Between- and within-subjects partial reinforcement effects as a function of response alternatives

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The between- and within-subjects partial reinforcement effect (PRE) was studied in 24 hooded rats with either one or two levers present in the test chamber. The between-groups analysis resulted in a conventional PRE for both one- and two-lever groups, but the effect of one vs. two levers was not significant. The within-subjects analysis yielded a significant reversed PRE (higher responding to the CRF stimulus). An analysis of errors in the two-lever groups yielded the following: (1) During acquisition, CRF produced fewer errors than PRF both between and within subjects, (2) within-subjects training yielded better discrimination than between-groups training, (3) during extinction, there was a large increase in errors in the between- and within-subjects CRF condition, and (4) the percent errors during extinction were greater with CRF than PRF in the within-subjects comparison, but not in the between-groups comparison.

It has been demonstrated in between-groups designs that rats will continue to respond for a longer period of time during extinction in a situation in which they have been trained on a partial reinforcement schedule (PRF) than will rats that have had similar training but with continuous reinforcement (CRF). This is called the partial reinforcement effect (PRE). Using a within-subjects design, however, in which each animal experiences both schedules (PRF under one condition and CRF in another), a reversal of the PRE frequently occurs. That is, subjects will respond longer in extinction under the condition that had been associated with CRF than they will under the condition associated with PRF.

Several studies (Pavlik & Carlton, 1965; Pavlik, Carlton, Lehr, & Hendrickson, 1967; Pavlik & Collier, 1973) have examined different aspects of this phenomenon. The standard operant procedure for the within-subjects design in these studies has been to alternate cues during training to signal which schedule (CRF or PRF) is in effect. The animal's responses, although recorded separately for each schedule, are made on the same lever.

In another study (Pavlik, Carlton, & Manto, 1965), a slightly different training procedure was used in which two levers (one for CRF, the other for PRF) were continuously available, but only responses to the signaled lever were reinforced. In this study, a conventional PRE was obtained. Since it is possible that the reversed PRE could be a result of the particular procedure employed (that is, one lever instead of two levers), the current study manipulated the two procedures on both between- and within-subjects bases.

The one-lever vs. two-lever procedures raise another question, however. The within-subjects PRE experiment does require that a discrimination be made; that is, the subjects must associate different external cues with different reinforcement schedules. Since discrimination performance typically is poorer under PRF than under CRF schedules (e.g., Pavlik & Born, 1962), different numbers of errors should occur in the PRF and CRF portions of within-subjects PRE experiments, and, in the two-lever situations, such "errors" would be attributed to the resistance to extinction of the "other schedule." The possible confounding of differential resistance to extinction with differential error rates was examined in the present study via detailed analyses of the performance of the subjects in the two-lever groups.

METHOD

Subjects

The subjects were 48 experimentally naive male hooded rats, 90 days old at the start of the experiment. They were maintained at 80% of their free-feeding weights, and all animals were housed individually with ad-lib water available.

Apparatus

The apparatus consisted of two identical Lehigh Valley Electronics rat chambers. One wall of the chamber was an aluminum panel containing two retractable levers; each lever had a set of three stimulus lights located directly above it. A house-light and white masking noise (82 dB) were present during the entire session. The reinforcer was one 45-mg Noyes pellet delivered to a food cup between and equidistant from the two levers.

Procedure

The experiment was run in two identical replications, 24 subjects in each. Since they were identical, the data have been combined in the analyses. The animals were magazine trained and shaped to barpress to a criterion of 75 responses in 15 min. Both

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levers were available during this training. After criterion was reached, training was continued with only one lever present during each session until the criterion had been reached for that particular lever.

The animals were then randomly assigned to one of three groups: a CRF control (Group C, $n = 16$), a PRF control (Group P, $n = 16$), and the within-subjects experimental group (Group C/P, $n = 16$). For half the animals in each of these three groups, only the lever directly below the alternating cue lights was available; the other lever was retracted during this time. For the other half of the animals in these groups, both levers were continuously available, but only responses to the signaled lever were reinforced. Half of the subjects in each of these groups started each daily session on the right lever; the other half started on the left lever. In Group C/P, the left lever signaled CRF and the right lever signaled PRF.

The control groups were on a multiple schedule, either a mult CRF-CRF (Group C) or a mult PRF-PRF (Group P); each component was signaled by one set of stimulus lights. Group C/P was on a mult CRF-PRF. The PRF component for Group C/P and for Group P was a variable-ratio (VR) 4. The components were alternated every 30 sec for all groups. The control group sessions were 10 min. Group C/P sessions were 20 min in length (so that Group C/P had the same length of time in each component as the control group for the particular schedule).

There were 12 daily sessions of acquisition, after which 3 sessions of extinction were run. The extinction conditions were the same as acquisition, except that no reinforcers were given.

