4-1-1993

Differential reinforcement of other behavior and response suppression: the effects of the response-reinforcement interval

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Keywords
reinforcement, elimination, conditioned response, suppresion

Comments
Initally published in *Psychological Record,* Spring93, Vol. 43, p271-288.

The Psychological Record, 1993, 43, 271-288

DIFFERENTIAL REINFORCEMENT OF OTHER BEHAVIOR AND RESPONSE SUPPRESSION: THE EFFECTS OF THE RESPONSE-REINFORCEMENT INTERVAL

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Three experiments were conducted comparing the effects of the relationship between the response-reinforcement interval and the reinforcement-reinforcement interval in a differential reinforcement of other behavior (DRO) contingency. The experiments followed an acquisition, treatment, and reacquisition sequence where rats were trained to press a lever for food, were exposed to response elimination contingencies (DRO and extinction), and finally tested for the effectiveness of their respective treatment conditions. Experiment 1 shows that the longer the response-reinforcement interval the more effective the suppressive effects of DRO. Experiment 2 shows that it is the relationship of the response-reinforcement interval to the reinforcement-reinforcement interval that is important for the effectiveness of DRO. Experiment 3 shows that the base schedule used during training can determine the durability of the treatment procedure used. Implications for the applied literature using DRO and extinction are discussed.

Differential reinforcement of other behavior (DRO) has often been used for the elimination of an operant response. This reinforcement-based response elimination procedure is frequently termed omission training (OT) in the applied setting and differential reinforcement of other behavior (DRO) in the laboratory setting. The DRO procedure is best defined by the temporal parameters described by Uhl and Garcia (1969). These contingencies are the response-reinforcement (R-S^R) interval and the reinforcement-reinforcement (S^R-S^R) interval. The response-reinforcement interval is the time that the reinforcement (S^R) is postponed after emission of a target response (R) (the response to be eliminated), and the reinforcement-reinforcement interval is the time between S^Rs should no response occur.

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We gratefully acknowledge the assistance of Sheila Hagerty, Peter Russo, Kathleen Collins-Pucino, and Stephanie Villari, in the collection of these data. Parts of these data were presented at the 57th and 58th Annual Meetings of the Eastern Psychological Association.

DRO has been used with nonhuman subjects, especially in studies comparing the response elimination effects of DRO and extinction (EXT) procedures (Mulick, Leitenberg, & Rawson, 1976; Uhl, 1973; Vyse, Rieg, & Smith, 1985; Zeiler, 1971). Although the majority of results support the hypothesis that DRO is more efficient than extinction (Johnson, McGlynn, & Topping, 1973; Leitenberg, Rawson, & Bath, 1970; Leitenberg, Rawson, & Mulick, 1975; Vyse et al., 1985), some studies have found no significant difference between DRO and extinction (Pacitti & Smith, 1977; Topping & Ford, 1975; Uhl & Sherman, 1971), and still others have found extinction to be more effective (Lowry & Lachter, 1977; Uhl, 1973; Uhl & Garcia, 1969; Uhl & Sherman, 1971).

At present, very few studies have investigated the effects of varying the response-reinforcement interval on the effectiveness of DRO in eliminating a response. Zeiler (1977) used a within-subject design to investigate this parameter by varying the number of DRO units that had to be completed per food delivery. The required time for not responding was divided into separate units such that the total DRO interval remained constant. The data indicate that the shorter the time unit of the DRO, the lower the response rate.

Only two studies have previously undertaken a detailed analysis of the phenomenon of reacquisition, when reinforcement for the eliminated response is again introduced. Vyse et al. (1985) found differences during the first few minutes of reacquisition only, and that this effect was dependent on whether short or long response-reinforcement intervals were programmed. Animals whose response history consisted of longer response-reinforcement intervals showed more suppression of original response responding during reacquisition. Pacitti and Smith (1977) found a similar resistance to the reacquisition of the original response.

The present experiments directly investigate different DRO intervals using a between-subjects design to compare three values of the R-S^R intervals and extinction (EXT) as response elimination procedures. Three experimental phases were used: acquisition, treatment, and reacquisition. No differences were expected between the groups in the number of responses emitted during the acquisition phase. During the treatment phase a response elimination effect was predicted for each of the groups. Based upon research by Zeiler (1977; 1979) it was hypothesized that the difference in the total DRO interval would make a difference between the groups. Predictions were that the longer R-S^R interval group would show significantly greater suppression of responding than the other three groups.

