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EFFECTS OF A DRL CONTINGENCY ADDED TO A FIXED-INTERVAL REINFORCEMENT SCHEDULE[1]

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Following 30 days of reinforcement for the bar press response of two white rats on 30-sec fixed-interval (FI), a DRL component was added so that a minimal interresponse time (IRT) for the reinforced response, in addition to the FI variable, was necessary for reinforcement. Marked control over response rate by the superimposed DRL requirement was demonstrated by an inverse hyperbolic function as the DRL component was increased from 1 to 24 sec within the constant 30-sec FI interval. Interresponse time and post-reinforcement (post-S^R) "break" distributions taken at one experimental point (DRL = 24 sec) suggested that a more precise temporal discrimination was initiated by an S^R than by a response, since the relative frequency of a sequence of two reinforced responses appeared greater than that of a sequence of a non-reinforced response followed by a reinforced one. This latter finding was confirmed with new animals in a follow-up experiment employing a conventional 24-sec DRL schedule.

The purpose of the present experiment was to explore response characteristics emerging when a DRL contingency is added to baseline performance on other schedules. Earlier studies by Ferster and Skinner (1957) suggest that response rate under these conditions will decrease in a manner roughly proportional to the length of the DRL requirement. Observation of these behavioral effects are extended in the present work to several values of DRL superimposed on a temporally defined schedule, in this case FI, and includes other response measures in addition to rate.

METHOD

Experiment I

Subjects. Two Sprague-Dawley male albino rats, approximately 90 days old on arrival in the laboratory, were used.

Apparatus. A standard Grason-Stadler unit (Cat. No. R3125B) contained a Gerbrands lever ("standard" lever, no catalogue number). The bar required 19 g for depression; the reinforcer (S^R) was 0.01 cc of a 50% mixture by volume of condensed milk and water. Automatic relay circuitry delivered S^R on schedule, and recorded data.

Procedure. After arrival in the laboratory, *S*s' free-feeding weights were determined over a period of about three weeks; they were then reduced and maintained within 80% ± 4% of those weights throughout experimentation. The base weight from which the 80% value was calculated was changed weekly using Zucker's (1953) formula so as to parallel the weekly weight increases with age that are noted in free-feeding animals. Unlimited access to water was provided. On day 1, and without prior "shaping" of the response, *S*s were given 45 min of regular reinforcement for bar pressing. On this day only, the S^R dipper was always in the up position (at cage floor level). A bar press lowered the dipper momentarily into a reservoir containing the milk-water mixture, the dipper then returning to the up position and remaining there till the next response. Beginning on day 2, and thereafter, S^R was changed to 3-sec access to the dipper in the up position, the dipper remaining down in the reservoir at all other times. Also on day 2, daily sessions were increased to 1 hr and the reinforcement schedule changed to FI 30 sec, as timed by the clock, rather than from the preceding S^R (Skinner, 1938; Ferster and Skinner, 1957). After 30 days at FI 30, a DRL component was added so that a bar press was still reinforced every 30 sec, but now only when it followed the preced-

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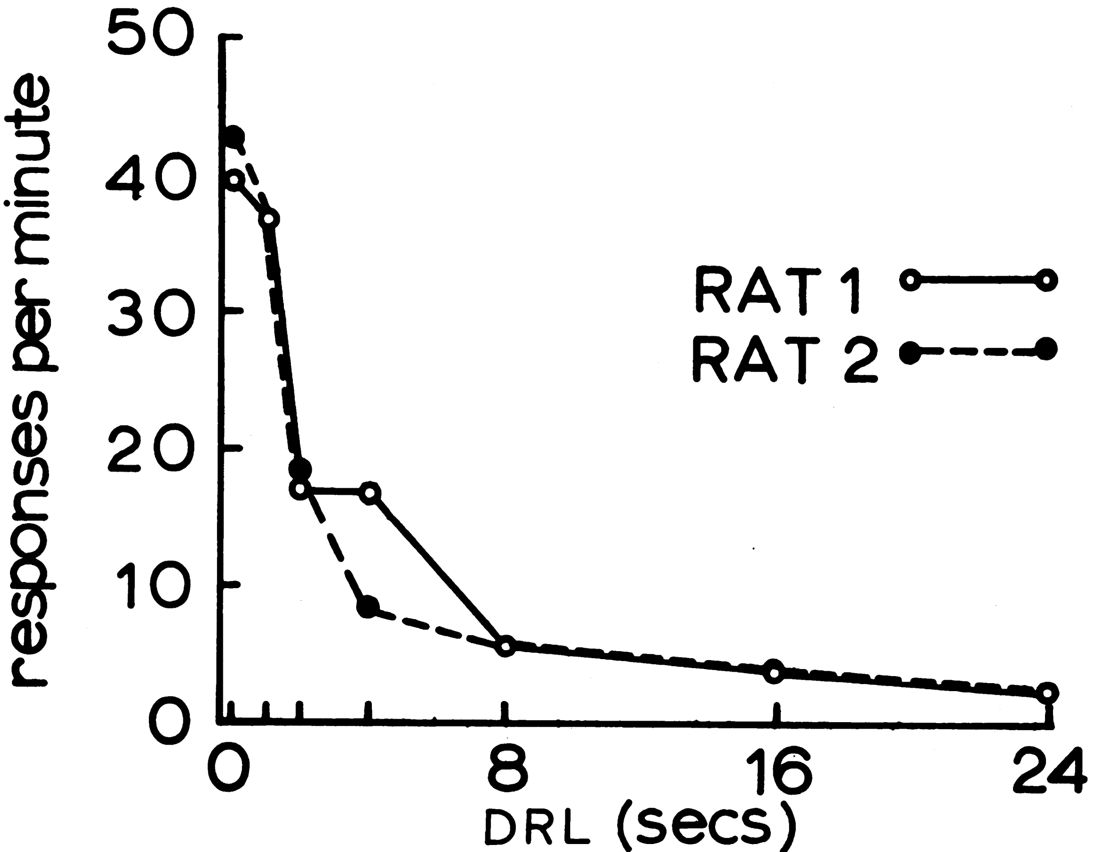

