Glaser

13(1)41-50(1970)

JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1970, 13, 41-50 NUMBER 1 (JANUARY)

DRL ESCAPE: EFFECTS OF MINIMUM DURATION AND INTENSITY OF ELECTRIC SHOCK[1]

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Three dogs were exposed to a DRL-escape procedure that required them to endure a minimum duration of electric shock without responding in order for a response to terminate that shock. When this minimum duration increased from 0 to either 2.25 or 7.00 sec, response latencies increased proportionately. With the minimum duration held constant at 2.25 sec, a gradual increase in shock intensity to 5.0 ma had no systematic effect upon latencies. Even under the highest shock intensity, 5.0 ma, latency and interresponse-time distributions were unimodal with very few latencies and interresponse times less than the minimum duration. Three additional dogs were exposed to an escape procedure in which every response was immediately reinforced. For these subjects, the same increase in shock intensity to 5.0 ma was accompanied by a decrease in latencies. The precise temporal spacing of responses obtained with the DRL-escape procedure may in part be due to the fact that every response latency and interresponse time that did not meet the minimum duration was not only extinguished but was also punished.

No mention of frequency

Most analyses of temporally spaced responding have used either schedules of positive reinforcement (*e.g.*, FI, DRL) or a Sidman avoidance procedure (*e.g.*, Anger, 1963; Sidman, 1966). There is little information on the effectiveness of escape procedures in maintaining such responding. Kaplan (1952) examined the performance of rats under a fixed-interval escape procedure described by Keller (1941). In Kaplan's experiment, lever presses during a t-sec interval of high illumination had no effect, whereas the first response after *t* sec terminated the light. In general, the rats responded at a relatively constant rate in the presence of the noxious stimulus, failing to space responses differentially within the fixed interval.

On the other hand, Bower (1960) did modify the average running speed of an escape response by exposing rats to an escape procedure in which a running speed of less than 1.6 ft/sec (49 cm/sec) in an electrified alley was selectively reinforced with a 20-sec shock-free period in the goal box, and a running speed greater than 1.6 ft/sec was followed by a 20-sec period of shock in the goal box. The relative frequency distribution of running speeds in the alley was unimodal with the modal speed slightly less than the reinforcement requirement (1.6 ft/sec) and very few running speeds greater than the requirement.

The present study examined temporally spaced responses of dogs exposed to an escape procedure in which both long response latencies, measured from shock onset, and long interresponse times (IRTs), measured from the previous response on a trial, were selectively reinforced with the termination of electric shock. Unlike the Kaplan or Bower procedures, the present procedure required a minimum duration of noxious stimulation without responding before a response could terminate that stimulation. Such a procedure enabled one to study the precision with which a subject can temporally space responses after an aversive stimulus is presented, as well as after the occurrence of a non-reinforced response in the presence of the aversive stimulus. Temporally spaced responses were examined also as a function of the intensity of the noxious stimulus.

[1]Portions of these results were presented to the American Psychological Association Convention, San Francisco, California, September, 1968. This research was supported by a National Institute of Health post-doctoral fellowship to the author and by USPHS Grant MH-04202 to Richard L. Solomon. The author is grateful to Dr. Leila R. Cohen for helpful criticism in preparing this manuscript. Reprints may be obtained from the author, Department of Psychology, Florida State University, Tallahassee, Florida 32306.

METHOD

Subjects

Six male mongrel dogs obtained from Lone Trail Kennels, Fredericksburg, Pa., were each from 15 to 19 in. (38.1 to 48.3 cm) high at the shoulders and weighed 24 to 28.5 lb (11 to 13 kg). For a minimum of one week before and throughout the study all dogs had free access to Purina Dog Chow and water in individual home cages.

Apparatus

A Pavlov-type hammock (Black, 1958) isolated in a sound attenuated chamber was constructed so that a dog's legs hung below its body through four holes. All four paws were securely tied to the base of the hammock with cloth straps. The dog's head was centered between two parallel response panels (8 by 8 in. [20.3 by 20.3 cm]) 10 in. (25.4 cm) apart, and a metal yoke was placed across the dog's neck. The hammock was oriented so that the response panels were centered in front of and perpendicular to a one-way mirror. Constant-current electric shocks were administered through 1.875 by 2.75 in. (4.8 by 7.0 cm) brass-plated electrodes, coated with electrode paste, and taped to the hind footpads.

fig. ?

The chamber was illuminated from above by two bulbs (totalling 150 w) and by a 15-w bulb mounted above the one-way mirror. A blower provided continuous ventilation and white noise (approximately 70 db re SPL) was continuously present. Experimental contingencies and recordings were scheduled by a system of relays, timers, and counters.