RESULTS

Data for this study were collected in the following manner. Responses to a lever when the associated stimulus light was on were considered "correct" responses (left correct = LC and right correct = RC). Responses made to a lever when the stimulus associated with the other lever was on were considered "incorrect" responses (left incorrect = LI and right incorrect = RI). "Incorrect" responses were collected for the two-lever groups; the one-lever groups had only one lever and its associated cue light available at a time. Analysis of the differences between groups was computed on the total "correct" responses; the error analysis was done using total responses for the two-lever groups, "correct" and "incorrect."

Figure 1 shows the results of the between-groups comparison for the one- and two-lever situations. A conventional PRE was obtained in both cases, with the PRF groups responding at a higher level than the CRF groups. The ANOVA showed a significant Schedule by Days interaction [$F(2,32) = 3.867$, $p < .05$] when collapsed over levers, but the effect of one vs. two levers was not significant.

The results of the within-subjects comparison (Group C/P) are shown in Figure 2, and they show a reversed PRE. The ANOVA showed the effect of schedule was significant [$F(1,8) = 5.31$, $p < .05$], as was the Schedule by Days interaction [$F(2,16) = 5.17$, $p < .05$]. The difference between CRF and PRF was significant on Day 1 of extinction (Wilcoxon $T = 11$, $n = 16$, $p < .01$), but it was not significant on Day 2 or 3.

To examine error rates under the different sched-

Figure 1. Mean responses for the between-groups comparison for the one- and two-lever conditions as a function of day of extinction.

Figure 2. Mean responses for the within-subjects comparison for the one- and two-lever conditions as a function of day of extinction.

Figure 3. Mean percent errors for the between-groups and within-subjects comparisons as a function of session (last two sessions of acquisition and three sessions of extinction).

ules, the responses of each subject in the two-lever groups were categorized as correct (i.e., responses to the lever with the illuminated cue lights) or incorrect (i.e., responses to the "dark" lever), and a "percent error" score (incorrect responses/correct + incorrect responses) was computed. For subjects in Group C/P, separate percent error scores were computed for the CRF (left lever illuminated) and PRF (right lever illuminated) conditions.

Mean error scores are shown for the final 2 days of acquisition and for extinction in Figure 3. At the end of acquisition, it is apparent that CRF was producing relatively fewer errors (better discrimination) than was PRF in both between-groups and within-subjects comparisons and that within-subjects training (Group C/P) yielded better discrimination performance than did between-subjects training (Groups C and P). Percent errors increased during extinction in all conditions, but to different degrees.

In the between-groups comparisons, a significant Groups by Sessions interaction was obtained [$F(4,56) = 8.16, p < .001$]. A large increase in percent errors occurred in Group C, but not in Group P; the groups differed in errors during acquisition, but not during extinction. In contrast, the within-subjects comparison, while also yielding a significant Schedules by Sessions interaction [$F(4,63) = 3.65, p < .01$], indicated schedule differences in percent errors in opposite directions for acquisition and extinction. CRF produced relatively

fewer errors in acquisition, but relatively more errors during extinction.

DISCUSSION

The principal results of this study indicate that, while between-groups comparisons yield a conventional PRE with either one or two levers, the within-subjects comparisons yield a reversed PRE in both cases. Thus, the conventional PRE with within-subjects comparisons obtained by Pavlik et al. (1965) with two levers must have occurred for reasons other than their use of two levers. Most probably, the procedural difference that produced the opposite outcomes in the two studies was the basis on which schedules were alternated during the acquisition period. In the present study, as well as in other free-operant studies that have obtained the within-subjects reversed PRE, the switch from schedule to schedule during acquisition was temporally based. In the Pavlik et al. (1965) study, however, the switch from schedule to schedule was response dependent, occurring only after a specified number of responses or reinforcements had occurred in the current schedule. As noted by Pavlik et al., such a response-contingent procedure makes possible the adventitious secondary reinforcement of PRF responding via the change to a more favorable schedule.

The results regarding percent errors (i.e., discriminative control) in the two-lever groups were both expected and unexpected. As expected, CRF produced better discriminative control (relatively fewer errors) during acquisition in both between-groups and within-subjects comparisons. Also expected was the increase in relative error rates during extinction when differential reinforcement of the two levers no longer was in effect. However, the finding that the Group C/P subjects made higher percent errors during extinction in the presence of the CRF cues than in the presence of the PRF cues was unexpected, suggesting that CRF responding during extinction under such conditions not only is more persistent but also "spills over" into other responses in a relatively uncontrolled fashion. Such a finding is consistent with theories of extinction emphasizing either frustration (Amsel, 1967) or generalization-decrement (Capaldi, 1967) mechanisms; however, the reversed PRE obtained in the within-subjects comparison is consistent with neither.

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