

*SEQUENTIAL RESPONSE EFFECTS IN THE WHITE RAT  
DURING CONDITIONING AND EXTINCTION  
ON A DRL SCHEDULE<sup>1,2</sup>*

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Sequential IRT data were obtained for three rats on a DRL 60-sec reinforcement schedule. It was found that first-order sequential dependencies exist under this schedule, including the partial dependence of the length of any given IRT on the length of the preceding IRT. The sequential analysis also served to extend the finding in the literature, based on frequency distributions, that the likelihood of a reinforced IRT is greater after a reinforced IRT than a non-reinforced IRT. Rapid extinction and reconditioning were obtained.

In a recent paper, Farmer and Schoenfeld (1964b) used interresponse time and post-reinforcement pause distributions to exhibit some sequential dependencies arising under DRL schedules of reinforcement. These experimenters found that the relative frequency of a sequence of two reinforced responses was greater than that of a sequence of a reinforced response following a non-reinforced response, a relationship which indicates a more precise temporal discrimination following a reinforcement. A related finding is that of Reynolds (1964) that reconditioning of DRL timing behavior is quite rapid. The present study was designed to explore these observations by examining sequential IRTs generated by the white rat working under a conventional DRL schedule.

## METHOD

### *Subjects*

Three Charles River type CD male albino rats, approximately 100 days old at the beginning of the experiment, were used. The subjects had free access to food in their individual home cages and were maintained on a 22½-hr

water deprivation schedule for the duration of the experiment.

### *Apparatus*

A Scientific Prototype Mfg. Co. rat box (Model 300) containing a single lever and liquid reinforcement dipper dispenser served as the experimental chamber. The reinforcement was 0.1 cc of a milk mixture, consisting by volume of 40% evaporated milk and 60% water. The schedule was programmed with BRS Electronic transistorized modules. Responses and reinforcements in each experimental session were tallied on counters, and cumulative response curves were obtained. In addition, two channels of a Grass EEG machine (Model 3d) registered the time sequence of responses and reinforcements, together with a 4-sec time marker (accurate to 0.1%), which was reset by a response or reinforcement. Cardiac systolic rate was recorded on a separate channel (these data will be reported elsewhere).

### *Procedure*

After receiving 50 regular reinforcements, each rat was exposed on four successive days for two 90-min sessions to DRL 10 sec, and two 90-min sessions to DRL 30 sec before going to the final value of DRL 60 sec. The DRL requirement was always timed from the last response (whether reinforced or not). Reinforcement consisted of 4-sec access to the dipper which remained in the milk mixture reservoir at all other times. Reinforcements were accompanied by a 10 per sec click stimulus of moderate intensity by means of a relay

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driven by a Grason Stadler electronic timer (Model E5350A). The clicker stimulus was used to facilitate conditioning by giving an exteroceptive cue of the availability of the dipper. Rat 66, Rat 67, and Rat 71, respectively, were run for 144, 142, and 129 consecutive daily 90-min sessions on DRL 60 sec to insure a stable temporal discrimination. After the last conditioning day, each rat was given five 90-min daily extinction sessions. The extinction procedure involved presenting an empty milk reservoir while continuing to present the dipper and its accompanying clicker stimulus after all IRTs greater than 60 sec. Subjects were then reconditioned for one session on a DRL 60-sec schedule. Before each session began, a belt for recording heart rate was fastened to each subject (Ferraro, Silver, and Snapper, 1965). Sequential recordings on the EEG machine were taken only on the last two conditioning sessions and on the first extinction session.

Each subject maintained a slow steady rate of responding and obtained a large number of the programmed reinforcements (for Rats 66, 67, and 71, the number of responses per reinforcement was 1.22, 1.40, and 1.60 respectively). The long runs of successive reinforcements noted by earlier workers (Kelleher, Fry, and Cook, 1959; Malott and Cumming, 1964; Farmer and Schoenfeld, 1964a) are occasionally interrupted (Fig. 1, points a,b,c) by an extended pause in responding or by a response "burst" (Sidman, 1956).