Procedure

Immediate-escape procedure. Each dog was initially trained to press its head against the panel on its left after electric shock by making shock termination coincide with successive approximations to panel pressing. Shock-off periods during this "shaping" were 30 sec in duration. Each subject was then exposed to its first session on the immediate-escape procedure. An immediate-escape trial began with the presentation of electric shock. If the dog pressed the left panel, shock terminated and remained off for 60 sec. Shock otherwise remained on indefinitely. A session consisted of 80 trials.

DRL-escape procedure. A DRL-escape trial also began with the presentation of shock. If a subject's latency of left-panel pressing was *t* sec or more (the minimum duration), shock terminated for 60 sec. If the latency was less than the minimum duration, shock remained on until an interresponse time of *t* sec or more had elapsed.

Phase 1. Three dogs were arbitrarily assigned to an Immediate-Escape Group and the other three dogs to a DRL-Escape Group. The procedures are outlined in Table 1. During Phase 1, Subjects P-5, P-10, and P-8 were exposed to sessions of the immediate-escape procedure with a fixed shock intensity of either 2.0 or 2.5 ma. Subjects P-1, P-2, and P-3 were likewise exposed to only one shock intensity (2.0 or 2.5 ma) throughout Phase 1, but after either two or three sessions of immediate escape, the DRL-escape procedure began. The minimum duration was gradually increased to 7 sec for P-1, to 2 sec for P-2, and to 2.1 sec for P-3 such that it was not greater than 80% of the latencies obtained from the preceding session. During the final six sessions, the minimum duration was changed to 2.25 sec for all three dogs.

Phase 2. The immediate-escape procedure remained in effect for the Immediate-Escape Group and the minimum duration was held constant at 2.25 sec for the DRL-Escape Group, while the shock intensity was gradually increased in 0.5-ma increments to a maximum value of 5.0 ma. All six subjects received from two to three daily sessions at each shock-intensity value.[2]

Phase 3. Subjects in the DRL-Escape Group were given two additional sessions on the DRL 2.25-sec procedure and then six sessions on the immediate-escape procedure, all eight sessions with a 5.0-ma shock intensity.

RESULTS

Figure 1 summarizes the data for the subjects of the DRL-Escape Group during the initial phase of the experiment. With a gradual increase in the minimum duration to 7 sec for P-1, to 2 sec for P-2, and to 2.1 sec for P-3, there was a proportional increase in median

[2]Between Phases 2 and 3, subjects in the DRL-Escape Group were exposed to one session of 14 trials on a discriminated escape-avoidance procedure in a two-way shuttlebox (Cohen, 1970). Since the data from that part of the experiment are not reported here, the details of the procedure are not given.

Table 1

Number of sessions under each experimental condition for all subjects. Included are the shock intensities (ma) as well as the procedures to which each dog was exposed.

	Subjects				
	P-8	*P-5*	*P-10*	*Procedure*	*Shock Intensity (Ma)*
Phase 1	25*	15	21	Immediate Escape	2.5
Phase 2	3	–	–	Immediate Escape	2.5
	2	2	2		3.0
	2	2	2		3.5
	2	3	2		4.0
	2	2	2		4.5
	2	2	2		5.0
	Subjects				
	P-1	*P-2*	*P-3*		
Phase 1	2*	2	3	Immediate Escape	2.5
	17*	7	12	Ascending DRL-Escape Values	2.5
	6*	6	6	DRL-Escape (2.25 sec)	2.5
Phase 2	3	–	–	DRL-Escape (2.25 sec)	2.5
	2	2	2		3.0
	2	2	2		3.5
	2	3	2		4.0
	2	2	2		4.5
	2	2	2		5.0
Phase 3	2	2	2	DRL-Escape (2.25 sec)	5.0
	6	6	6	Immediate Escape	5.0

*Sessions at 2.0 ma.

latency. During most daily sessions, the median latency was either equal to or greater than the minimum duration. There was no systematic change in variability (interquartile ranges) over sessions.

With a decrease (right-hand panel) in the minimum duration from 7 to 2.25 sec for P-1, the median latency also decreased from approximately 7 sec to 2.25 sec, and then remained approximately equal to or greater than the minimum duration. Similarly, the median latencies of Subjects P-2 and P-3 were equal to or greater than the 2.25-sec minimum duration during the final six sessions of Phase 1.

P-5, P-10, and P-8 of the Immediate-Escape Group, however, showed no systematic increase in median latency analogous to that observed for the DRL-escape subjects throughout Phase 1. P-10 consistently responded with latencies of less than 2 sec, whereas P-5 and P-8 exhibited greater inter-session variability with median latencies ranging from 0.5 to 9.1 and 1.0 to 5.0 sec, respectively.

Figure 2 shows that with a gradual increase in shock intensity to 5.0 ma, the DRL-escape subjects (left-hand panel) exhibited neither a systematic increase nor decrease in median latency, latencies remaining equal to or greater than the 2.25-sec minimum duration. The three immediate-escape subjects (right-hand panel), on the other hand, showed a decrease in median latency to less than 1 sec with no overlap between interquartile ranges obtained under the highest and lowest shock intensity values.