Fig. 1. Mean response rate, for the last five criterion days at each DRL value, triply corrected: by subtracting (a) total S^R time (3 sec multiplied by the number of reinforcements), (b) total post-S^R break time (time from termination of S^R to the occurrence of the first response following), and, (c) the number of reinforced responses from the total number of responses. (See text.)

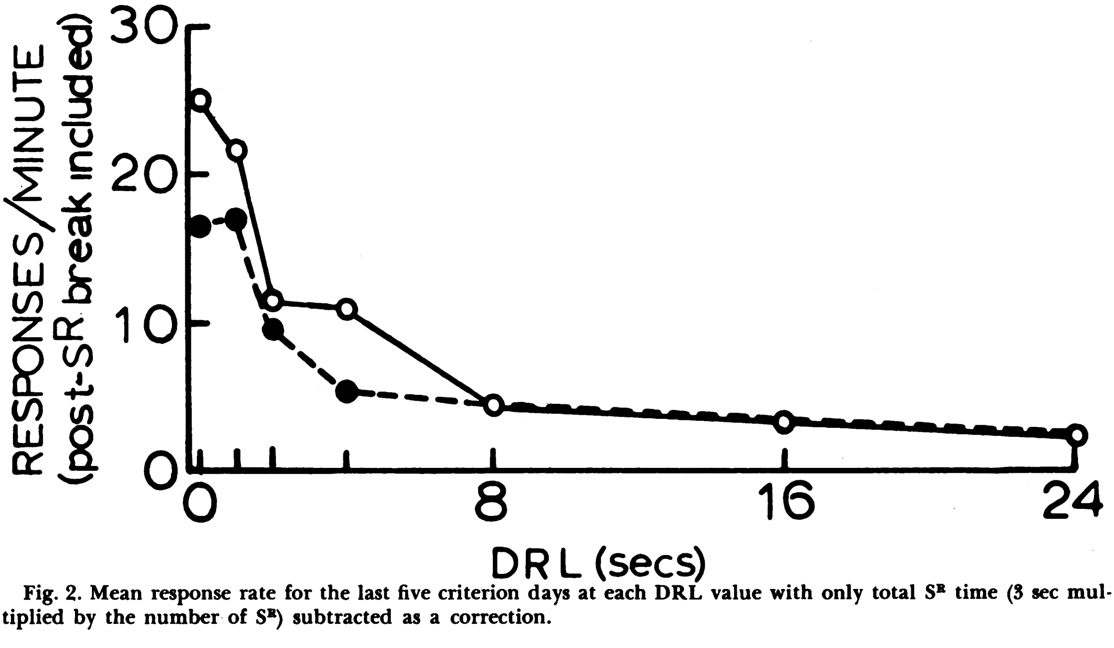

Fig. 2. Mean response rate for the last five criterion days at each DRL value with only total S^R time (3 sec multiplied by the number of S^R) subtracted as a correction.