The accuracy of the timing behavior can be seen from the interresponse time (IRT) and interreinforcement time (IS<sup>R</sup>T) distributions in Fig. 1, which are based on the arithmetic means of the last two conditioning sessions. The shapes of the IRT distributions show that there is a relationship between the modal category and the frequency of short responses for the three subjects. The farther the mode is below the reinforced delay, the higher is the frequency of short IRTs (and the higher is the frequency of very long IS<sup>R</sup>Ts). The IS<sup>R</sup>T distributions are similar to those reported by Farmer and Schoenfeld (1964a) with the modal IS<sup>R</sup>T value falling at or near the DRL requirement. Although the IS<sup>R</sup>T distributions

RESULTS AND DISCUSSION

1. Conditioning

The cumulative response records of Fig. 1 were taken during the last conditioning ses-

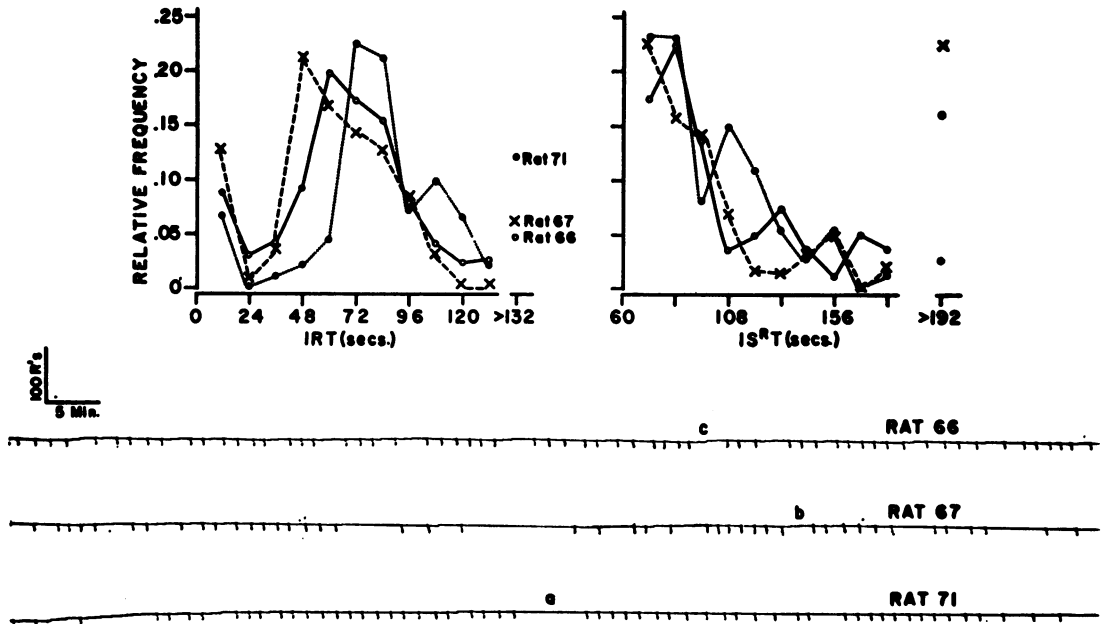


Fig. 1. Cumulative response records of the three subjects during the last 90-min conditioning session on a DRL 60-sec reinforcement schedule. The IRT and IS<sup>R</sup>T distributions were compiled from both the last two conditioning sessions of each subject in order to increase the N. The last category on the IRT abscissa contains all IRT values greater than 132 secs, the plotted point for each animal is the relative frequency of such occurrences; similarly for the IS<sup>R</sup>T abscissa where the last category contains all IS<sup>R</sup>Ts greater than 192 secs.