As can be seen in Fig. 3, under both the DRL- and immediate-escape conditions, latency distributions were unimodal. The DRL-escape subjects, P-2, P-3, and P-1 had 5, 13, and 5% respectively, of their total latencies less than the minimum duration and 0, 1, and 0% of their latencies less than 1 sec. In contrast, the immediate-escape subjects, P-5, P-10, and P-8 had 73, 89, and 95% respectively, of their total latencies equal to or less than 1 sec.

As previously noted, Fig. 3, under the highest shock intensity, 5.0 ma, the three DRL-escape subjects had relatively few trials (from 5 to 13%) on which the initial latency was less than the minimum duration. For the purpose of further analyzing trials on which the mini-

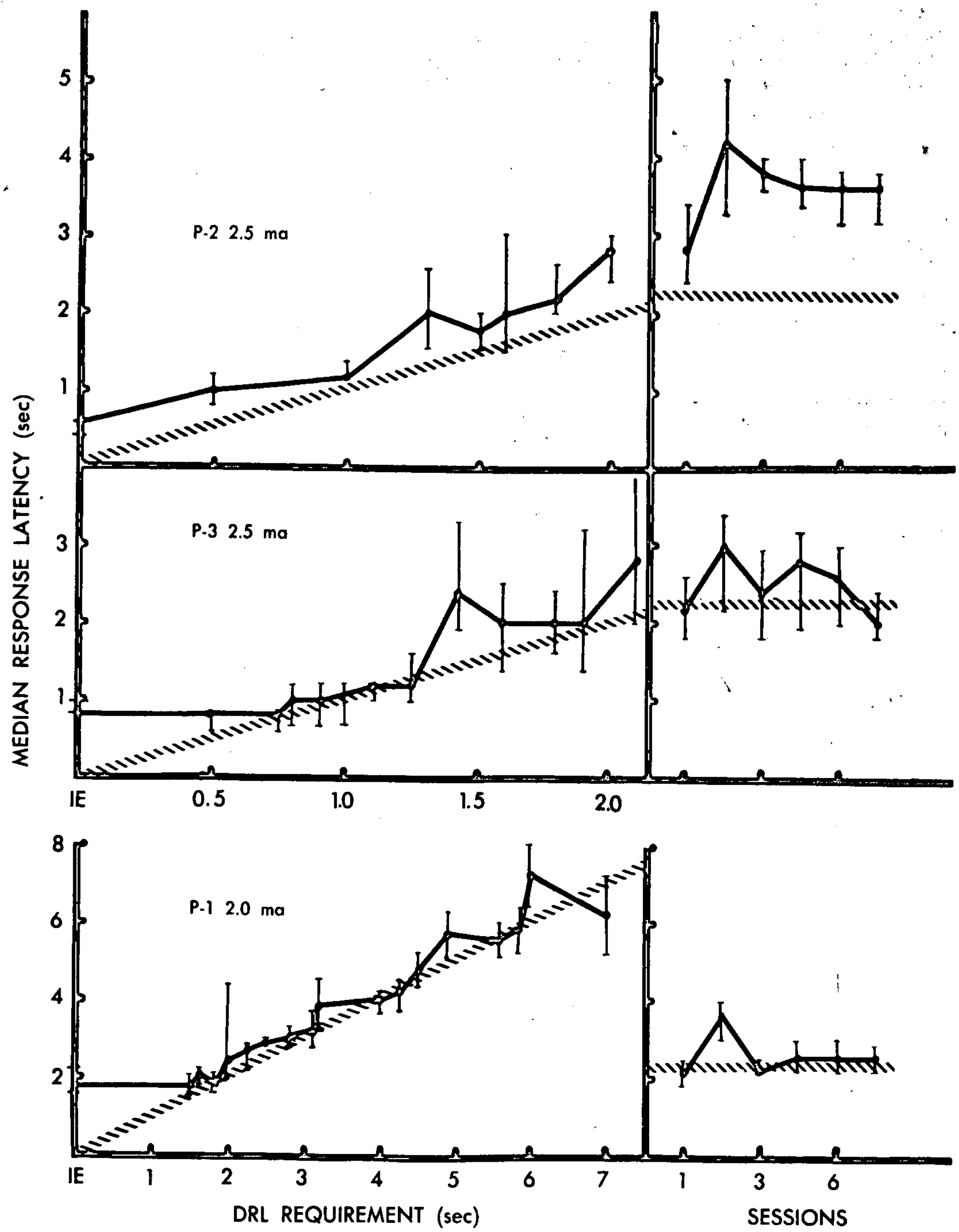

Fig. 1. DRL-Escape Group during Phase 1. On the ordinate is median response latency (sec) and on the abscissa for the left-hand panel is minimum duration (sec) with IE representing the final day under the immediate-escape condition. Successive daily sessions are indicated on the abscissa of the right-hand panel. Each data point represents one 80-trial session and the vertical lines are interquartile ranges. The striped lines in the left-hand panel correspond to points at which the median response latency is equal to the minimum duration, and in the right-hand panels indicate that a minimum duration of 2.25 sec was in effect throughout.