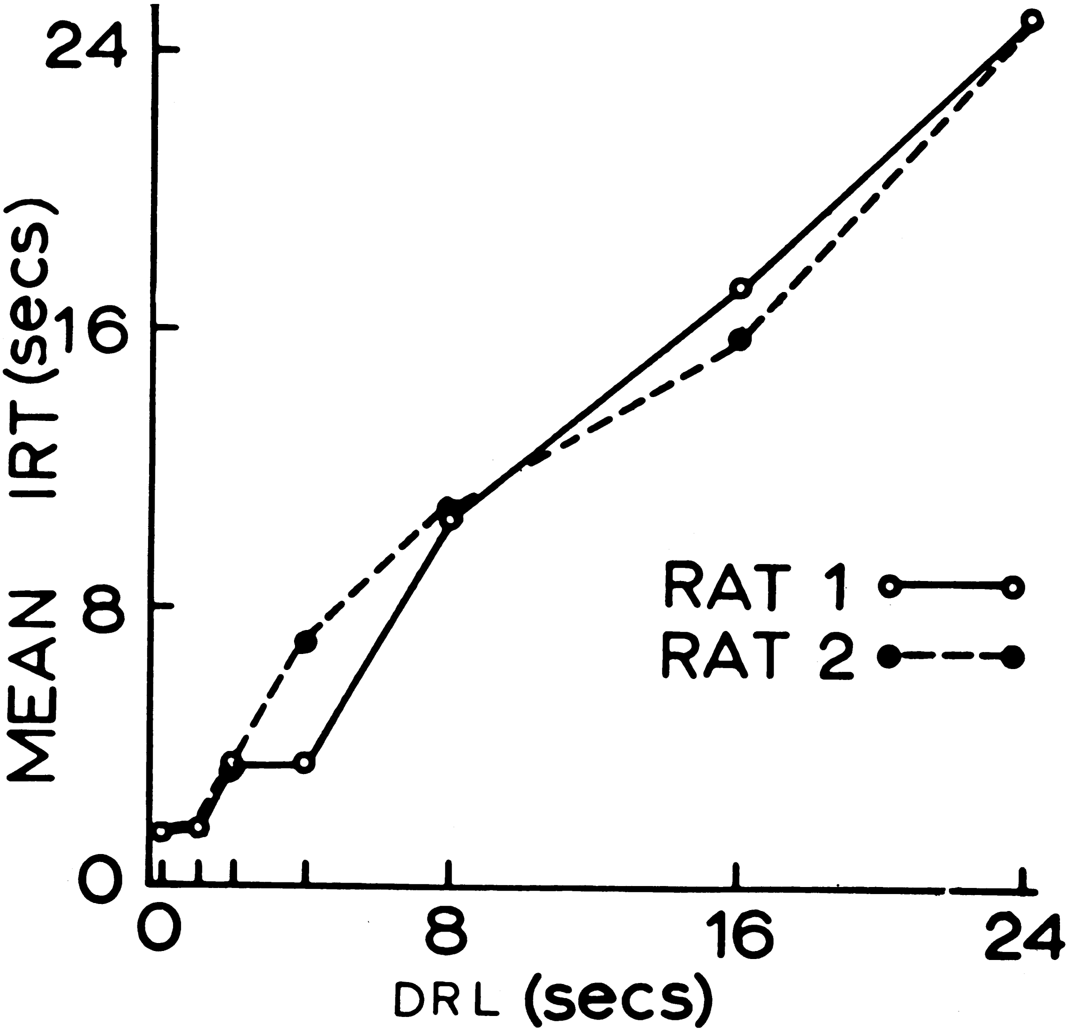

Fig. 3. Mean IRT as a function of DRL. These IRTs are the reciprocals of the corrected response rate functions in Fig. 1.

ing bar press by at least the time interval (or IRT) required by the DRL. This schedule, in which two contingencies must be met to achieve reinforcement, has been called "conjunctive" and may be written in the present case as "conjFIDRL" (Ferster and Skinner, 1957). This schedule can also be described precisely, though at somewhat greater length, within the *t* system of schedule classification[3]

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[3] Briefly, this system is grounded on a repeating time cycle, T, which is divided into alternating subperiods t^D and t^Δ in which different (respectively, higher and lower) reinforcement probability contingencies are provided. The experiment to be described here featured two contingencies: (a) only the first response in t^D was reinforced, and, (b) each response in t^Δ recycled t^Δ, that is, began timing t^Δ anew. In addition, T was held constant, and t^Δ was systematically varied as the experimental independent variable. With these conditions, when t^Δ is zero, the schedule is equivalent to an FI of period T as "timed by the clock" rather than from the preceding reinforcement. When $T > t^\Delta > 0$, the procedure approximates so-called "DRL with limited hold" except that, in the latter, every response starts a period of non-reinforcement; in the present method, only responses falling in t^Δ do so, while extra responses in t^D do not postpone the next opportunity for reinforcement. This latter procedure thus resembles "DRL with limited hold" when not all responses in the "hold" recycle (*e.g.*, the DRL20 LH5 FR2 schedule of Kelleher, Fry, and Cook, 1959). Furthermore, the present procedure incorporated a minimum of 30 sec between reinforcement availabilities despite variation in the length of t^Δ, whereas, in conventional DRL schedules, the DRL requirement and minimal inter-reinforcement availability time are equivalent.

