Sequential effects on latency and other indices in free operant discriminated avoidance

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Six squirrel monkeys were run on a series of free operant discriminated avoidance schedules in which a variable warning stimulus duration (S_1 , S_2 interval), assigned values of 1, 2, 4, 8, and 16 sec, was paired with a constant safe stimulus duration (RS_1 interval) of 4 sec. Three monkeys were exposed to the series of warning stimulus durations in ascending order (1, 2, 4, 8, 16 sec) and three were exposed to the series in descending order (16, 8, 4, 2, 1 sec). The ascending series generated shorter response latencies in the warning stimulus than the descending series, but in both cases latency was directly related to warning stimulus duration. The descending group had high shock rates under the 1- and 2-sec warning stimulus durations relative to the ascending group.

This study is concerned with the relationship of warning stimulus duration to latency of responses emitted during the warning stimulus in free operant discriminated avoidance behavior. In this paradigm, "warning stimulus duration" is analogous to the CS-US interval in discrete trial avoidance. It is the programmed interval between warning signal onset and shock onset. In both free operant and discrete trial avoidance, latency refers to the time between warning signal onset and response.

In group studies of discrete trial avoidance (e.g., Brush, Brush, & Solomon, 1955; Kamin, 1954), there is agreement that latency varies directly with CS-US interval (warning stimulus duration). However, in these studies, each animal was exposed to only one value of the CS-US interval. In a study in which rats were exposed to a series of gradually increasing warning stimulus duration values in free operant discriminated avoidance, Ulrich, Holz, & Azrin (1963) found that latencies were uniformly short and independent of warning stimulus duration. A possible reason for this discrepancy was uncovered by Hyman (1969), who showed that rhesus monkeys initially exposed to a short warning stimulus duration continued to respond with short latencies, even when the warning stimulus duration was increased. The present experiment, a parametric study of warning stimulus duration, was suggested by that finding. However,

the present study employed a larger number of warning stimulus durations than the previous study and a methodology more suited to the investigation of latency than the more general method of the previous study. By holding the safe stimulus constant, it was possible to study more directly the behavioral effects of changes in warning stimulus duration.

SUBJECTS

Six squirrel monkeys (*Saimiri sciureus*), ranging in weight from 538 to 574 g, were employed. They were housed in individual cages and maintained on Purina Chow and water, supplemented with occasional pieces of fruit.

APPARATUS

Electromechanical relay circuitry was employed for programming and control. Latencies were recorded on an Elmeg Model ZDG3 printing counter. The counter was programmed to advance at the rate of 10 counts/sec, and it was accurate to approximately .2 sec. The warning stimulus was a

clicking sound produced by interrupting, at the rate of 10 times/sec, a .35-V current fed into a Quam Model 4A07 speaker. White noise was piped into the experimental room but not directly into the animal chamber. Shock of approximately 4-5 mA, 60 Hz, and 0.3 sec duration was delivered to the tail of the monkey through a constant current source (Foringer Model 1154). During experimental sessions the monkeys were restrained in a Lehigh Valley squirrel monkey chamber, Catalogue No. 1619.

PROCEDURE

The Ss were given 25 pairings of warning stimulus and shock. The warning stimulus duration was 1 sec for Monkeys SS-3, -7, and -18 and 16 sec for Monkeys SS-4, -8, and -14. The warning stimulus duration corresponded to that employed in the first avoidance schedule, to which each monkey was exposed.

Without being removed from the chamber, the animal was switched to a schedule of continuous positive reinforcement. Water was employed as the reinforcing agent, and a barpress was the required response. The water reinforcement schedule was continued until each animal, in the estimation of the E, had a response rate substantial enough to enable him to be switched to aversive control with a very low probability of failure. (None of the animals failed to learn to avoid.) The animals were kept on 23-h water deprivation during the time they were working for water.

