

Differential operant behavior based on time of day

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Animals were given water reinforcement for leverpressing on daily sessions alternating between DRL and FR schedules of reinforcement. One group received the DRL and FR schedules of reinforcement at different times during the day (morning or afternoon), while another group received their DRL and FR schedules of reinforcement at the same time each day (again morning or afternoon). The results indicated that for certain behavioral indices, animals receiving DRL/FR schedules at different times during the day appeared to display more appropriate response patterns than animals receiving their DRL and FR schedules at the same time each day.

Recent research in our laboratory (Holloway & Wansley, 1973a, b; Wansley & Holloway, 1975) has indicated that retention performance for active and passive avoidance or for appetitive conditioning varies systematically and periodically as a function of time since training. Performance is best when testing occurs exactly 24 h after initial training, intermediate 12 h after training, and poorest when testing occurs 6 h after training or at multiples of 12 h from this 6-h posttraining period. We have suggested that some endogenously fluctuating aspect of the organismic state at the time of training becomes a relevant factor in the retrieval of such training experiences. The present investigation attempts to determine whether an animal can learn to display one pattern of responding at one time of day and a different pattern of responding at another time of day. Numerous reports in the literature indicate that animals' ability to utilize information about time of day has adaptive significance. Such time-of-day information typically concerns some aspect of external changes in the environment or some aspect of the internal biological clock. Koltermann (1971) reports that bees can remember scents or colors at the same time of day in which sensory training initially took place but less well at other times of day. Pittendrigh (1974) also reviews studies showing that the navigational ability of birds depends both upon the natural light and dark conditions and internal circadian clocks.

There are no systematic studies on differential responding by rodents based on time of day. Overton (1964) has reported that rats are unable to learn to

escape shock by running to the left or right in a T-maze when the differential parameter signifying the appropriate response was morning vs. evening, a 12-h time-of-day difference, and are also unable to learn differential responding for morning vs. afternoon, a 6-h time-of-day difference (Overton, personal communication). Furthermore, Stavnes (1971), in a somewhat different task, also failed to find left-right differential responding in mice when the differential condition was time of day. However, the animals' internal state may play a lesser role in influencing retrieval operations in tasks which involve highly salient external cues, such as the left and right arms of a T-maze. Such external cues may, in fact, mask internal state changes.

In the present study, we attempted to address the latter problem by using a task in which external cues presumably play a minimal role. We trained animals to produce different patterns of operant behavior based on fixed ratio (FR) or differential reinforcement of low rates of responding (DRL) schedules of reinforcement, depending upon the time of day each reinforcement contingency was in effect. As indicated by the earlier avoidance retention studies (Holloway & Wansley, 1973a, b), the states of the organism at different times of day (6 h apart) appear to be different. Thus, the development of DRL and FR behaviors at different times of day should be more effective than conditioning such behaviors at the same time of day. The FR and DRL behaviors conditioned at the same time of day would be expected to interact, while such behaviors conditioned at different times of day would not, due to differences in organismic state.

METHOD

Subjects

The subjects in this experiment were eight male Long-Evans hooded rats weighing between 300 and 400 g at the beginning of the experiment. These animals were maintained on ad-lib food under a light/dark cycle of 12 h light and 12 h dark (light period being from 8:00 a.m. to 8:00 p.m.). The subjects were randomly assigned to two groups.

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Apparatus

The apparatus used in this experiment was a modified Skinner box enclosed in a soundproof enclosure (Lehigh Valley 143-27). The Skinner box was equipped with a retractable microswitch lever so that the number of leverpresses could be recorded. The water reinforcement in this experiment was provided by a solenoid activated water dispenser. BRS Electronics solid state logic was used to program the DRL and FR schedules of reinforcement.

Procedure

Subjects were water deprived for 23 h prior to commencing the conditioning procedure and for at least 18 h prior to each session. Every animal was magazine trained to press the lever for water reinforcement on a continuous reinforcement schedule. During the experimental phase, animals received water reinforcement on a DRL 15-sec or an FR 15 schedule of reinforcement. The DRL 15-sec was such that the animal had to wait 15 sec since the last response before another reinforcement was available. The FR animals received a reinforcement at the end of the 15th response.

The experimental design for the present investigation is given in Table 1. Animals were randomly assigned to Groups S (FR and DRL schedules at the same time of day) or D (FR and DRL schedules at different times of day) and to one of the two time-of-day conditions within each group. Subjects were designated by prefixes S or D. Animals D1 and D2 and animals S1 and S2 were given 30-min sessions on DRL schedules of reinforcement between the hours of 9:00 a.m. and 11:00 a.m. for a 7-day period. Animals D3 and D4 and animals S3 and S4 were given 30-min sessions on DRL schedules of reinforcement during the hours of 3:00 p.m. and 5:00 p.m. for 7 days. During Days 1-2, the reinforcement schedules were DRL-5, during Days 3-4, DRL-10, and during Days 5-7, DRL-15. At the end of this first 7-day period, animals D1 and D2 were placed on the FR schedule at the opposite time of day, i.e., 3:00 p.m. to 5:00 p.m. for a 7-day period and animals D3 and D4 were placed on FR schedules at the opposite time of day, i.e., 9:00 a.m. to 11:00 a.m. However, animals S1 and S2 were placed on the FR schedule at the same time of day that they had received the DRL sessions, i.e., 9:00 a.m. to 11:00 a.m.; and animals S3 and S4 were switched to the FR schedule for 7 days at the same time of day, 3:00 p.m. to 5:00 p.m. All sessions were 30 min in duration. As during the first week, the schedules of reinforcement for all animals progressed from FR-5 (Days 1-2) to FR-10 (Days 3-4) and, finally, to FR-15 (Days 5-7). At the end of this 14-day preliminary training period, all animals began a 14-day period during which daily 30-min sessions were alternated on successive days between the DRL-15 and FR-15 schedules of reinforcement. During this second 2-week period, all the animals in Group D received their DRL and FR sessions at different (morning or afternoon) times of day, while animals in Group S always received their DRL and FR sessions at the same time each day. The programming apparatus was set so that the first 10 min of