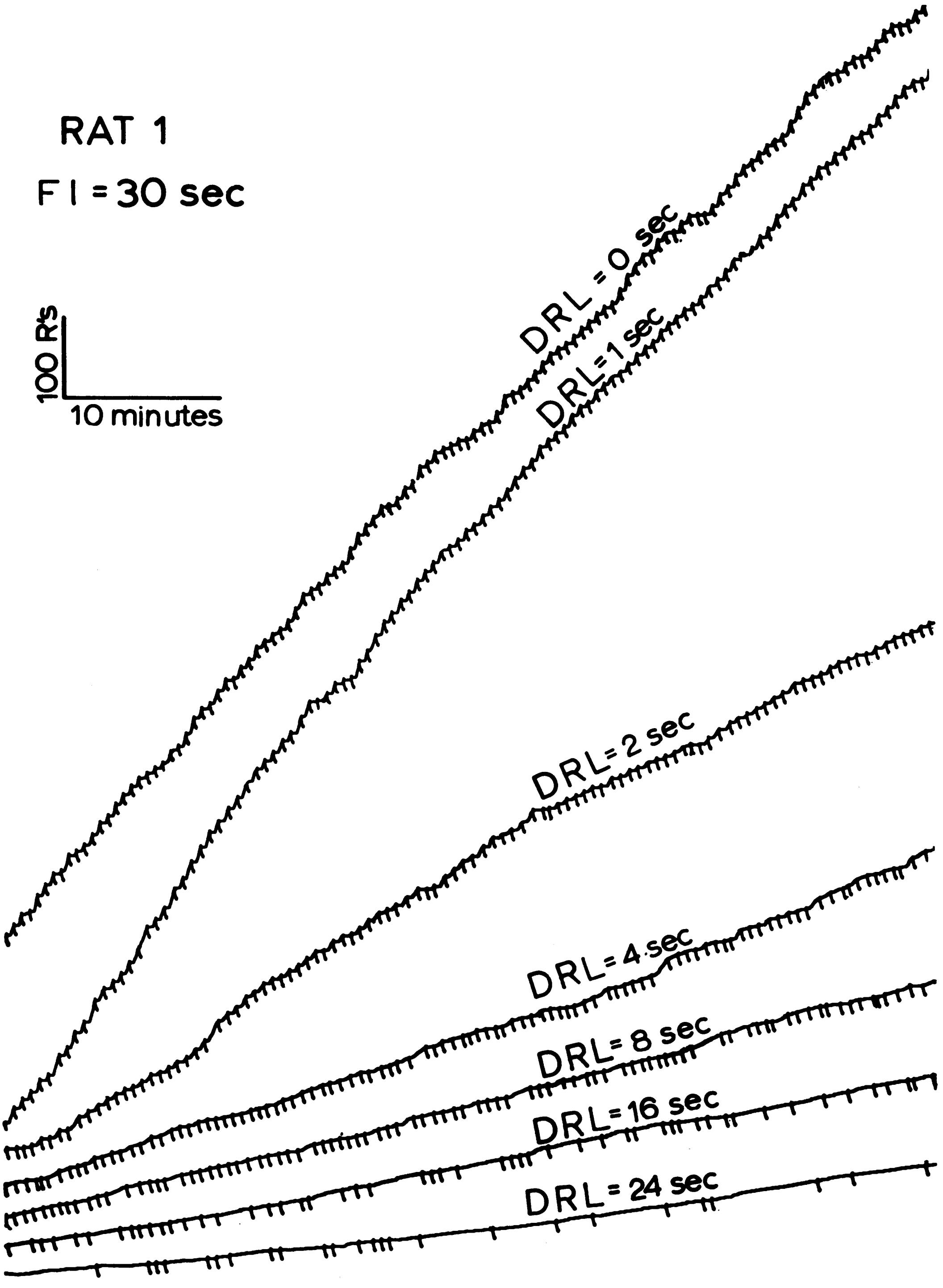

Fig. 4. Sample cumulative response curves for rat 1, each record from DRL = 0 to DRL = 4 sec being of a complete 60-min experimental session, while the records at DRL values from 8 to 24 sec are each of the last 60 min of a 2 hr session. Each pip represents a 3-sec S^R.

(Schoenfeld, Cumming, and Hearst, 1956; see also the study by Hearst, 1958, which employed the present procedure save for the recycling contingency in t^Δ which we have added).

After the initial 30 days at FI 30, both *S*s were exposed successively to six increments of DRL in the following order: 1, 2, 4, 8, 16, and 24 sec. For each of these DRL values, exposure was 20 days, save for conjFI30 sec DRL24 sec which was used for 40 days. Session lengths were increased to 2 hr beginning at conjFI30-DRL8. The last five days at each DRL value were considered as final stable performance criterion days across which means were computed. These means constitute the data reported below.