The Ss were then switched to shock avoidance. For the first 30 or 40 min of the initial avoidance session, the animals worked on concurrent schedules of water reinforcement and shock avoidance. That is, each barpress

Table 1
Individual Mean and Median Latencies

Warning Stimulus (Sec)		Ascending Group			Descending Group		
		SS-3	SS-7	SS-18	SS-4	SS-8	SS-14
1	Median	0.4	0.3	0.4	0.5	0.8	0.6
	Mean	0.4	0.4	0.4	0.5	0.7	0.6
	SD	0.2	0.2	0.2	0.2	0.2	0.2
2	Median	0.6	0.6	0.5	0.8	1.3	0.7
	Mean	0.7	0.8	0.5	0.8	1.3	0.8
	SD	0.3	0.6	0.2	0.3	0.4	0.4
4	Median	1.0	1.0		1.0	2.2	
	Mean	1.0	1.0		1.0	2.1	
	SD	0.5	0.6		0.4	0.7	
8	Median	1.0	1.4	1.0	2.1	3.7	2.1
	Mean	1.0	1.5	1.2	2.3	3.7	2.4
	SD	0.5	1.0	0.7	1.2	1.4	1.6
16	Median	2.6	1.5	2.2	3.7	4.6	3.4
	Mean	2.8	1.8	2.5	3.7	4.8	3.8
	SD	1.9	1.3	1.6	1.8	2.2	2.4
16 (Recovery)	Median				1.4	4.3	
	Mean				1.5	4.6	
	SD				0.7	2.5	

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Fig. 1. Mean latency as a function of warning stimulus duration. Each point represents the combined data of the three animals in each group.

effected the delivery of water and avoided shock. The water was then turned off, but the water solenoid, which made a clearly audible click, was left on for at least one additional session.

All Ss were exposed to a series of five different schedules of free operant discriminated avoidance. This paradigm is created when a preshock warning stimulus is superimposed upon a Sidman avoidance schedule. A response postpones a due shock for the value of the response-shock interval. The response-shock interval is fractionated into the safe stimulus (or RS₁ interval) and the warning stimulus (or S₁S₂ interval). Following a response, warning stimulus onset

Fig. 2. Relative latency distributions. Each graph represents the combined data of the three animals in each group. The number of shocks associated with each histogram is: Desc. column: 81, 32, 3, 4, 4; Asc. column: 16, 1, 1, 1, 1.

Fig. 3. Response rate as a function of warning stimulus duration. The 4-sec points for Monkeys SS-14 and SS-18 have been omitted (see procedure section).

occurs at the end of a time interval specified by the safe stimulus value, and shock follows after an interval specified by warning stimulus duration. A response, then, interrupts what would otherwise be a recurring cycle of warning stimuli and shocks. A response during the safe stimulus postpones both the warning stimulus and the shock, while a response during the warning stimulus terminates the warning stimulus and postpones the shock.

The safe stimulus was held constant at 4 sec throughout the study, while the warning stimulus was assigned values of 1, 2, 4, 8, and 16 sec. Three monkeys, SS-3, -7, -18, were exposed to the values in ascending order (1, 2, 4, 8, 16 sec); three, SS-4, -8, -14, were exposed to the values in descending order (16, 8, 4, 2, 1 sec). Two of the latter, SS-4 and -8, also worked under the 16-sec duration at the end of the regular series in order to determine whether or not the behavior associated with the original exposure to the 16-sec warning stimulus could be recovered.

Eight sessions of steady-state data were collected for each monkey at each warning stimulus value (with two exceptions to be noted shortly). A minimum of the first eight sessions at each duration value was routinely set aside as transition behavior, except for

the 1-sec warning stimulus, where at least 12 sessions were set aside. More time was allotted for a transition if trends continued to appear in the daily mean latency data, or in some cases, the shock rate data. Only steady-state data are employed in the present paper. Because of time limitations, SS-14 and -18, the exceptions noted at the beginning of the paragraph, were run at the 4-sec warning stimulus value for only four sessions each. This exposure enabled them to experience working at the 4-sec duration, but they presumably generated no steady-state data under that condition, and none is included in the paper.

Each daily session lasted 1 h. Animals were removed from the home cage and secured in the apparatus chair. Small amounts of EKG sol were applied to the depilated tail until the skin resistance measured between 15K and 40K, whereupon the electrodes were clamped to the tail. The start of the session was signaled by the onset of the houselights.

RESULTS

The study generated two different functions for mean latency vs warning stimulus duration—one for the ascending series of durations and one for the descending series (Fig. 1). In both cases, latency was directly related to warning stimulus duration. The descending series, however, generated

Fig. 4. Shock rate as a function of warning stimulus duration. The 4-sec points for Monkeys SS-14 and SS-18 have been omitted.

a function with a steeper slope than the ascending series. Individual mean and median latencies are given in Table 1. All latency data were derived from a sample consisting of every 10th latency.