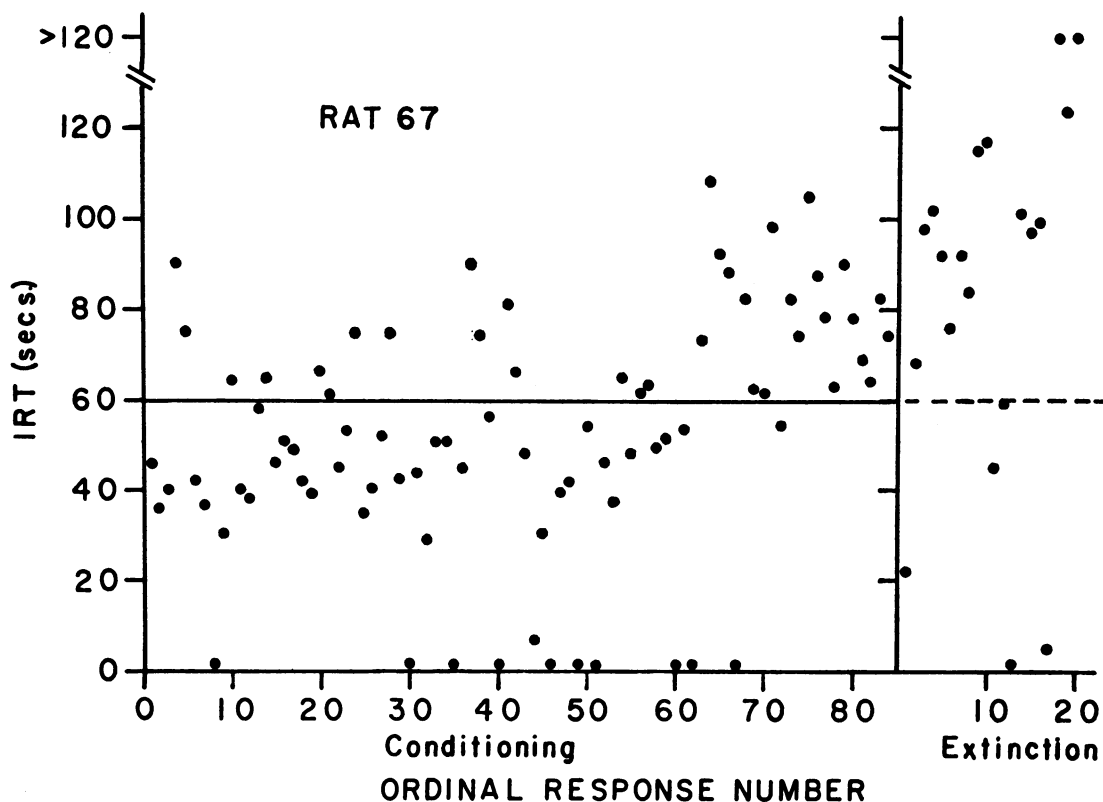


Fig. 2. IRT as a function of ordinal response number for the next-to-last conditioning session, and for the first extinction session for Rat 67.

seem to show second smaller modes, these do not fall at multiples of the reinforcement criterion as suggested in the IS<sup>R</sup>T distributions of Farmer and Schoenfeld (1964a) for DRL 10 and DRL 40 sec. The very long IS<sup>R</sup>Ts observed in Fig. 1 may be due to the summation of a sequence of near-criterion IRTs followed by short IRTs which, in turn, lead to a criterion IRT, rather than simply to long IRTs. This is suggested by Sidman's (1956) finding that the probability of very short IRTs is highest following non-reinforced IRTs which are close to the criterion delay for reinforcement.

Figure 2 is a sequential plot of each IRT for the next-to-last conditioning session, and for the first extinction session, of Rat 67. Although these data are typical of those obtained for the other two subjects, the conditioning session shown in Fig. 2 was chosen since it best illustrates the tendency toward longer IRTs as sessions progress.

Figure 3 displays for each rat in mean form, from its last two conditioning sessions, the sequential dependency of the length of an IRT

value upon the length of the preceding IRT value. In each panel: the number next to the filled-in circle represents the mean of the distribution of preceding IRTs which were greater than 132 secs; the dotted line has a slope of 1.00 and indicates the shape the function would take if consecutive IRTs were of the same length; and the mark at 60,60 divides the space into unreinforced and reinforced quadrants (*e.g.*, the upper right quadrant represents reinforced IRTs preceded by reinforced IRTs, and the lower left quadrant unreinforced IRTs followed by unreinforced IRTs). The obtained first-order sequential dependencies show that the subjects tended to repeat the behavior just emitted whether or not it was reinforced. The decreased reinforcement density, which results when long IRTs follow long IRTs, or short IRTs follow short IRTs, has an effect upon the apparent underlying sequential dependencies in the rats' behavior. Thus, the curves pass very close to the point of intersection at IRT = 60 sec which is an area of high reinforcement density. How-

