

Conventional and reversed partial reinforcement effects in human operant responding

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Acquisition and extinction of button pressing on multiple schedules of continuous-continuous (CRF/CRF), variable ratio n -variable ratio n (VR n /VR n), and CRF/VR n schedules of reinforcement were examined using human subjects. In contrast to similar animal studies, responding during acquisition was consistently higher on CRF schedules relative to VR groups and components. Extinction data for between-subject comparisons of schedules showed typical partial reinforcement effects (PREs). Within-subject comparisons revealed small but reliable reversed partial reinforcement effects (RPREs). These data extend the findings of the RPRE in nonhuman animals to humans. The validity of the PRE as a universal generalization for extinction phenomena is examined and rejected.

There is a widely held belief that the differential effects of continuous (CRF) and partial reinforcement (PRF) on responding during extinction are known and universal to response persistence during extinction. This generalization is known as the *partial reinforcement effect* (PRE).

However, there is a growing body of evidence that shows that the PRE is true primarily in between-groups experiments using instrumental conditioning preparations. Early within-subjects studies of the PRE using hungry rats in runways consistently failed to find a PRE. Rather, the typical result was that no schedule effects were obtained within subjects, but persistence was greater than for CRF-only controls and less than for PRF-only controls. This has been termed the *generalized partial reinforcement effect* (GPREF; Amsel, 1967; Brown & Logan, 1965; Pavlik, Carlton, & Hughes, 1965).

A growing body of studies, employing within-subjects designs in free-operant conditioning preparations, have found that the response trained with CRF is actually more persistent than that trained with PRF. This finding is known as the *reversed partial reinforcement effect* (RPRE; e.g., Nevin, 1974; Pavlik & Carlton, 1965).

Although no study has directly investigated the within-subjects PRE in human free-operant behavior, in a recent series of studies (Pittenger & Pavlik, 1988, 1989; Pittenger, Pavlik, Flora, & Kontos, 1988a, 1988b), we used a discrete-trial, selective-learning procedure to investigate both between-groups and within-subjects PREs in humans. The procedures (e.g., the experimenter sat directly behind the subject during the entire experiment, etc.) involved considerable implicit task demands that the sub-

ject continue to respond. Between-group comparisons yielded a PRE, within-subject comparisons yielded a GPREF, and response declines during extinction were not large.

In the present study, we attempted to avoid the task demands of the Pittenger and Pavlik (1988, 1989) and Pittenger et al. (1988a, 1988b) studies by using a free-operant procedure. Such a procedure does not force responses during extinction, but allows the subject to repeat or not to repeat the response.

METHOD

Subjects

The subjects were 52 introductory psychology students at the University of Georgia who participated in the experiment to fulfill part of the course requirement or to gain extra course credit.

Apparatus

The apparatus used for the experiment was a Commodore 128 computer interfaced with two pushbuttons. The buttons protruded from the top of a 25 × 10 cm platform, which was 10 cm high. The left half of the platform was white and the right half was blue. One button was located at the center of each half of the platform. All sessions were run in a small, white room.

Procedure

Points served as reinforcers; the person who had the highest score won \$10. A tone was sounded with each point earned. Each time the programmed schedule of reinforcement was satisfied, one point was earned. The subject's score was continuously updated and presented on the screen during the entire session following "Your points = ,," which was printed on the center of the screen.

All subjects received instructions informing them that they scored points by pressing buttons, that the person who scored the most points would win \$10, and that it was up to them to figure out the best way to score points. The experimenter then said, "The experiment starts now," pressed a key to start the experiment, and went into the room across the hall.

The only responses recorded by the computer when the monitor screen was blue or white were those on the blue or white button, respectively. The monitor screen alternated between blue and white every 20 sec. Thus, the experimental design consisted of a multiple schedule with 20-sec components. In each component of the multiple schedule, reinforce-

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ment was delivered either after every response (CRF) or after a variable ratio (VR) of responses.

Sixteen subjects were assigned to four control groups for between-group comparisons ($n = 4$). Three females and 1 male were in each of the control groups, except for the VR10/VR10 group, which consisted of 4 females. The four control groups were CRF/CRF, VR3/VR3 (range: 1-5), VR5/VR5 (range: 1-9), and VR10/VR10 (range: 1-19).

Acquisition consisted of two phases for all groups except for Group VR10/VR10, which had three phases. The first phase for all groups consisted of three blocks (one block comprised one blue and one white component) of CRF for both components. The final phase consisted of 15 blocks in which reinforcement was delivered on the designated schedule. Group VR10/VR10 had an additional interpolated three-block VR5/VR5 phase following CRF/CRF.