Figure 2 shows the relative latency distributions. As would be expected from the differences in means and medians, the data for the descending group is marked by shifts to longer latencies relative to that of the ascending group. Furthermore, the ascending group generated clear-cut modes at each warning stimulus duration, except at the 4-sec value, while the latencies of the descending group were more evenly distributed and do not show obvious modes. This is due, at least in part, to the utilization of longer latencies by the descending group monkeys.

Response rate was inversely related to warning stimulus duration at the longer durations but showed no consistent relationship at the shorter durations (Fig. 3).

Shock rate was higher for all animals at the 1-sec warning stimulus duration than at the longer durations (Fig. 4). The most striking result regarding shock rate, however, was the extremely high rates for the descending group under the 1-sec duration and, to a lesser extent, under the 2-sec duration. The effect persisted, in attenuated form, for the longer durations as well.

As previously stated, two monkeys in the descending group, SS-4 and -8, were reexposed to the 16-sec warning stimulus at the end of the study. For both animals, shock rate was recovered, while the percentage of responses emitted during the warning signal showed a reliable increase during the second presentation. Response rate was recovered for SS-4 but was significantly lower during the attempted recovery for SS-8. Finally, mean latency was significantly shorter for SS-4 during the second presentation but remained unchanged for SS-8.

DISCUSSION

The major finding of the study, in agreement with the results of Hyman (1969), is that latencies were affected by the order of presentation of the warning stimulus duration values. Thus, it may be supposed that the

short warning signals elicited conditional aversive temporal stimuli (Anger, 1963) very shortly after warning signal onset and that the temporal stimuli persisted even after warning stimulus duration was increased, mediating short latencies in the ascending group monkeys.

The ascending group latencies are in general agreement with those reported by Ulrich et al (1964). Since these investigators also presented the warning stimulus durations in ascending order, the order effect presumably accounts for the short latencies generated in their study. However, the long latencies reported by Stretch & Skinner (1967) remain unaccounted for. Stretch and Skinner reported median latencies of 7-9 sec for a 15-sec warning stimulus duration which was presented after a 5-sec duration. This value actually exceeds the median latencies generated by the descending group at the 16-sec duration in the present study.

Had there been no responding during the safe stimulus, response rate would have been an inverse function of warning stimulus duration, and changes in latency would have been responsible for all of the variability in response rate. However, heavy, and rather irregular, responding during the safe stimulus overrode the effect of the relatively small latency changes at the 1-, 2-, and 4-sec warning stimulus durations, and so the response rate at those points showed no consistent trends. Due to the present method of varying the warning stimulus duration, changes in warning stimulus duration were accompanied by changes in the response shock interval. Therefore, response rate changes may have reflected changes in the response-shock interval as well as the warning stimulus duration.

It is also possible that latency changes reflected the changes in response-shock interval as well as in warning stimulus duration. However, this latter possibility is discounted by my previous finding (Hyman, 1969) that, when warning stimulus duration is held constant, changes in safe stimulus duration generally have little effect upon latency. This latter procedure also produces changes in the response-shock interval, but without varying the warning stimulus duration.

The descending group showed a loss of ability to avoid shock at the shorter warning stimulus durations. One may suggest that the high shock rate was only a transitional state, but the animals were run for 20 sessions at the 1-sec duration to test this notion, and their shock rates showed no downward trends. It appears, then, that the formation of a temporal discrimination based on a relatively long warning stimulus interfered with effective avoidance behavior under a short warning stimulus. This is in contrast to the finding of Hyman (1969), in which the animals avoided with equal effectiveness on all schedules. One may, perhaps, appeal to phylogenetic differences between *Macaca mulatta*, employed in the previous study, and *Saimiri sciureus*, especially since the overall shock rates were higher in the present study than in Hyman (1969).

The recovery attempt with Monkeys SS-4 and -8 produced mixed results. Consequently, no specific conclusions may be drawn. Nevertheless, this aspect of the data does reinforce the general thesis of the study—that reinforcement history is an important parameter of current behavior.

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