Experiment II

Three new rats were exposed for 40 hr (20 2-hr daily sessions) to a conventional DRL 24-sec schedule following a regular reinforce-

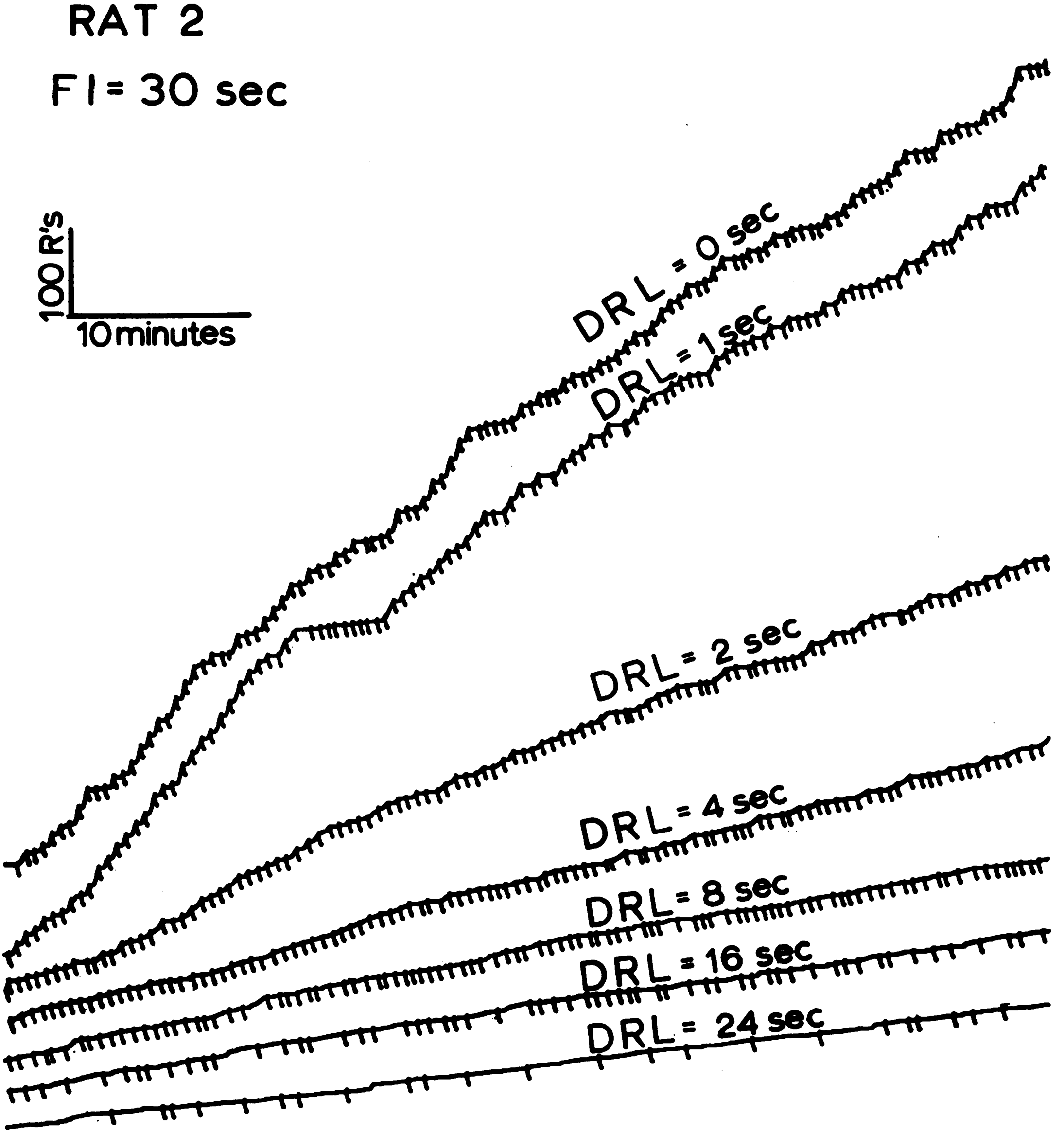

Fig. 5. Sample cumulative response curves for rat 2, each record from DRL = 0 to DRL = 4 sec being of a complete 60-min experimental session, while the records at DRL values from 8 to 24 sec are each of the last 60 min of a 2 hr session. Each pip represents a 3-sec S^R.