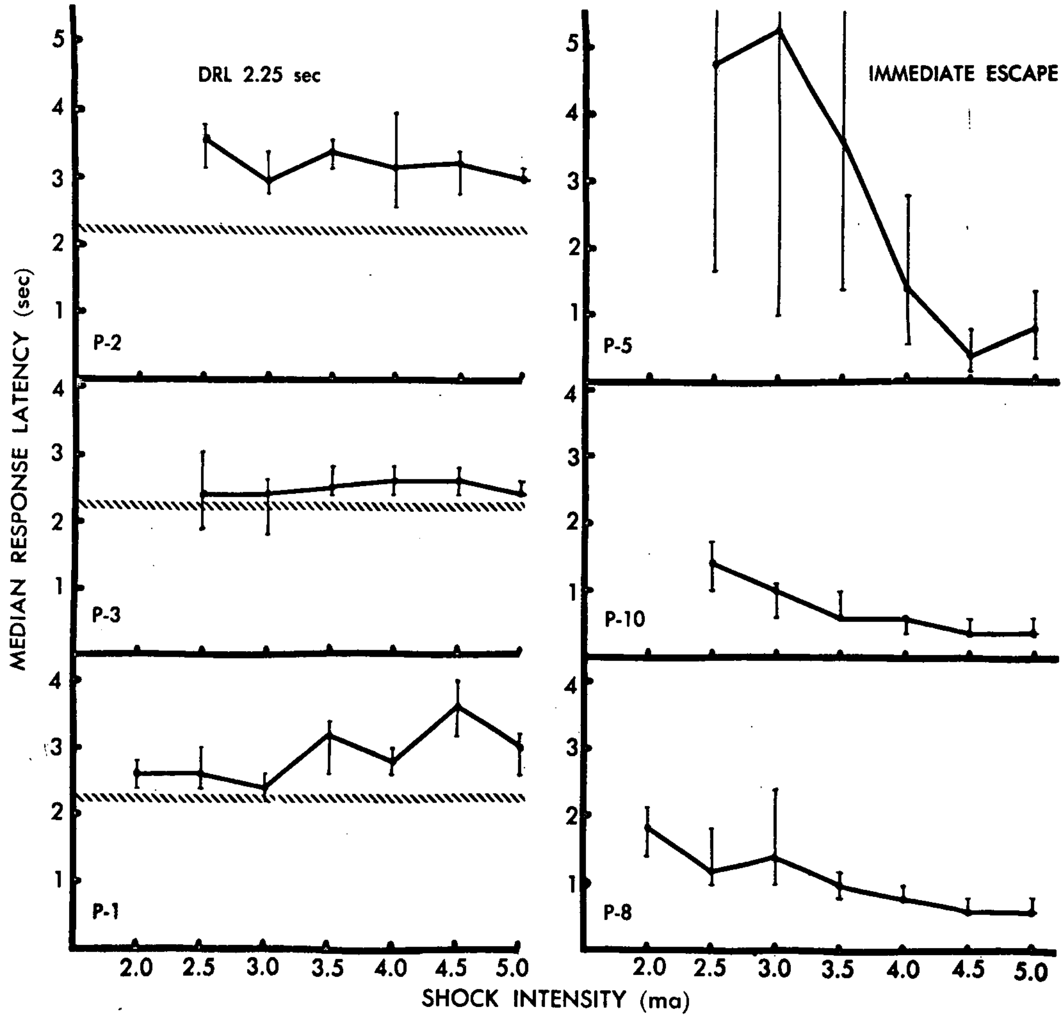

Fig. 2. Median response latency (sec) as a function of shock intensity (ma) for the DRL- and Immediate-Escape Groups. Each data point corresponds to either two or three sessions and the vertical lines are interquartile ranges for those sessions. The striped horizontal line in the left-hand panel indicates that the minimum duration remained constant at 2.25 sec. For each subject, the latency plotted for the lowest shock-intensity value corresponds to the median response latency during the final two sessions of Phase 1.

mum duration was not met, the data from such trials are combined for Subjects P-2, P-3, and P-1 and summarized in Fig. 4. As the individual relative frequency distributions in Fig. 3 suggest, 36 of the 46 latencies (bottom panel) that were less than the minimum duration (indicated by the vertical line) were either 2.0 or 2.2 sec in duration.