After the acquisition phase, all subjects went directly into 15 blocks of extinction, which were identical to acquisition except that reinforcement was no longer given for responding. Thus, all subjects were exposed to 10 min of the terminal phase of acquisition and 10 min of extinction. The experiment lasted 22 min for Groups CRF/CRF, VR3/VR3, and VR5/VR5, and 24 min for Group VR10/VR10.

There were three experimental groups of subjects for within-group comparisons. Each group was counterbalanced to control for sequence effects such that an equal number of subjects were first exposed to either CRF or the relevant VR schedule. The three experimental groups were CRF/VR3 ($n = 12$; 7 males, 5 females), CRF/VR5 ($n = 12$; 5 males, 7 females), and CRF/VR10 ($n = 12$; 4 males, 8 females). A blue screen was always associated with CRF, and a white screen was associated with the appropriate VR schedule. Thus, for the experimental groups, depending on the counterbalancing assignment, the experiment started with either a blue or a white component. The procedure for the experimental groups was otherwise identical to that for the control groups.

RESULTS

Between Subjects

During acquisition, the CRF/CRF group responded the most, the VR10/VR10 group responded the least, and the VR3/VR3 and VR5/VR5 groups both responded at an intermediate rate. However, an ANOVA of mean responses

over the last three blocks of acquisition was not significant [$F(3,12) = 1.85, p > .10$]. During extinction, Group CRF/CRF responded the least relative to Groups VR3/VR3, VR5/VR5, and VR10/VR10, a typical between-groups PRE. The VR10/VR10 group was less persistent than either the VR3/VR3 or the VR5/VR5 groups. The overall ANOVA of total extinction responses [$F(3,12) = 10.2, p < .01$] and post hoc comparisons revealed that Groups CRF/CRF and VR10/VR10 did not differ, but both were reliably less persistent than Groups VR3/VR3 and VR5/VR5, which did not differ from each other.

Within Subjects

During acquisition, responding was significantly higher in the CRF component than in the VR components ($p < .05$ for the CRF/VR3 and CRF/VR10 comparisons, and $p = .054$ for the CRF/VR5 comparison).

Figure 1 shows acquisition and extinction performance in the CRF component for groups that experienced different schedules in the alternative component, relative to the CRF/CRF control. Groups that experienced a VR schedule in the alternative component responded at a higher rate during acquisition on the CRF schedule than did the group that experienced only CRF. However, an ANOVA of response rates in the final three blocks of CRF responding was not significant [$F(3,36) = 1.26, p > .05$].

Figure 1 also depicts relative enhanced persistence (greater responding during extinction) of a continuously reinforced response as a result of alternating experiences with a partially reinforced response. This parallels the typical finding of positive contrast in similar comparisons with nonhuman subjects (e.g., Pavlik & Carlton, 1965). The ANOVA yielded a significant overall effect [$F(3,36) = 2.90, p < .05$], and subsequent planned com-

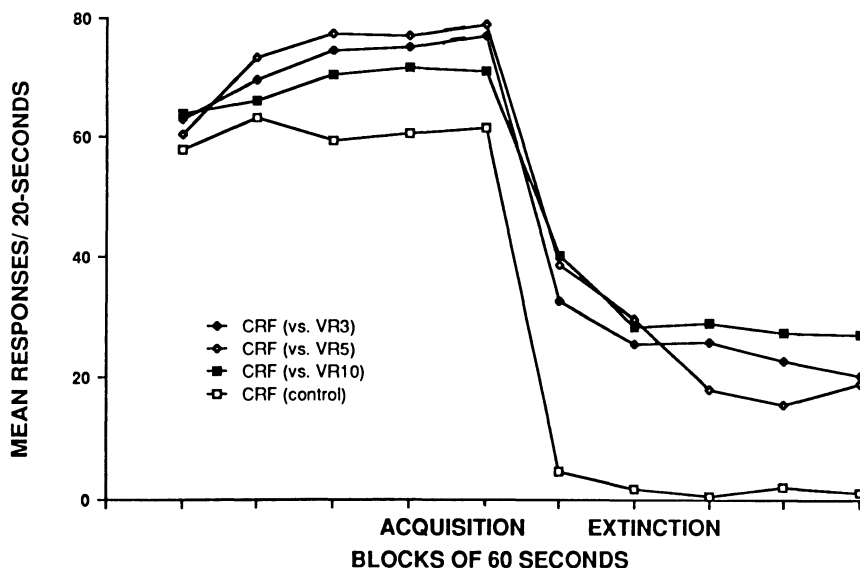


Figure 1. Between-groups comparisons of performance across acquisition and extinction in the continuous reinforcement (CRF) component of the multiple schedule as a function of the schedule in the alternative component.

parisons indicated that persistence in the CRF component was lower in Group CRF/CRF than in the other groups ($ps < .05$), which did not differ from one another.