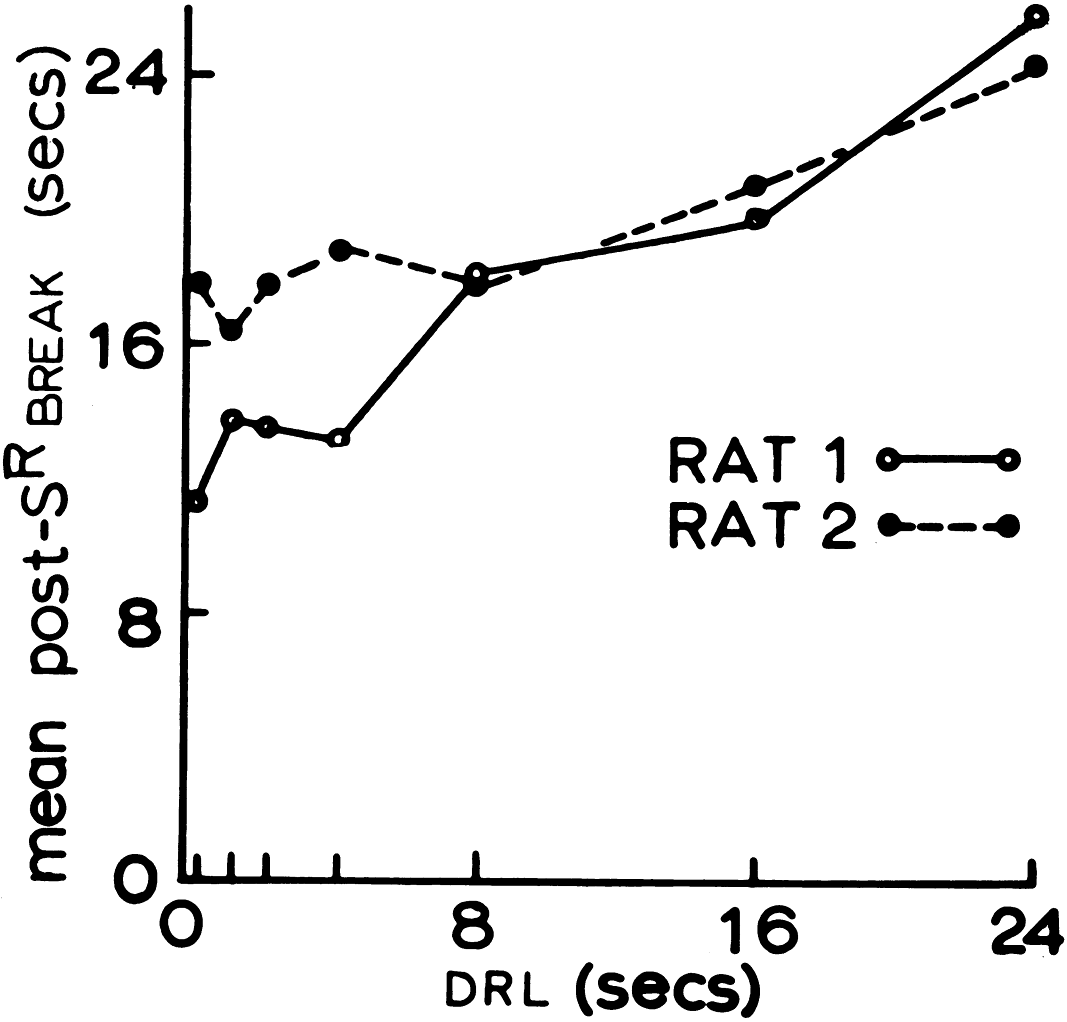

Fig. 6. Mean post-S^R break for the last five criterion days at each DRL value. The mean break values were obtained by dividing the total post-S^R break time (time from 3-sec S^R termination to the occurrence of the first response following) by the number of S^R delivered.

ment history for bar pressing identical to that given the two rats of Experiment I. Reinforcement again was 3-sec access to 50% condensed milk-water mixture and the DRL requirement was timed from the termination of this 3-sec S^R. Relative frequency distributions of the IRT and post-S^R break times were taken for all *S*s during two 3-hr sessions following the 40-hr exposure to the DRL schedule.

RESULTS AND DISCUSSION

Figure 1 plots mean response rate calculated after removal of (a) S^R time (or, 3 sec multiplied by the number of S^R), and, (b) post-S^R break time (or, time from S^R termination to response occurrence). Since corrections (a) and (b) eliminate from rate calculations the time between the reinforced response and the next one following, they produce, if taken alone, an artifactual "simultaneity" of occurrence of these two responses. To correct for the spurious high rates that would be produced in this way, especially at high S^R frequencies, it was necessary to subtract the total number of reinforced responses from the total number of responses made in the session. This reduced number of responses was then divided by the reduced session time to give the corrected mean rate data plotted in Fig. 1. (To facilitate comparisons, Fig. 2 replots response rates with post-S^R^ breaks included.) The curves of Fig. 1 appear hyperbolic, with the reciprocals of their plotted values consequently yielding the linear mean IRT plot of Fig. 3.