The IRT distribution immediately above this latency distribution includes IRTs between the first and second responses in the presence of shock. All but one IRT were greater than 1.4 sec and the mode, 2.4 sec, was longer than the 2.25-sec minimum duration. The distribution above this latter one includes all additional IRTs obtained from trials on which three to six responses occurred in the presence of shock. This distribution is likewise unimodal with the mode, 2.6 sec, longer than the minimum duration.

The effects of changing the contingency from a DRL- to an immediate-escape condition are summarized in Fig. 5. During the final two sessions on the DRL-escape procedure, indicated as Sessions 1 and 2, the median latencies, as well as the interquartile ranges, were again greater than the minimum duration. With the reintroduction of the immediate-escape

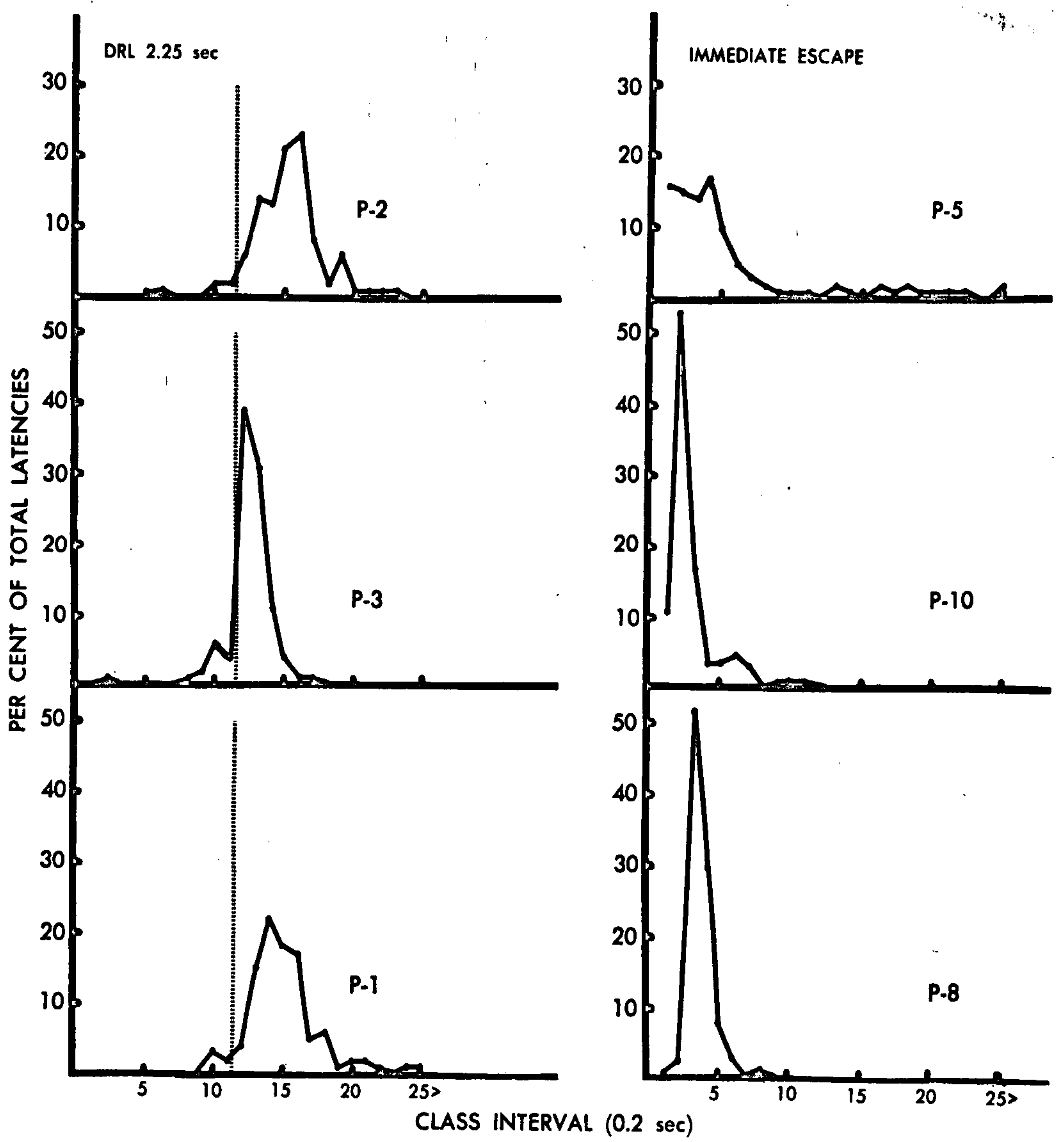

Fig. 3. Relative frequency distributions of latencies for the DRL- and Immediate-Escape Groups under the highest shock intensity, 5.0 ma. Per cent of total latencies is plotted as a function of 0.2-sec class intervals.

procedure, the median latencies of P-2 and P-3 decreased within two and four sessions, respectively, to less than 1 sec. On the other hand, the median latencies for P-1 continued to be longer than what had previously been the minimum duration (2.25 sec) with only 2% of the latencies less than that value.