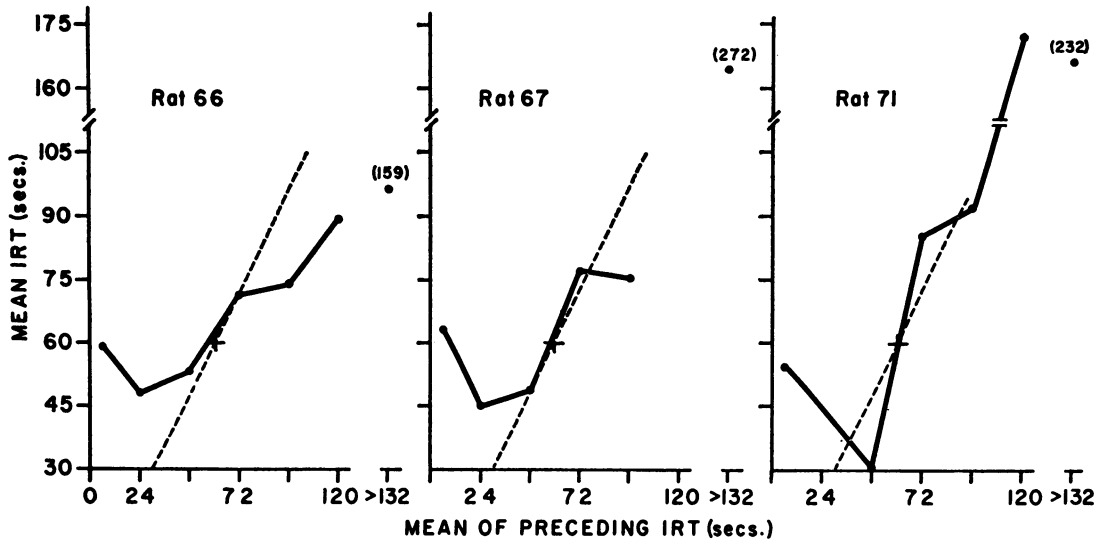


Fig. 3. Mean IRTs during the last two conditioning sessions as a function of the mean of the preceding IRTs during these sessions. On each abscissa the last category contains all cases where the preceding IRT values were greater than 132 secs.

ever, the subjects do not act to maximize reinforcement density, since the obtained function slopes would in that case approach zero at  $IRT = 60$  sec rather than fall between zero and unity as they do. The similarity of successive IRTs is least following IRTs in the 6-sec category. Very short IRTs seem to be a better initiator of the criterion response pause than longer but still unreinforced IRTs.

The filled data points in Fig. 3 suggest that the long  $IS^R$ Ts observed in Fig. 1 do not arise from long IRTs, but rather from some combination of unreinforced IRTs. Inspection of response sequences indicated the existence of some higher-order dependencies; for example, a run of responses with IRTs just below criterion may be often followed by a short IRT which in turn is followed by a reinforced IRT. This indication is also found in Sidman's (1956) data and is recognized in some statements made by Farmer and Schoenfeld (1964a). The presently obtained similarity of successive IRTs also extends the finding by Farmer and Schoenfeld (1964b) that the likeli-

hood of a reinforced IRT is greater after a reinforced IRT than a non-reinforced IRT.<sup>3,4</sup>

## 2. Extinction and Reconditioning

The similarity of the cumulative records of extinction responding by all subjects (Fig. 4) supports the typical sequence shown in the right-hand panel of Fig. 2. Generally speaking, good timing behavior was maintained in extinction, and there was a trend toward long IRTs before responding stopped. The extinction records in Fig. 4 represent all the responding in both the first and fifth extinction sessions for each rat. As can be seen, the rate of responding during extinction was very low (the number of responses made during the first extinction session, and the total number for all five sessions, for each rat were: Rat 66, Ext 1 = 29, Ext 1-5 = 68; Rat 67, Ext 1 = 22, Ext 1-5 = 50; Rat 71, Ext 1 = 11, Ext 1-5 = 54). The small number of extinction responses emitted by each subject made distributional and sequential analyses of the data inadvisable. These extinction data conform well with those obtained from shorter DRL require-

<sup>3</sup>Explanations of sequential response dependencies in DRL schedules in terms of collateral behavior (Wilson and Keller, 1953), internal variables which change as a function of time (Anger, 1956), or the cue properties of reinforcement (Farmer and Schoenfeld, 1964b), do not rule out the possibility of inherent non-random sequences in behavior. Along this line, Mechner (1958) has observed sequential dependencies in a

free-operant situation with a schedule not involving temporal discrimination.