As seen in Fig. 1 and 3, the DRL contingency can produce a response rate, or IRT, proportional to it even when that contingency represents a relatively small portion of the temporal cycle which defines reinforcement availability, *e.g.*, at DRL values of 1, 2, and 4 sec. Cumulative records (Fig. 4 and 5) indicate that the rising mean IRT lengths are superimposed on a baseline FI pattern of "break and (terminal) run" without disrupting that pattern. The mean break length remains fairly constant for DRL values up to 4 sec (Fig. 6), while the longer IRTs are revealed generally as a slower terminal run to S^R. The absence of any systematic change in mean break length across the short DRL values may be attributed to the lack of any direct contingency between S^R and break length. In other words, at short DRL values, relatively wide variations in mean break length may occur without delaying S^R, with longer DRL components, however, the limits decrease over which the post-S^R break may vary without delaying S^R. Under these conditions (at DRL 16 and 24 sec, Fig. 6), mean break length begins to increase similarly to the way the mean IRT has been increasing; *i.e.*, mean break length also begins to approximate DRL length.

A comparison of post-S^R break length distributions with the IRT distributions (not shown) suggested a greater precision of timing behavior when initiated by an S^R than by a response, since the relative frequency of a sequence of two reinforced responses appeared greater than that of a sequence of a non-reinforced response followed by a reinforced one. To determine whether this trend was perhaps due to the FI component, or, to the fact that the DRL component could begin while the rat was still drinking, Experiment II was carried out. Three new rats were run on a conventional DRL 24-sec schedule (in which the DRL requirement was timed from the 3 sec S^R termination). Since all *S*s gave similar results, data are presented here from one *S* chosen at random. Figure 7 contains the obtained IRT and post-S^R distributions, and Fig. 8 the response probability form of these

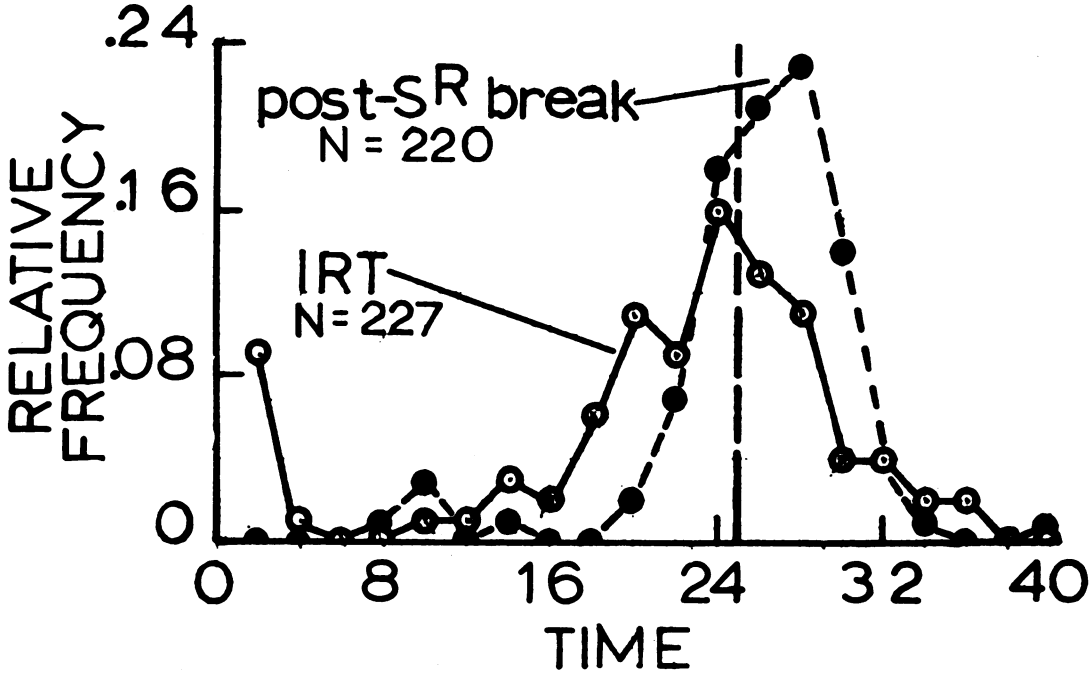

Fig. 7. Comparison of relative frequency distributions of the IRTs and post-S^R break times taken from one rat. These values were secured during one 3-hr session after 40 hr exposure to conventional DRL 24 sec, without the FI component. Each plotted point represents the upper bound of its class interval which is 2 sec wide for both distributions.

