated only after a lever-press response. Perhaps this compound stimulus came to signal a period of safety (see Bolles, 1970) because it was followed by 21 sec of shock-free time. During the second phase

of preliminary training which was the Constant Delay training, retraction of the lever now occurred under two circumstances: (1) After a bar-press response, (2) 1 sec after shock when no bar-press response occurred. During the initial trials of the CD procedure, it is possible that some other responses, not observed or measured, were occurring while the lever was being retracted 1 sec after shock. These unmeasured but reinforced responses then may have interfered with and competed for the discrete trial bar-press response causing these slow responders to become poor responders. One would need to use careful observational techniques to determine if in fact competing responses were being reinforced under the conditions that were used in this research.

A larger proportion of responders survived on the CD procedure than on any other delay procedure. Since the R-S interval was fixed at 19 sec, the procedure enabled the subject to form a temporal discrimination and this discrimination made the subject better able to predict the onset of the delayed shock. In the S-LD and L-LD procedures a temporal discrimination was not as readily available because each different response latency produced a different delay of shock (see Figure 1) and, therefore, it would be difficult for an animal to predict when the shock was expected. Perhaps one of the conditions for good avoidance responding, when responses are not shock elicited, is that the delayed shock be located at a predictable point with respect to the response, (a constant R-S interval) or with respect to some external event (e.g., the onset of the CS and bar extension, Hineline, 1970). The variable delay of shock may also be a cause of the rapid decrease in responding for the several animals in the S-LD

and L-LD conditions. The variable delay of shock does not allow the animal to form any temporal discrimination and the shock is unsignalled. Several researchers have suggested that animals prefer signalled to unsignalled shock (Lockard, 1963; Badia, Stuart, and Culbertson, 1971; Perkins, Seymann, Levis, and Spencer, 1966).

It should be possible to use a conditioned suppression paradigm to determine, (1) if the R-S delay period is aversive and, (2) if the delay period which is fixed in the CD procedure is less aversive than the delay period which is variable in the S-LD and L-LD procedures. A unique signal could be presented during the delay period and then tested using a conditioned suppression procedure to see if the signal had any suppressive effect on an appetitively-maintained response.

The findings from the No-Delay condition were rather unexpected because it was predicted that responding would cease under this procedure. However, responding was maintained in three of five animals. Recently Gibbon and O'Connell (1973) have reported some data from a procedure very similar to the No-Delay procedure. Their data were very similar to the present results. They used a retractable bar procedure with an ITI of 100 msec. The ITI in this 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, however, their responding was almost exclusively after shock or shock elicited.

This shock-elicited responding also characterized the behavior that animals showed on the No-Delay condition in this 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 the research, animals did control the location of shock and it was observed that their responses occurred almost exclusively before shock. The left panels of Figures 2, 4, and 6 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 10 placed most of their responses after shock. Also the poor responders in the delay and No-Delay conditions behaved in a similar fashion. Both made a relatively high frequency of responses after shock. In summary, the good responders in the No-Delay condition responded mainly after shock and the good responders in the CD, S-LD and L-LD delay conditions responded mainly before shock.

This research also bears on the issue of whether animals respond to changes in the relative frequency of events (Herrenstein, 1969; Rescorla, 1967), or whether they respond to changes in temporal contiguities of events (Benedict and Ayres, 1972; Hineline, 1970). If animals are really sensitive to the relative frequencies of events, what is the mechanism that enables relative frequencies to exert control on the animals? There are only two possible mechanisms. To use the avoidance procedure as an example, first, the animal may count shocks during some unit of time. And if the number of shocks before a response is greater than the number of shocks after a response, then the animal may discriminate the difference in number. 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, however, requires a great deal of memory from the animal and, thus, is highly unlikely. The second mechanism is based on a temporal discrimination. The animal may "time" the intervals between shocks before and after a response. And, if the shock-response-shock interval is greater than the shock-shock interval, the animal may form a discrimination that responding decreases the temporal contiguity of shocks and increases the interval between shocks.

The responding found in this 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 form 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, making the interval between successive shocks equal 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 to respond because responses increase the duration between shocks.

Gibbon (1972) has recently presented a mathematical model of

avoidance behavior that is based on this second discrimination process, the process of comparing different temporal intervals. He assumes that animals respond according to a scalar timing process and that they are capable of distinguishing different time intervals. Because of this capability, they are able to compare different shock-shock intervals. The two important intervals are one without a response and the other with at least one response. His model formulates a probability that an animal will make the discrimination that responses are worth their while and increase the interval between shocks. Gibbon argues that this discrimination is based on a biased decision rule because experimental literature (e.g., Sidman, 1962) shows that rats will not respond to avoid shock until there is a huge advantage for doing so.

This 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. However, Gibbon assumes that discriminations occur only after a shock. Perhaps discriminations can occur after other events as well. The two possible events in the procedures used in these studies are the beginning of each cycle and a response. The response appears to be the more important event for two reasons. First, it was with respect to the response that animals in the S-LD and L-LD conditions maximized the interval until shock. Second, if the beginning of each cycle were important then all of the animals in the CD procedure would have displayed long latencies in order to maximize the interval between trial onset and shock. But they all did not show long latencies.

However, both events may be important in the discrimination process. Perhaps the animal compares the time interval between the onset of the

trial and shock and the time interval between response and shock. And if the R-S interval is sufficiently greater than the trial-onset-shock interval without a response, then the animal may continue to respond. And if the R-S interval is not sufficiently greater, the animal chooses either not to respond at all or to respond only after shock. This post-shock response, in a way, does in fact produce the longest R-S interval for this subject if it does not respond before shock.

Gibbon's model is successfully quite able to predict the asymptotic behavior on Sidman avoidance and on Herrnstein and Hineline's (1966) shock probability experiment. However, his model has some difficulty in predicting asymptotic behavior in Hineline's shock-postponement experiments, when Gibbon assumes that discrimination trials occur only after a shock. This research suggests that discriminations may also begin after responses, because animals were found to alter their response latencies in order to maximize the R-S interval. The results reported here can not 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 Response-Shock interval.

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