

A comparison of pretrial and intertrial rewards on runway extinction

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In two experiments, rats were trained to run a straight alley for food reward in the goalbox. During subsequent extinction sessions, food rewards were given in the holding cages either immediately pretrial or during the intertrial interval. Pretrial rewards retarded extinction. Importantly, this resistance to extinction was also apparent on nonprefed test trials that occurred either embedded within the daily extinction sessions or at the start of the daily sessions. The results suggest that food reinforcers have a temporary aftereffect that can maintain already conditioned behaviors.

A basic principle of instrumental conditioning is that extinction reduces the frequency of previously learned responses. Less clear, however, is the process behind the response reduction. Mackintosh (1985) noted that the removal of reinforcement may affect either of two factors: reducing the response-reinforcer contingency, and removing the reinforcer itself from the experimental situation.

Since reward conditioning is typically defined as the establishment of a positive contingency between some response and the occurrence of reinforcement, extinction (i.e., response reduction) of the response-reinforcer association should occur when the reinforcer no longer regularly follows the response. Thus, one procedure for producing extinction would be to continue presenting reinforcers, but no longer contingent on the response (Rescorla & Skucy, 1969). Although such presentations of "free" reinforcers may reduce instrumental responding, it appears that this approach is much less effective than omitting the reinforcer completely (Boakes, 1973; Boakes & Halliday, 1975; Rescorla & Skucy, 1969).

Such findings have led to the consideration of other, nonassociative factors that influence the rate of extinction when the reinforcer is omitted. In discussing the Pavlovian situation, Rescorla (e.g., Rescorla & Heth, 1975) suggested that the response loss seen in extinction is due both to the reduction in event contingency and to the degradation of the memory representation of the reinforcing stimulus. Continued presentations of the latter stimulus, although not paired with a response, would maintain the representation of the reinforcer, and some responding would thus still occur during extinction with free reinforcers. Rescorla and Skucy (1969) also considered the possibilities of response elicitation by the reinforcers presented during extinction, and the maintenance of in-

centive motivation, as mechanisms for extinction resistance.

One potentially effective variable that is relevant to the above hypotheses is the temporal interval separating the noncontingent reinforcers and the extinction trials. Nagaty (1951a, 1951b) found that there was less extinction when the reinforcer was presented 1 sec pretrial than when it was presented 20 sec pretrial. This effect was significant in extinction of an avoidance response, and, in addition, both groups receiving shock evidenced less extinction than did a nonshocked control group. A similar pattern was found during extinction of a food-rewarded response, although none of the differences were statistically significant in this case.

When reinforcers are presented proximal to the extinction trials, it is likely that responding is enhanced through carryover effects from the previous reinforcer. Such "priming" effects have frequently been observed to facilitate instrumental responding during extinction, as shown by within-subject comparisons of prefed and nonprefed trials (Eiserer, 1978; Terry, 1980). Thus, to assess the effects of pretrial reinforcers on the course of extinction, one would like to have test trials that are remote from these free reinforcers. Nagaty (1951a, 1951b) did present such trials during a session at the end of extinction training, but found no differences among the several groups. However, testing then would not have been sensitive to differences earlier on during extinction.

The first experiment to be reported assessed extinction of running in a straight alley under conditions in which food was given immediately pretrial or several minutes pretrial, in an attempt to document the effect observed by Nagaty (1951a, 1951b). In the subsequent experiments, the test-trial conditions were varied and an extinction-only control was included. The presence of food between extinction trials should increase resistance to extinction (Rescorla & Skucy, 1969), and, to be consistent with Nagaty's (1951a, 1951b) results, running should be even more persistent in subjects receiving food just prior to each extinction trial than in those receiving it minutes earlier.

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However, the intertrial food groups should be equivalent with respect to several alternative variables: a reduction in the response-reinforcer contingency; an equivalent overall level of drive, incentive motivation, or hunger; and an ability to maintain the memory of food in the experimental context. Test trials without intertrial reward were included in each session to assess responding in the absence of any transient aftereffects of reward on responding.

EXPERIMENT 1

Method

Subjects. The subjects were 20 male Sprague-Dawley rats (Harlan Sprague-Dawley, Indianapolis, IN), with preexperimental weights of 235 to 285 g. All animals were individually housed in a colony room maintained on a 12:12-h light:dark cycle.

Apparatus. The apparatus and procedures were identical to those described by Terry (1983). Briefly, the runway used was 11 cm wide and 15 cm high, and was divided into start (30 cm long), run (100 cm), and goal (28 cm) sections by guillotine doors. Photocells and timers recorded start and run times. The goalbox contained a glass dish, 3 cm in diameter, for the food reinforcers. A similar dish was used to give pretrial reinforcers.