In regard to reacquisition data, data from Vyse et al. (1985) shows that differences should occur in only the first few minutes of reacquisition dependent on whether the animals had experienced a shorter or longer DRO. Within the present study similar effects were expected. It was predicted that the animals receiving the longest response-reinforcement interval would show the slowest reacquisition of lever responding during this last phase.

Experiment 1

The first experiment compared three values of the R-S^R intervals (DRO 2, DRO 6, DRO 18) and extinction (EXT) as response elimination procedures. In the three DRO procedures the subject received reinforcement on a recurrent 10-s schedule if no response occurred. However, if the subject emitted a response, a delay of 2 s, 6 s, or 18 s intervened before the next reinforcer was received. This delay was immediate and concurred with the 10-s S^R-S^R interval. In this way the DRO 2 group could respond until 8 s into the S^R-S^R without lengthening the R-S^R interval. Likewise, the DRO 6 subjects had the added R-S^R interval affect their S^R-S^R interval if they responded during the 6 s before the next reinforcer was scheduled. For the DRO 18 animals, any response during the reinforcement-reinforcement interval increased their effective time from reinforcer to reinforcer anywhere from 18 to 28 s. An extinction control group was also run.

Method

Subjects

The subjects were 40 experimentally naive Sprague-Dawley male rats obtained from Charles River Breeding Laboratory. They were housed separately and maintained on ad libitum food and water prior to the experiment. During the experiment all the subjects were maintained at 80% of their free-feeding weight. The weights of the animals ranged between 250 g and 350 g (mean = 285 g) prior to experimentation.

Apparatus

Two Coulbourn Instruments Model #E10-10 operant chambers were employed, each in Coulbourn sound-attenuating enclosures. A 3-cm wide food cup was recessed into the middle of the front wall 2 cm above the grid floor. A house light was situated 27 cm from the grid floor in the middle of the front wall. Masking noise was provided by the ventilation fans of each chamber. Programming was accomplished by software written by the authors for an Apple II+ computer interfaced with a MED Associates Interface. Bio Serve 45-mg precision “Dustless” food pellets were used as reinforcers.

Procedure

Four days prior to shaping each subject was weighed and food deprived. Subjects were randomly assigned to one of the four treatment conditions and one of the two experimental chambers. Following 2 days of habituation, each animal was hand shaped on a continuous reinforcement (CRF) schedule until 30 responses were emitted. On the next 2 days, animals were allowed to respond for 30 min on an FI 10-s schedule.

Acquisition. During the acquisition phase of the experiment the subjects were allowed to respond for food on an FI 10-s schedule. This phase consisted of five 15-min sessions. Each subject had to average at least 100 responses per day across the five acquisition days in order to continue in the study.

Treatment. This phase of the experiment consisted of 10 sessions in which each subject was exposed to EXT or one of three response-stimulus (R-S^R) treatment conditions: DRO 2, DRO 6, or DRO 18. For all three DRO contingencies the S^R-S^R interval was 10 s. Thus, reinforcement occurred every 10 s if the subject did not make the previously reinforced response, that is, a lever press. However, if the subject emitted a response the R-S^R interval was in effect. This caused a delay in addition to the 10-s reinforcement-reinforcement interval until the next reinforcement occurred. The extinction group received no reinforcement whether a response occurred or not.

Reacquisition. This phase of the experiment was run on the day following the 10th treatment session. It consisted of one 15-min session during which an FI 10-s schedule of reinforcement was in effect for all groups.

Results

Acquisition phase. A 4 x 5 (groups x sessions) ANOVA was performed on the acquisition data. All analyses were reported as significant at $p < .05$. The analysis indicated a significant effect for sessions, $F(4, 144) = 45.15$, no significant effect for treatment groups and no significant interaction effect. Throughout this phase there was a marked increase in mean lever responding for all four groups over the five sessions. Mean response rates for the groups ranged between 387 and 442 responses during the last 15-min session. The lack of significant differences for the group treatment effect establishes the equivalence of the four groups' responding during this phase.