distributions (Anger, 1956), for this *S* after 40 hr of exposure to this DRL 24-sec schedule. It appears from a comparison of these two sets of distributions that even without the FI component there is still a tendency toward more accurate timing behavior following S^R termination. Supporting evidence that timing is more accurate following S^R termination has been reported by others (*e.g.*, Kelleher, Fry, and Cook, 1959; Malott and Cumming, 1964) in cumulative records which showed that reinforced responses tend to occur in relatively long sequences. This closer accuracy in timing a DRL interval from S^R termination may rest on the greater intensity of exteroceptive cueing which accompanies the latter event, since, with our apparatus, reinforcement termination is acompanied by an auditory stimulus as the dipper hits the reservoir bottom. This is more audible than the microswitch sound accompanying the bar press. Against this likelihood is the fact that Kelleher *et al.* (1959), reported no difference in timing behavior after removal of auditory feedback for the bar press response on DRL LH schedules. Another possibility is suggested by Malott and Cumming (1964), who found long post-S^R breaks on DRL LH schedules which they related to the observation that following S^R "all *S*'s reliably exhibited a homogeneous response chain consisting of water dipper licking" (p. 236). This type of chaining was impossible in the present instance since the dipper was always inaccessible except during the 3 sec S^R period. Even so, it cannot be ascertained whether the response and the S^R initiated different chains to which the greater timing accuracy following S^R may be attributed. A final possibility may account

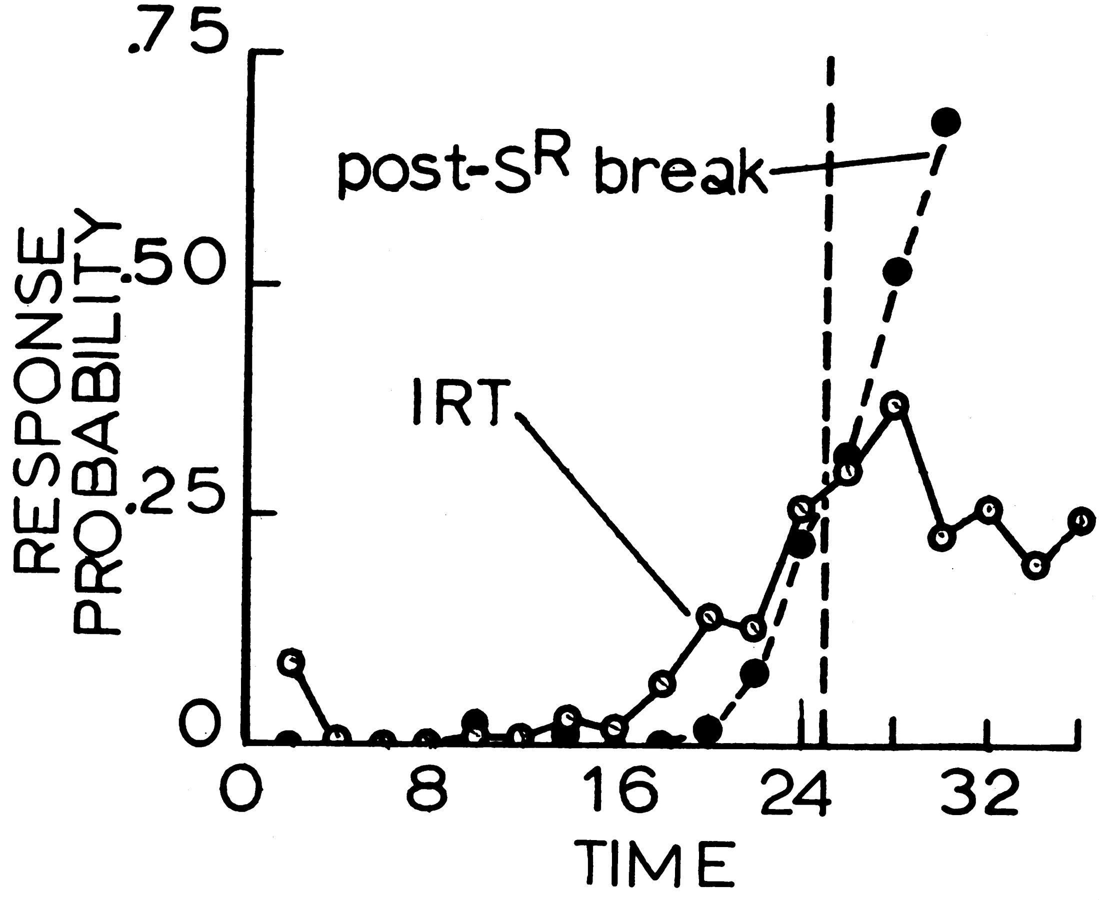

Fig. 8. Comparison of the response probability forms of the IRT and of the post-S^R distributions of Fig. 7. Response probability was computed by dividing the number of responses in each 2-sec class interval by the total number of responses occurring in that and all succeeding intervals. The plotted points terminate where the total remaining number of responses fell below 20.

for the more accurate timing observed after S^R, namely, that after S^R termination a situation prevails that is relatively unambiguous compared with that after response occurrence. After S^R termination, the next S^R is available not less than 24 sec later, while after a response the two possibilities exist that S^R is either postponed 24 sec, or it occurs immediately.

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