DISCUSSION

Over the range of values used, median latencies were directly proportional to the minimum duration. All three DRL-escape dogs tended to reduce the total amount of shock during a session by escaping with latencies that were generally equal to or greater than the minimum duration. In addition to escaping with long latencies, the DRL-escape dogs spaced successive responses in the presence of shock. Even under the highest shock intensity used (5.0 ma), IRTs tended to be equal to or greater than the minimum duration. In general, all three DRL-escape subjects temporally spaced responses after shock was presented as

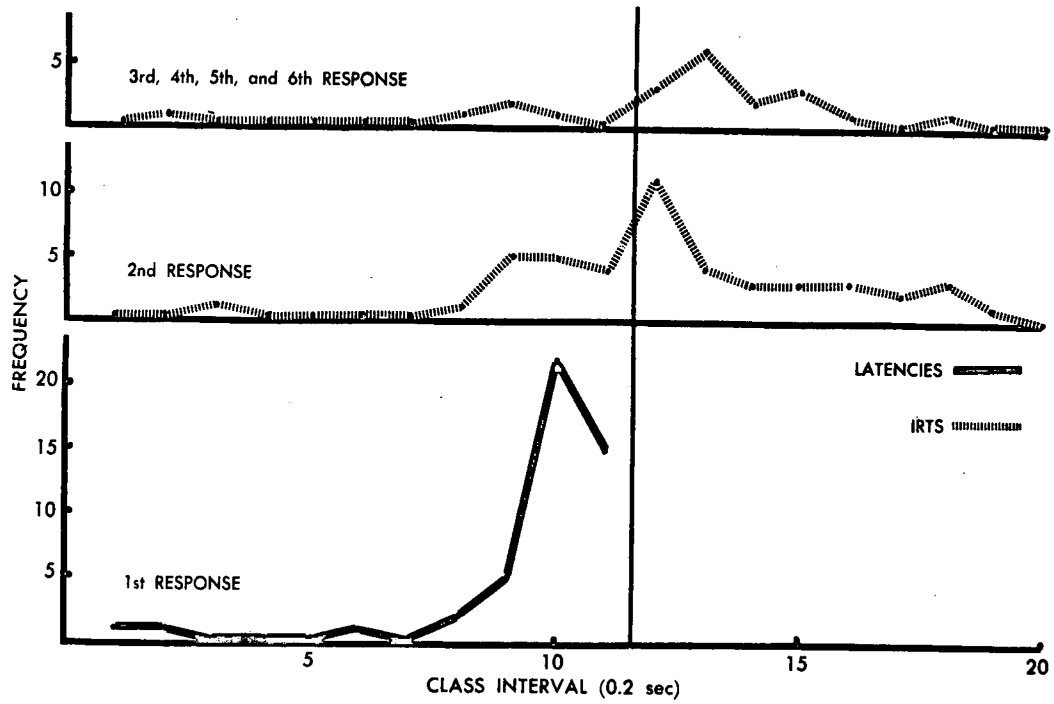

Fig. 4. An analysis of those DRL-escape trials, under the 5.0-ma shock intensity condition, on which the initial response latency was less than the minimum duration. The latency as well as IRT distributions include the combined data for Subjects P-1, P-2, and P-3. The bottom panel is a frequency distribution of a total of 46 latencies. The IRT distribution in the panel immediately above the latency distribution includes IRTs between the first and second responses in the presence of shock. The distribution immediately above this latter one provides a comparable analysis of 22 additional IRTs obtained from trials on which three to six responses occurred in the presence of shock.

well as after the occurrence of a non-reinforced response in the presence of shock.

These observations are consonant with Bower's (1960) finding with rats that the running speed of an escape response in an electrified alley was subject to the effects of differential negative reinforcement. As was the case with escape latencies and IRTs in this study, the relative frequency distribution of running speeds was unimodal, with the modal speed slightly less than the reinforcement requirement and very few greater than the requirement.

The unimodal IRT distributions obtained with a DRL-escape procedure are, in general, not characteristic of IRT distributions obtained with rats (*e.g.*, Sidman, 1956), pigeons (*e.g.*, Staddon, 1965), or monkeys (Weiss and Laties, 1967) on free-operant DRL schedules of positive reinforcement. Even with a DRL requirement as small as 2 sec (Malott and Cumming, 1964) IRT distributions, for a rat, tend to be bimodal with one mode approximately equal to the DRL value and the second mode located at a value shorter than the DRL criterion. One factor that might have contributed to the precise spacing of responses in this study is that every IRT (as well as latency) that did not meet the minimum duration was not only extinguished but was also punished. Every response that failed to meet the minimum duration immediately extended the duration of aversive stimulation by a predetermined minimum amount.