Treatment phase. An F_{max} test on these data showed violations of homogeneity. A natural log transformation was performed in order to equalize variances (Winer, 1971). A 4 x 10 (groups x sessions) ANOVA was computed on the transformed data. Both the main effect for treatment group and sessions were found to be significant, $F(3, 36) = 5.80$, and $F(9, 324) = 98.01$ respectively. The treatment by session interaction was also significant, $F(27, 324) = 4.87$. These data (Figure 1) show an early gradual decrease in responding over sessions, and a final leveling out of the rate of responding by the 10th session.

Simple effects tests were performed for each session during this phase. The Satterthwaite method (Winer, 1971) was used to compute the degrees of freedom for the denominator for each of the simple effects test and this method was used for all simple effects tests reported. The simple effects test on Session 1 was found to be nonsignificant. The remaining nine simple effects test for Sessions 2 through 10 were all found to be significant. Newman-Keuls follow-up tests for each significant simple effects test revealed differences between all four groups at each session except during Sessions 2 and 3 where the DRO 2 and EXT groups were not different, and for Sessions 9 and 10 where the DRO 6 and DRO 18 groups were not different from one another but were different from all the others.

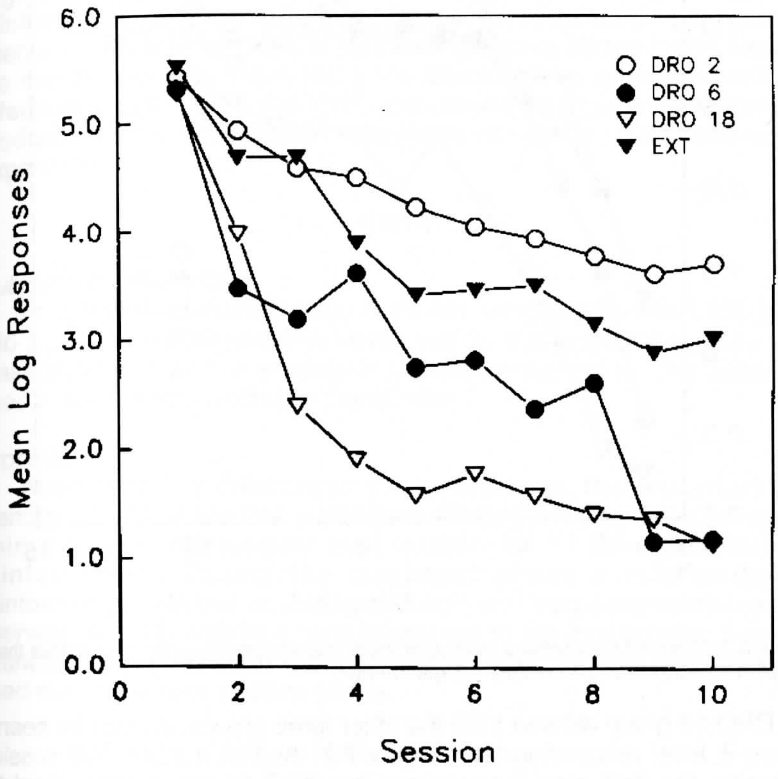

Figure 1. Natural log transformed means for lever responding for each group across the 10-session treatment phase during Experiment 1.

Reacquisition phase. Because an F_{max} test of homogeneity of variance was found to be significant for the reacquisition data, a natural log transformation was performed and all further analyses were performed on the natural log transformed data. Figure 2 shows these data. A 4 x 15 (groups x minutes) ANOVA was computed on the minute by minute data. The main effect for groups was found to be significant, $F(3, 36) = 4.80$, as was the main effect for minutes, $F(14, 504) = 52{,}595$. The group by minute interaction effect was not significant.