Table 2
Session Averages During Experimental Phase

Experimental Variable		First 10 Min			Last 20 Min	
		DRL Score	FR Score	No. Resp.	No. Rfs.	No. Resp.
Group D*						
DRL Day	Mean	14.5	5.1	75.8	33.6	191.9
	SD	4.2	5.0	73.7	11.6	94.8
FR Day	Mean	11.6	4.4	65.8	37.5	562.2
	SD	5.1	3.3	50.2	13.6	197.6
Group S*						
DRL Day	Mean	10.5	5.7	85.3	32.1	227.6
	SD	4.9	3.3	47.5	10.9	68.9
FR Day	Mean	11.9	3.9	58.9	31.7	476.9
	SD	5.9	3.1	34.2	10.6	298.1

*Group D: DRL and FR schedules were either in the a.m. or p.m.; Group S: DRL and FR schedules were both in the a.m. or both in the p.m.

each day's session during these test sessions was an extinction period where no response resulted in reinforcement. During the last 20 min of the day's session, the appropriate schedule of reinforcement was in effect.

The data derived from the testing sessions permitted an examination of five indices of the animal's behavior. Number of responses during the initial 10-min extinction, number of responses during the 20-min reinforcement condition, and the number of reinforcements during the 20-min reinforcement condition were recorded. The other two indices were reinforcement scores, derived from leverpress responses during the initial 10-min extinction period. These scores were designated DRL scores or FR scores and were calculated by determining the number of reinforcements the animal would have received had the DRL or FR reinforcement contingency been in effect.

RESULTS

The results of this experiment are presented in Table 2. Three-way analyses of variance (time of session by group by trials) were performed on three of the five behavioral indices from FR or DRL sessions. During the last 20 min of the daily sessions, no significant differences (all $F_s < 1$) were noted in the number of reinforcements or responses between Group D and Group S or between different times of day for either the DRL or FR days. There also were no significant group differences (all $F_s < 1$) in number of responses during initial 10-min extinction periods for either the DRL or FR day. However, when the DRL reinforcement scores during the initial 10 min were examined (four-way ANOVA, time of session by group by reinforcement schedule by trials), it was clearly apparent that Group D animals, which received DRL and FR sessions at different times of day, displayed higher DRL scores on the DRL day than on the FR day ($FR = 15.02$, $df = 1/4$, $p < .01$). There were no such differences between DRL and FR days for the DRL scores in Group S animals, which received DRL and FR sessions at the same time of day. This pattern of results, however, did not obtain for FR reinforcement scores. Finally, it should be noted that

Table 1
Experimental Design

Day	Schedule	Subjects (Group D)				Subjects (Group S)			
		D1	D2	D3	D4	S1	S2	S3	S4
1	FR	a.m.	a.m.	p.m.	p.m.	a.m.	a.m.	p.m.	p.m.
2	DRL	p.m.	p.m.	a.m.	a.m.	a.m.	a.m.	p.m.	p.m.
3	FR	a.m.	a.m.	p.m.	p.m.	a.m.	a.m.	p.m.	p.m.
4	DRL	p.m.	p.m.	a.m.	a.m.	a.m.	a.m.	p.m.	p.m.
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
13	FR	a.m.	a.m.	p.m.	p.m.	a.m.	a.m.	p.m.	p.m.
14	DRL	p.m.	p.m.	a.m.	a.m.	a.m.	a.m.	p.m.	p.m.

the level of DRL scores made by Group D animals receiving DRL and FR sessions at different times of day was significantly higher on the DRL days than similar scores for Group S animals receiving their DRL and FR sessions at the same time each day ($F = 43.55$, $df = 1/4$, $p < .01$).

When the behavioral indices from the initial 10-min extinction period were examined, it was apparent that the animals were progressively being extinguished over trials. The following behavioral indices displayed a significant decline across trials: number of responses on DRL days ($F = 10.5$, $df = 6/24$, $p < .01$), number of responses on FR days ($F = 7.01$, $df = 6/24$, $p < .01$), DRL reinforcement scores ($F = 3.98$, $df = 6/24$, $p < .01$), and FR reinforcement scores ($F = 13.34$, $df = 6/24$, $p < .01$).

DISCUSSION

The results of this experiment indicate only partial confirmation of the hypothesis that animals may be able to learn differential (high or low) rates of responding based on time of day during which an FR or DRL contingency was in effect. There were no differences in the responding on FR days between those animals receiving the DRL/FR schedules at the same vs. different times of day. However, examination of DRL reinforcement scores during the initial 10-min of nonreinforcement showed that animals with DRL/FR schedules at different times of day had significantly higher scores when the DRL schedules were appropriate than those animals receiving their DRL/FR schedules at the same time each day. It is apparent that the extinction period was probably too long, as all behavioral indices from that period declined significantly over trials. Thus, while

these pilot data are supportive of the hypothesis that time of day may be a relevant factor in the manner in which an animal responds, much additional work is needed. Present data also indicate that the DRL scores on days when the DRL pattern of behavior was appropriate were not due to a primary effect of a session being in the morning or afternoon, but rather to the appropriateness of the DRL behavior for the time of day during which this behavior was learned.

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