Procedure. The subjects were placed on a 22-h food-deprivation schedule, with water continuing ad lib. On the first 2 days, the subjects were handled and given 4-min periods of exploration in the runway. Food was not available here, but 45-mg Noyes pellets were given in the holding cage during these sessions.

All subjects then received six runway acquisition sessions. The first two sessions consisted of three reinforced trials for each animal, and the remaining sessions had six such trials. On each trial, the subject was placed in the startbox, 2 sec were timed, and the startbox door was opened. After the subject entered the goalbox, a second door was closed and the subject was confined there for 10 sec. Reinforcement consisted of four Noyes pellets. The subjects were run in rotation, using squads of 5 animals.

Two experimental groups ($n=10$ each) were then formed. These groups were matched on acquisition performance, using both initial and terminal start and run speeds. On the day following the last acquisition session, extinction testing began and food was omitted in the goalbox of the runway on all trials. The groups differed in the schedule of reinforcers given between these trials. The pretrial group received a reward immediately prior to some extinction trials each day, whereas the intertrial group received a reward several minutes prior to some extinction trials. Specifically, for subjects in the pretrial group, a food dish containing four pellets was placed in the holding cage. When the subject appeared to have finished eating, it was placed in the runway to begin the extinction trial. For subjects in the intertrial group, the reward was given approximately 1 min following an extinction trial, and 4 min preceding the next trial.

Four such pretrial or intertrial reward episodes were given on Days 1 and 2 of extinction, and two such episodes on Day 3. In addition, regular extinction trials without a pretrial or intertrial reward were scheduled daily. These occurred as Trials 3 and 6 of the first two extinction sessions, and as Trial 3 of the last session. Thus, a total of 15 extinction trials occurred, 10 having the pre- or intertrial rewards and 5 without any proximal reward.

Running squads consisted of intermixed subjects from the experimental groups, and the intertrial interval was maintained for at least as long as it was during acquisition—that is, approximately 5 min. During extinction, the subjects were not confined in the goalbox, since many had a tendency to dart back out before the door could be lowered. Therefore, they were simply maintained in the runway until the running times could be recorded, and then removed.

The subjects were allowed a maximum of 60 sec for each extinction trial.

Results

Since both start and run times showed a similar pattern of results, they were combined to provide a single measure of total running time. In the data presentation and analysis, the maximum time used for any trial is 30 sec. The left panel of Figure 1 shows daily mean running times on trials preceded by food for subjects receiving pretrial or intertrial rewards. The right panel shows the data on the test trials in which food was not presented during the preceding intertrial interval. Each point is an average of two trials.

As can be seen, although both groups started the test sequence at nearly identical levels, the presence of pretrial food retarded extinction relative to intertrial presentations. Running was faster immediately following the feeding on three out of four blocks of trials beyond the first, which could be expected due to a transient priming effect. However, running was also faster for the pretrial group on the test trials, which occurred several minutes away from a food presentation. Although the two groups even differed on the first day's test trials, since these trials occurred later in the session than did prefed trials, the difference would seem to reflect the effects of the several prior prefed trials.

For statistical analyses, the median total running time across all trials for each subject was obtained. The medians are less influenced by occasional extreme scores and are more representative of the individual subjects' typical performance. A 2×2 analysis of variance showed a significant overall difference between the pretrial and intertrial groups [$F(1,18) = 9.72, p < .05$], but no significant difference between prefed and test trials and no interaction of the two factors ($F_s < 1$). Given the theoretical importance of comparing extinction performance on trials remote from the food, a separate analysis was also done on the test-trial data alone. Again, the pretrial and intertrial groups were significantly different [$F(1,18)$

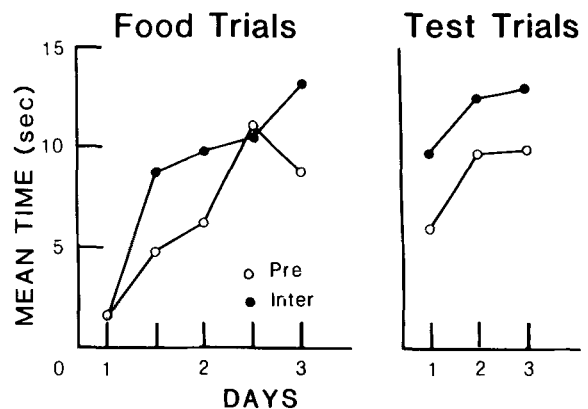


Figure 1. Mean total running times across two-trial blocks within Days 1-3 of Experiment 1. Left panel: Trials in which food immediately preceded extinction trials (pretrial group) or occurred during the intertrial interval (intertrial group). Right panel: Test trials without food pretrial or during the intertrial interval.