Informal observations of the dogs exposed to DRL escape indicated that on each trial, a dog barked a fixed number of times (two or three) after shock was presented and then pressed the left-hand panel. One dog (P-3) combined a stereotyped head bobbing movement with such a barking sequence. These observations are analogous to the findings (*e.g.*, Wilson and Keller, 1953; Bruner and Revusky, 1961; Segal and Holloway, 1963; Laties, Weiss, and Weiss, 1969) that a subject, performing with a high degree of accuracy on

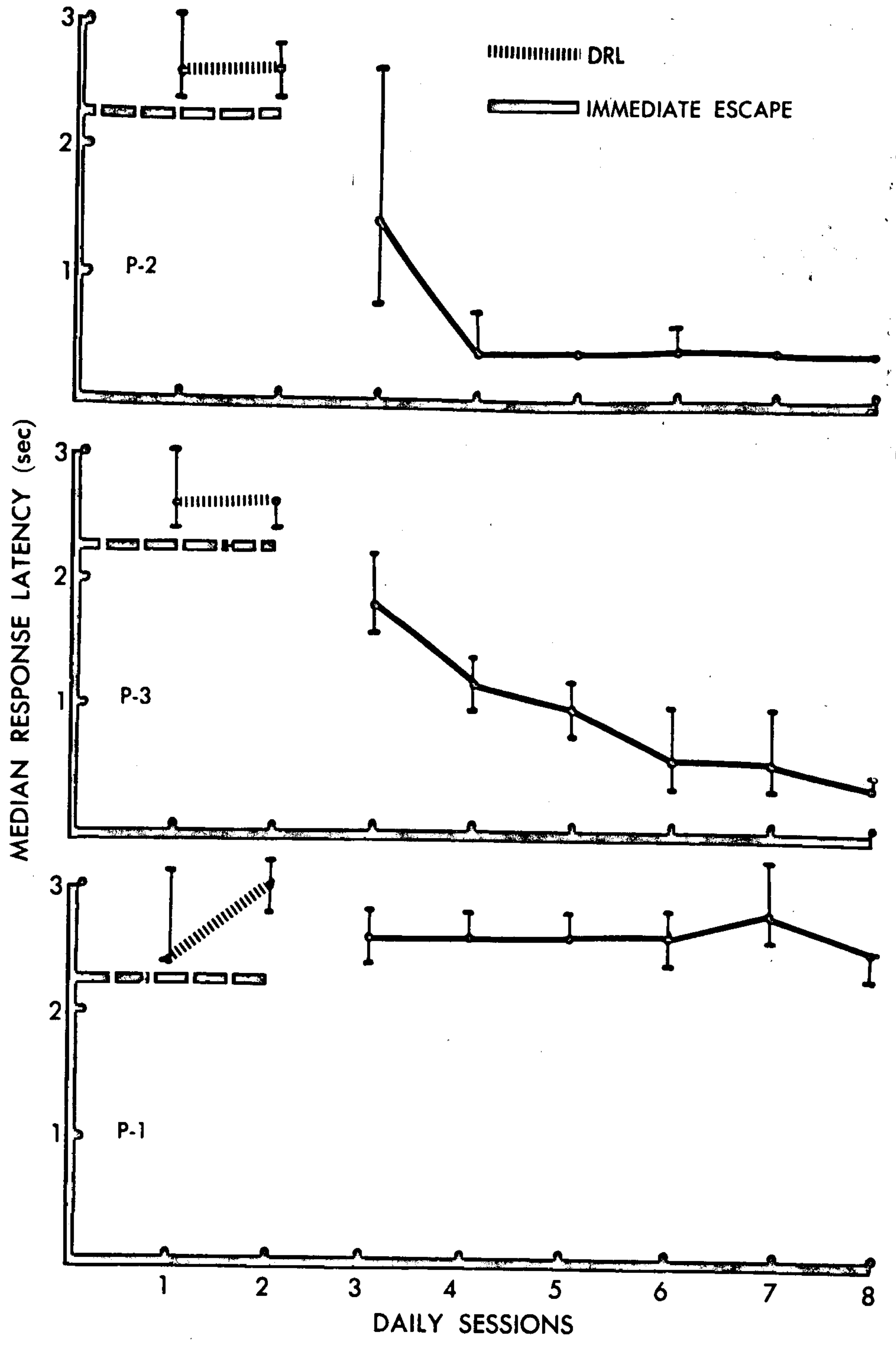

Fig. 5. Median response latency (sec) for the final two sessions on the DRL-escape procedure and for six subsequent sessions on the immediate-escape procedure. Each data point corresponds to one 80-trial session and the vertical lines are interquartile ranges. The shock intensity was 5.0 ma.