Figure 2 shows acquisition and extinction performance in VR3, VR5, and VR10 schedules for groups that received either CRF or the same VR schedule in the alternative component. In each case, the acquisition data suggest that responding was faster when the alternative schedule was CRF than when it was the same VR schedule. Analyses of response rates over the last three blocks of the VR schedule during acquisition, however, yielded a significant outcome only in the CRF/VR3 versus VR3/VR3 comparison [$F(1,14) = 5.39, p < .05$].

Figure 2 also depicts relative reduced persistence of a partially reinforced response as a result of alternating experiences with a continuously reinforced response in Groups CRF/VR3 and CRF/VR5, but not in Group CRF/VR10. This difference was significant, however, only in the VR5 comparison [$F(1,15) = 6.44, p < .03$]. Such reduced responding has also been seen in studies with nonhumans (e.g., Pavlik & Carlton, 1965).

Figure 3 presents the mean total extinction responses for each schedule component for all of the groups in the experiment. The data for the purely within-subjects comparisons in Figure 3 (i.e., Groups CRF/VR3, CRF/VR5, and CRF/VR10) indicate that persistence was numerically greater in the CRF schedule than in the alternative VR schedule—an RPPE. Analyses of these data yielded a highly significant effect in the CRF/VR3 comparison [$F(1,11) = 19.70, p < .001$], a marginally significant effect in the CRF/VR10 comparison [$F(1,11) = 4.03, p < .07$], and a nonsignificant result in the CRF/VR5 comparison. All 12 subjects in the CRF/VR3 condition responded more in the CRF component during extinction. Furthermore, collapsing all the within-subject data into an overall CRF versus PRF comparison yielded a highly significant within-subjects RPPE for the entire experiment [$F(1,34) = 9.62, p < .01$].

DISCUSSION

The data of the present experiment clearly show that the generalization that partially reinforced responses are more resistant to extinction than are continuously reinforced responses is often false. Our human subjects, like the nonhuman subjects in previous similar experiments, exhibited a conventional PRE only in between-groups comparisons; they exhibited a reversed PRE in within-subjects comparisons. The latter effect, though numerically smaller than in comparable studies with nonhumans, was nevertheless highly significant when pooled across the various within-subjects comparisons.

Herrnstein (1961, 1970) showed that the rate of a behavior is not only dependent on its contingent reinforcement, but also on all other reinforcement that is available to the behaving organism. That is, the effect that contingent reinforcement has on one response is relative to all other possible reinforcement. The organism will match its behavior to the relative reinforcement rates in accordance with the matching law (Herrnstein, 1970). The present results, along with other previous within-subject design research on extinction (Adams, Nemeth-Coslett, & Pavlik, 1983; Collier, Steil, & Pavlik, 1978; Nemeth-Coslett & Pavlik, 1982; Nevin, 1988; Pavlik & Carlton, 1965; Pavlik & Collier, 1977), show that the rate of responding during extinction is not only a function of the response's rate of reinforcement during acquisition, but also of the rates