= 6.82, $p < .05$], with mean times of 4.53 and 9.84 sec, respectively. The mean median times on trials following food were 2.00 and 7.33 for the pretrial and intertrial groups, respectively.

EXPERIMENT 2

The results of the first experiment showed that the presentation of food just prior to the extinction trials increased resistance to extinction of the running response. The second experiment was conducted to provide a replication and an extension of the prefeeding effect. An important change was that test trials were given at the start of each session, rather than within the session. The first experiment showed that, for the pretrial group, responding on test trials was enhanced by exposure to the reward during the session, even if the reward was remote from the test trials. It is possible that performance on these trials still reflected a temporal gradient of priming. Food presentation occurred closer to a given test trial n for the pretrial subjects (i.e., just prior to trial $n-1$) than to a given test trial n for the intertrial subjects (i.e., approximately 4 min prior to trial $n-1$). By having test trials occur 24 h after the last experimental trials, the rate of extinction could be assessed on occasions equally uninfluenced by any recent reward occurrence.

Two experiments were conducted, one comparing an extinction control with an intertrial food group, and the second comparing intertrial and pretrial reward groups.

Method

The apparatus and general procedures were the same as those in the first experiment. The subjects in Experiments 2A and 2B were 40 rats weighing 260–335 g prior to the studies. Each subject received four (Experiment 2A) or five (Experiment 2B) periods of exploration in the runway, with food present in the goalbox at this time. On the first two of these sessions, food was presented in the holding cage to acquaint the subjects with the experimental procedure. Following this, 5 days of runway acquisition training were given, and then extinction was begun. In each experiment, two groups ($n = 10$ rats each) were formed, matched on acquisition performance.

In Experiment 2A, the extinction group simply received nonreinforced runway trials; this group was not given food presentations on or between any of the trials. The intertrial group received food between the runway extinction trials but not in the goalbox, as was the case in Experiment 1. These feedings occurred before Trials 3–6 of the first two extinction sessions, and before Trials 3–4 of the third session. The first two trials of each day were test trials, and were not preceded by food in the holding cage. For the extinction control group, the first two trials of each session were also designated as test trials, although in fact all trials were alike for these subjects.

In Experiment 2B, an intertrial-food group was compared with a pretrial-food group. Food presentations occurred prior to each of Trials 3–6 on Days 1–3, and prior to Trials 3–4 of a fourth extinction session. No food presentations occurred prior to the first two trials of each session (the test trials). Thus, subjects in Experiments 2A and 2B received six trials during each of the first extinction sessions, and four trials on the final session, using a 5-min intertrial interval. In other respects, the procedures were like those of Experiment 1.

Results

Start and run times showed an identical pattern of effects in these two studies, so total running times were again used in the analyses. Figure 2 plots the mean time over two-trial blocks within days on trials following food (left panel) and on unprimed test trials (right panel) for the intertrial group, and on trials occupying the same location in the session for the extinction group. The two groups had similar levels of performance on the first session of extinction. However, the intertrial food group showed faster running over Days 2 and 3 on those trials preceded (albeit by several minutes) by food. On the test trials, however, the two groups remained similar in their levels of performance.

Statistical analysis used the median total running times across Days 2–3 for each subject. A 2×2 analysis of variance showed a significant interaction of the two groups with the type of trial [$F(1,18) = 6.79, p < .05$]. The main effects of the difference between the two groups, and between the food-primed and test trials, were not significant. Post hoc Newman Keuls tests showed that the intertrial food group ran faster than did the extinction group on trials following food presentation (mean of median times = 6.94 and 11.91 sec), but not on the test trials (mean of median times = 7.99 and 9.65 sec). The mean values show that the intertrial subjects ran slightly faster on food-preceded trials than on test trials, whereas the extinction subjects ran slightly slower on the later trials of the sessions. These within-group differences were significant only at the .10 level.

The effects of intertrial reward replicate the results of noncontingent reward on extinction noted by Rescorla and Skucy (1969) and by Boakes (1973). The test-trial data suggest a limiting condition: either that response-independent food does not affect spontaneous recovery, or that it only elevates responding during those trials proximal to food presentation.