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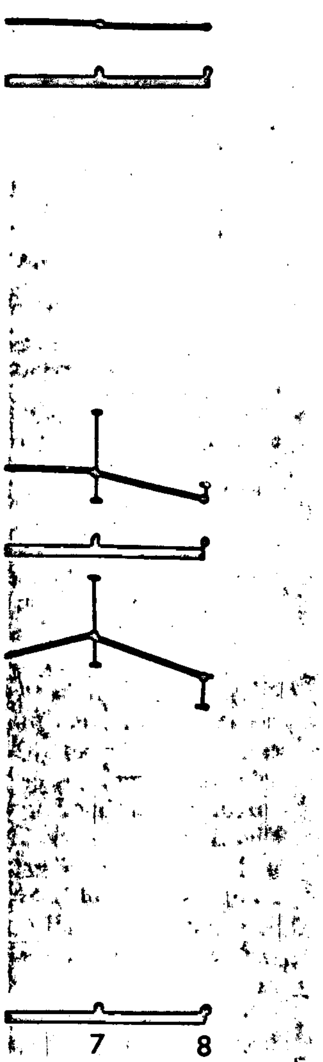

procedure and for six subse-
one 80-trial session and the

a DRL schedule of positive reinforcement, typically exhibits a stereotyped sequence of behavior (*e.g.*, gnawing, running, drinking) between successive responses. The suggestion that such stereotyped collateral behavior may function as a discriminative stimulus in a temporal discrimination (*e.g.*, Bruner and Revusky, 1961) has recently been supported by the work of Laties *et al.* (1969). They observed that the precision with which a rat performed on a DRL schedule is positively correlated with the "amount" of collateral wood-nibbling behavior.

When the reinforcement contingency was changed from DRL-escape to immediate-escape, Subjects P-2 and P-3 readily responded with latencies less than 2.25 sec, whereas P-1 did not. This failure to respond with short latencies may be related to the fact that P-1 had been exposed to a maximum DRL-escape value of 7 sec, whereas P-2 and P-3 had been exposed to a maximum DRL-escape value of only 2.25 sec.

Both DRL and FI schedules of positive reinforcement modify the temporal spacing of the reinforced response. Bower's experiment (1960), together with this one, are evidence that such effects can be obtained also in the presence of electric shock when running speeds, latencies, and IRTs are selectively reinforced with the termination of that shock. One might expect that subjects exposed to an FI escape procedure would likewise exhibit temporally spaced responding in the presence of the aversive stimulus. Kaplan (1952) examined the performance of rats under several FI escape values. He exposed each rat to an average of 15 sessions on each FI value (12 to 300 sec) and found no evidence of temporally spaced responding in the presence of the aversive light. All subjects responded at a relatively constant rate, failing to exhibit the FI scallop that characterizes performance on an FI schedule of positive reinforcement. It is not clear from Kaplan's study why his subjects did not temporally space responses during the fixed interval. One possibility is that such behavior would not necessarily serve to minimize the total duration of aversive stimulation, as was the case in the present study and in Bower's (1960). On the other hand, this failure may have been due to some unique feature (*e.g.*, the use of light as an aversive stimulus) of Kaplan's experiment.

For the three immediate-escape subjects, a gradual increase in shock intensity to 5.0 ma was accompanied by a decrease in median latency to an asymptotic value of less than 1 sec. Both Boren, Sidman, and Herrnstein (1959), using a multiple procedure involving avoidance, escape, and extinction, and Winograd (1965), using an FR escape procedure, have reported, for rats, a comparable inverse relationship to approximately 1.0 ma. An increase in shock intensity to a level beyond this value had little or no effect upon the mean escape latency.

In contrast, the DRL-escape subjects failed to exhibit a systematic decrease or increase in median latency with a gradual increase in shock intensity to 5.0 ma. Under all shock intensities used, the median latencies remained approximately equal to or greater than the minimum duration. If one considers shock presentation as a drive establishing operation, then an increase in shock intensity would be analogous to an increase in deprivation time. Adherents to such a view might have predicted the results of the present study based upon Conrad, Sidman, and Herrnstein's (1958) and Logan's (1961) findings that a wide range of deprivation conditions had no systematic effect upon a subject's performance on a DRL schedule of positive reinforcement. For example, in the Conrad *et al.* (1958) free-operant DRL experiment, the response rates of one rat and of one monkey were approximately invariant over water deprivation conditions ranging from 20 to 72 hr. In that same experiment, the steady-state, DRL performance of four additional rats was examined over a 10-hr session, during which time the accumulation of reinforcements produced satiation. During the initial 2 to 8 hr (depending on the subject) there was little or no change in response rate on the DRL schedule. Similarly, Logan (1961) reported that rats maintained on 16 g of food per day responded with approximately the same degree of precision on a discrete-trial DRL procedure as did subjects maintained on 9 g of food per day. It is not clear, however, whether the invariant relationship between DRL-escape performance and shock intensity observed in this study would hold under all conditions. An abrupt, rather than gradual, increase in shock intensity to 5.0 ma might have disrupted the temporal spacing of responses.

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Received 9 May 1969.