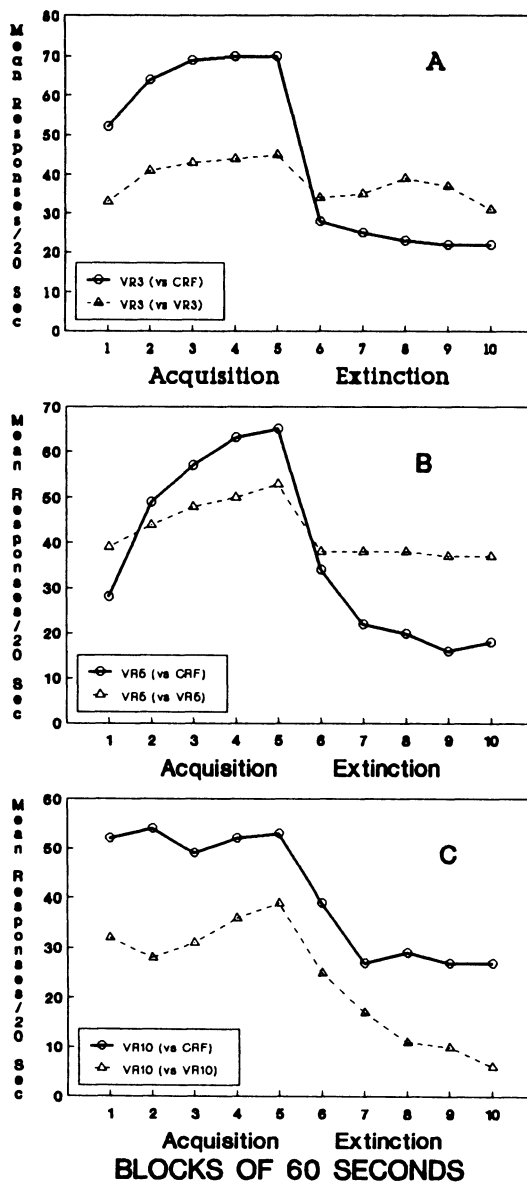


Figure 2. Performance across acquisition and extinction in the variable ratio (VR) component of the multiple schedule as a function of either continuous reinforcement (CRF) or the same VR schedule in the alternative component.

of reinforcement for all other responses to which the organism is exposed. That is, the effect of reinforcement on resistance to extinction is also relative. Generally, the organism will persist in a response during extinction in accordance with the relative rate at which that response was reinforced during acquisition. Relative extinction matching predicts that, compared with single-schedule controls, persistence on a more favorable schedule will be enhanced according to how much less favorable the alternative schedule is, and that persistence on a less favorable schedule will be lessened according to how much more favorable the alternative schedule is. The net result of these effects, depending upon their magnitude, could be a decrease in the size of the conventional PRE, a generalized PRE, or the RPPE seen in this and similar experiments with nonhumans.

Although relative extinction matching accounts for and predicts the observed within-subject PREs, it is not clear how it addresses the con-

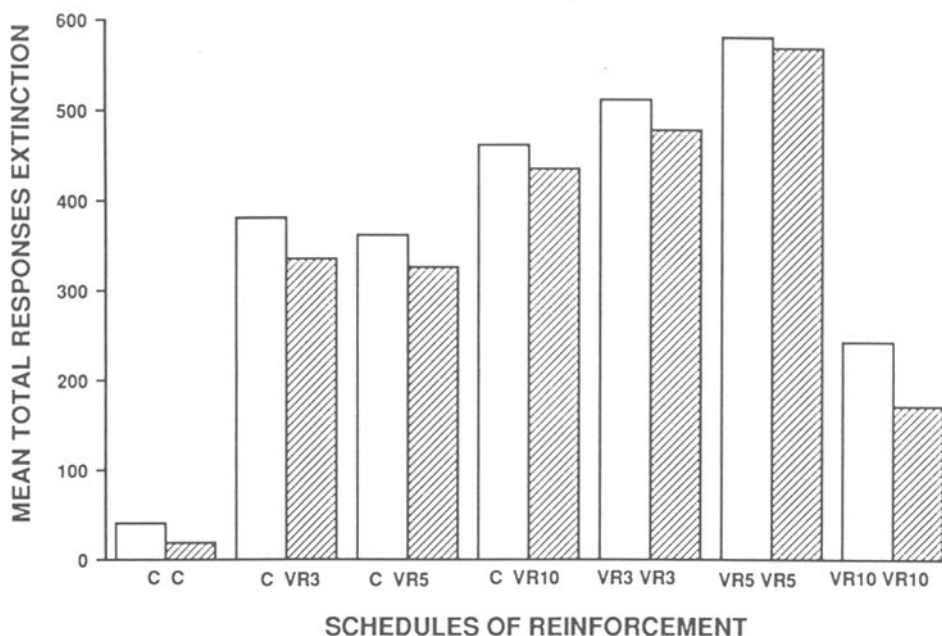


Figure 3. Mean total responses during extinction in each component of the multiple schedule for each of the experimental groups. Unshaded bars in the single-schedule groups are the first component encountered in extinction.

ventional between-subjects PRE. However, it should be noted that the conventional between-subjects PRE depends upon having a CRF-only group of subjects that have never experienced any PRF schedule in the experimental context. In experiments such as these, it is the CRF-only group that exhibits a level of persistence that is highly discrepant from those of all other groups in the experiment (see Figure 3). This indicates that any subject experiencing PRF, as part of either a PRF-only group in a between-subjects design or a CRF/PRF group in a within-subjects design, will show an enhanced level of persistence. Other factors—and we have suggested the matching law—then come into operation to modulate the generally enhanced persistence produced by experience with a PRF schedule.

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