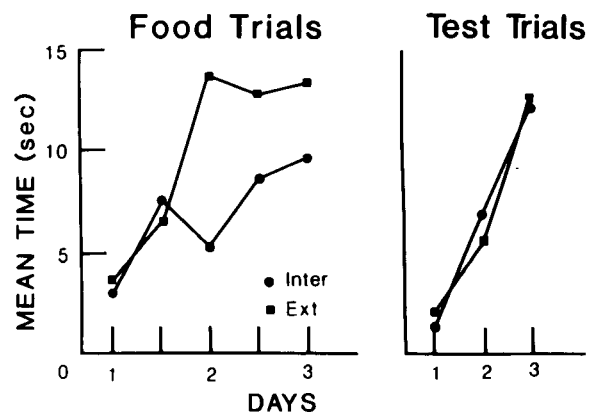


Figure 2. Mean total running times across two-trial blocks within Days 1–3 of Experiment 2A. Left panel: Trials preceded by food during the intertrial interval (intertrial group) and on comparable trials for subjects not receiving food (extinction group). Right panel: Trials at the beginning of each session with no prior food rewards.

The results of Experiment 2B are shown in Figure 3. In general, these subjects showed a slower course of extinction than those of the other studies. However, as was the case in Experiment 1, pretrial feedings maintained running more so than did intertrial feedings. This effect was observed both on the food-preceded trials (left panel), and more importantly, on the test trials (right panel) occurring 24 h after the last food-primed extinction trials. A 2×2 analysis of the median total times across Days 2–4 showed a significant difference between the pretrial and intertrial groups [$F(1, 18) = 4.96, p < .05$]. The difference between test-trial and food-trial performance, and the interaction of this factor with the groups factor, was not significant. Again, a separate analysis of test-trial responding showed a significant between-groups difference [$F(1, 18) = 6.47$] (mean median times = 2.39 and 6.70 sec for the pretrial and intertrial groups, respectively; for food-preceded trials, these values were 3.81 and 5.61 sec, respectively).

By having test trials at the start of the session, spontaneous recovery in the different conditions could be assessed uncontaminated by a prior feeding. However, there was little evidence for recovery of the extinguished response between sessions. Neither of the intertrial groups nor the extinction control showed any consistent recovery, whereas the pretrial group showed slight recovery on the last two sessions. Boakes and Halliday (1975) reported that spontaneous recovery is not observed when free food presentations are given during extinction.

GENERAL DISCUSSION

The present experiments demonstrate that the temporal placement of a food reward in the intertrial interval during extinction can affect the course of response reduction. Rewards given immediately pretrial led to more persistent running. Although this could simply be attributed to a priming arousal effect, the important present finding was that the pretrial reward groups were more persistent, even on the test trials.

Previous research has shown that response-independent food can retard extinction of operant responding (Boakes, 1973; Rescorla & Skucy, 1969). The factors offered to explain the effects of response-independent food cannot obviously explain the differential effects of pretrial and intertrial rewards. Both conditions should be equal in terms of instrumental response-reinforcer (or discriminative stimulus-reinforcer) contingency reduction; overall drive, hunger, and incentive-motivation conditions during the session should be equivalent; and the memory trace of the reinforcer would be maintained by an equal number of refresher presentations.

Certain differences between the pretrial and intertrial conditions also do not account for the prefeeding effect. The pretrial food may have had a response-eliciting effect (comparable to a priming effect) that would enhance performance on those trials, as compared with the intertrial group. Yet, rapid running was maintained on the test trials, in the absence of an elicitor on those occasions. Another possibility is that the food in the holding cage still reinforced the running response, but was now a delayed reward. If this was the case, the subjects in the intertrial group should have received the most benefit, since the rewards more closely followed their trials than they did for the pretrial group.

However, this interpretation of delay-of-reward effects may be simplistic. Lett (1979) found that delayed rewards given in the startbox were more effective than rewards given in the home cage. The present prefeeding condition may have closely approximated a startbox condition, to the degree that the effects of the food carried over to the start of the trial.

The response decline in extinction is often attributed to generalization decrement, due to the change in stimulus conditions between acquisition and extinction. Possibly there was differential generalization decrement between groups. It is not clear how this explanation can be applied to the present findings, since for both pretrial and intertrial food conditions, reward was continued during the extinction sessions. If the food reward had become

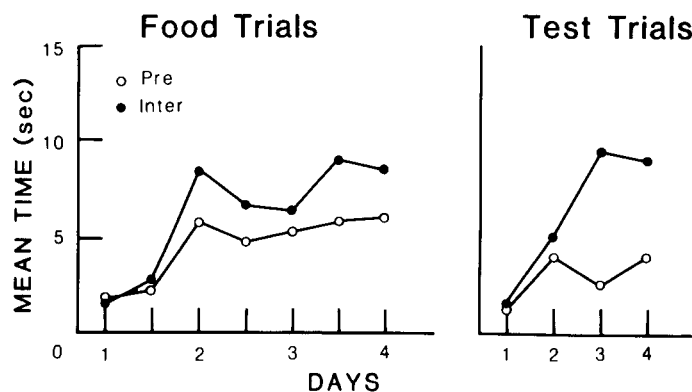


Figure 3. Mean total running times across two-trial blocks within Days 1–4 of Experiment 2B. Left panel: Trials in which food immediately preceded extinction trials (pretrial group) or occurred during the intertrial interval (intertrial group). Right panel: Trials at the beginning of each session with no prior food rewards.