<sup>4</sup>Since this article was submitted for publication, Wertheim (1965) has found a similar sequential dependency between the lengths of successive IRTs generated under an aversive temporal schedule (non-cued avoidance).

ments (Wilson and Keller, 1953; Kelleher, Fry, and Cook, 1959), save that they found considerably greater resistance to extinction in terms both of number of responses made, and of length of time over which responding was maintained. Resistance to extinction following a schedule of the type used here seems to be a complex function of several interacting variables. Among these are the temporal period of the schedule (Wilson, 1954), the length of exposure to the schedule (Lewis and Duncan, 1958), and the presence or absence in extinction of discriminative stimuli trained during conditioning (Bitterman, Fedderman, and Tyler, 1953). In the present experiment, extreme values of several of these variables were used: a DRL period of 60 sec, exposure to the schedule of over 200 hr, and a clear-cut signal accompanying dipper presentation in conditioning and extinction. Although the precise interactions among these variables in determining extinction are unknown, our values apparently sufficed to quicken the process.

Reynolds (1964), using pigeons on a 20-sec DRL schedule, reported reconditioning to pre-extinction performance after two or three reinforcements. The present experiment provided an opportunity for parallel observations on the rat, and subjects 66 and 67 were conditioned for that purpose (Rat 71 was not reconditioned because of a procedural error). The cumulative records of Fig. 4 show that reconditioning was rapid, although the timing behavior was not as accurate as for the last pre-extinction session (for Rat 66, responses per reinforcement were 3.03; for Rat 67, 1.9). In fact, Rat 66 exhibited a large number of very short IRTs, behavior for which it had not been reinforced during 148 days of conditioning and 5 days of extinction, a total of 153 days.

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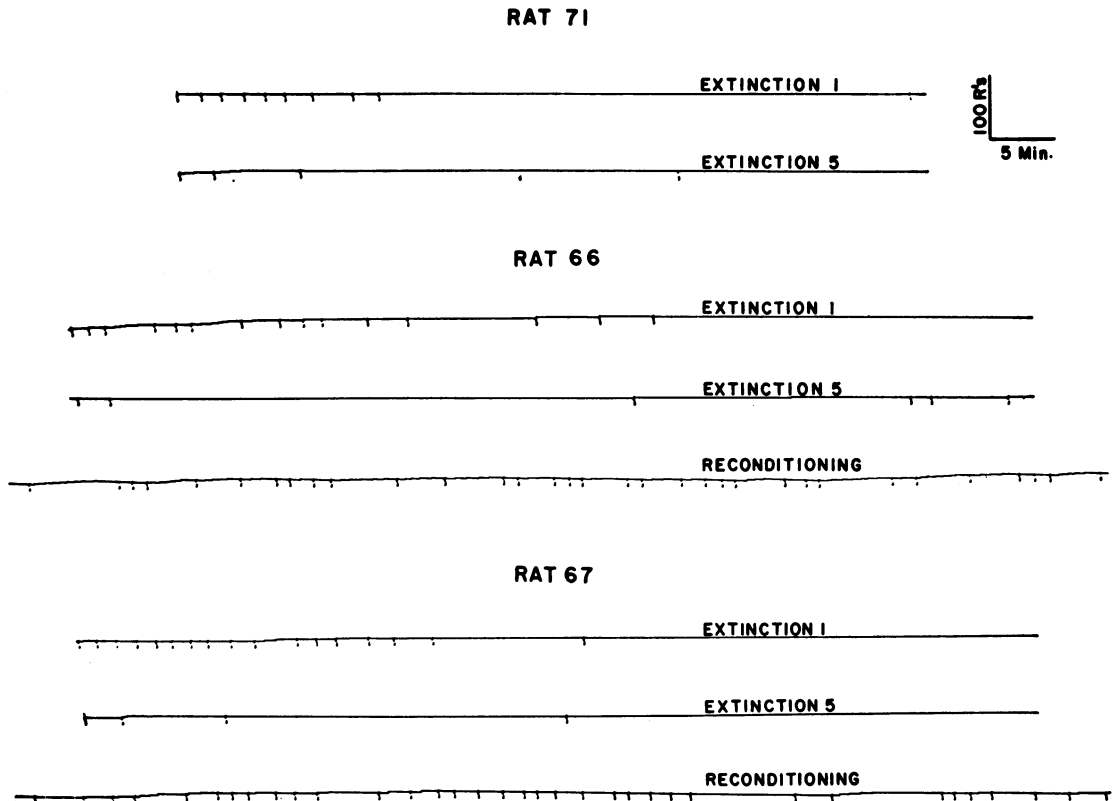


Fig. 4. Cumulative response records for the first and fifth 90-min extinction session for each rat. The slash marks indicate when reinforcement would have been presented had it been programmed. The cumulative response records for reconditioning of Rat 66 and Rat 67 were obtained on the day after the fifth extinction session.

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