a signal for subsequent food during the acquisition phase, one could argue that this stimulus was more intense in the pretrial food conditions, not having as much time to decay before the onset of an extinction trial. Alternatively, one could argue that conditions had changed less for the intertrial groups, since food reward preceded trial onset by several minutes, just as in acquisition.

Finally, there are potential learned stimulus properties of a food reward introduced during extinction. For example, the pretrial reward could have become a signal for food absence in the goalbox. Haggbloom (1983) showed that pretrial food could readily acquire signal value and control running speed in a straight alley. Alternatively, the prefeeding may have led to some overshadowing of the runway stimuli and responses, thus protecting the latter from extinction. Rilling, Howard, and Johnson (1980) found that food would overshadow a key-light stimulus in a pigeon operant task, and the food became the dominant discriminative stimulus controlling responding. However, either of these interpretations suggests that patterned running would have developed. The pretrial-food subjects should have run more slowly on the primed trials in the presence of the food as a discriminative stimulus for nonreward in the runway. Running would be faster on test trials in the absence of the discriminative or overshadowing stimulus. However, patterned running by pretrial subjects was not consistently observed, either in within-subject or between-groups comparisons.

The present studies suffer because there is no direct comparison of pretrial food and an extinction control condition. Because the present results were obtained in simple two-group comparisons, one logical explanation is that the intertrial food facilitated extinction rather than that the pretrial food inhibited extinction. However, previous research has in fact shown that intertrial food retards, not enhances, extinction (Boakes, 1973; Rescorla & Skucy, 1969). Similarly, Experiment 2A found no evidence for facilitated extinction in comparing an intertrial food group to an extinction control group. Homzie, Gohmann, and Hall (1971) also found a response-enhancing effect if intertrial rewards were presented during extinction of runway behavior. In any event, the major question here was whether the differential placement of the intertrial reward would be differentially effective, and the results clearly gave an affirmative response.

The results, while replicating and extending those of Nagaty (1951a, 1951b), are still unexpected. Given that prefeeding retards acquisition of responding for food reward (Terry, 1983), one could have anticipated a reverse effect that would facilitate learning about nonreward. Opponent-process theories might also predict more rapid extinction, inasmuch as the runway stimuli and responses were paired with an opposing aftereffect from the preceding food (Schull, 1979).

Although the present study demonstrates a prefeeding retardation of extinction, and also discounts some hypotheses for this effect, the designs do not suggest a likely explanation for the results. At the very least, the

data argue against certain molar theories and point to the need for more momentary factors. Thus, a general theory of contingency effects across a session would not describe the differential effect of noncontingent reward at different pretrial intervals. Any of several short-term aftereffects of the pretrial food might have been responsible for the present results. The recent receipt of food might have minimized the frustration normally experienced in the empty goalbox at the onset of extinction. Alternatively, following acquisition training, changing the response-reinforcer interval might have still maintained the response, even if that interval would not have been initially effective in producing conditioning. Nagaty (1951b) found that switching to a 20-sec delay before reinforcement still maintained the previously trained behavior. A symmetrical shift in the opposite direction, presenting the reward prior to the trial, was only minimally effective in his studies, but was found to be more robust in the present case.

Given that pretrial food enhances resistance to extinction, an interesting question is whether priming would minimize the effect of nonrewarded goal exposures during acquisition, as would occur with a partial-reinforcement schedule. Terry (1985) trained rats with a 50% reward schedule, and gave pretrial feedings on half of the daily trials. In this study, food given prior to nonrewarded trials did not show any benefit over food given prior to rewarded trials; both of these groups responded more slowly than did an intertrial-food group. Thus, pretrial food did not compensate for nonreward in the goalbox during acquisition training. One potentially important difference between prefeeding during acquisition versus extinction is the time interval separating prefeeding and goal entry. During the initial training trials, these intervals approached 20 sec, whereas during the initial extinction trials, this interval was only a few seconds at most. This reward-response or reward-goal interval, especially over the shorter delays of 1-30 sec, may be an important determinant of whether facilitation or inhibition of learning occurs.

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