Follow-up Newman-Keuls tests were computed for Minutes 1, 2, 3, 4, and 5. At Minute 2, comparisons indicated no differences for the DRO 2 and EXT groups, with all other comparisons being different. For Minute 3, all groups were different from one another. For Minutes 4 and 5, only

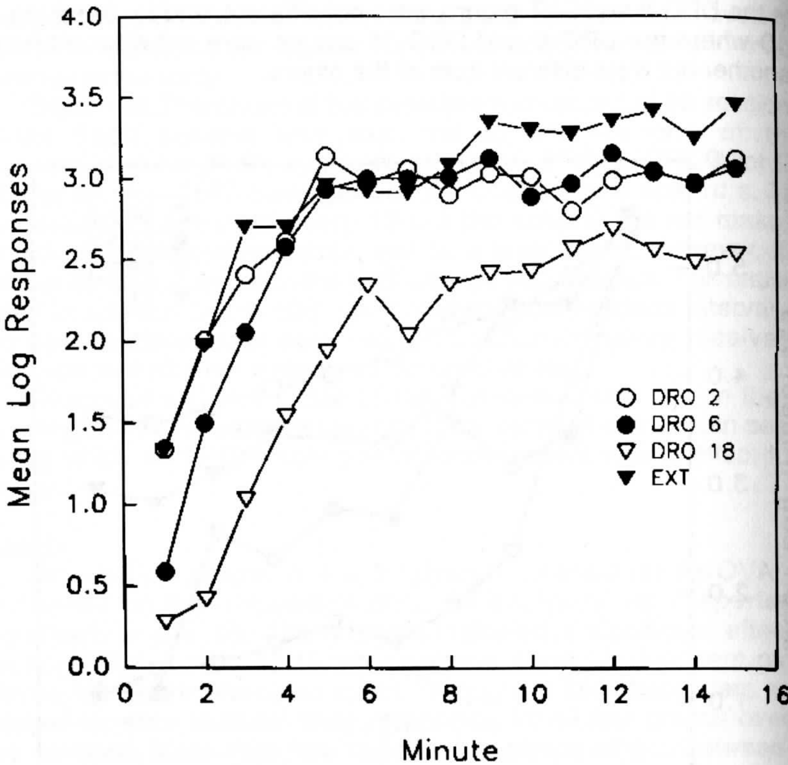

Figure 2. Natural log transformed means for lever responding for each group across the 15 min of the reacquisition phase during Experiment 1.

the DRO 18 group differed from the other three groups. As can be seen in Figure 2, lever responding recovered within the first 5 min of this session. However, the data also indicate that the DRO 18 group reacquired the responding at a slower rate than the DRO 2 and EXT groups.

Discussion

The results of this experiment are similar to those of previous studies showing that longer response-reinforcement intervals caused a greater suppression of responding than did shorter response-reinforcement intervals (Vyse et al., 1985). However, because Vyse et al. (1985) used only DRO intervals of 1 and 10 s, this experiment extends our knowledge as to the effects of longer response-reinforcement intervals.

Experiment 2

A question left unanswered by Experiment 1 was whether the suppressive effects were produced by the absolute length of the response-reinforcement interval or the relationship of this interval to the reinforcement-reinforcement interval. To answer this question a second experiment was conducted to determine if it is the relative length of time rather than the absolute time without reinforcement that affects behavior. If greater response suppression is caused by the longer response-reinforcement interval in relation to the reinforcement-reinforcement interval, the relative pattern of responding should be the same between the two experiments. However, if the absolute time without a reinforcer affects behavior, then the DRO conditions in Experiment 2 should produce greater suppression relative to extinction, than observed in Experiment 1.

Method

Subjects and Apparatus

Forty naive Sprague-Dawley male rats weighing between 250 g and 350 g prior to experimentation were used for this experiment. They were maintained just as the animals in the first experiment. The apparatus used was the same as that in Experiment 1.

Procedure

Apart from the differences presented here, the procedure was identical to that of the first experiment. During the acquisition phase all animals were allowed to respond on an FI 20-s schedule of reinforcement. During the treatment phase a reinforcement-reinforcement interval of 20 s was used and response-reinforcement intervals of 4, 12, and 36 s were presented to the four groups. Again an extinction group was run during this phase. An FI 20-s schedule was used during the reacquisition phase.

Results

Acquisition phase. A natural log transformation was performed to remove violations of homogeneity of variance. The following two-way analysis of variance revealed no significant main effect for groups establishing the equivalence for the groups prior to treatment. There was of course a main effect for sessions, $F(4, 144) = 19.36$, reflecting the fact that all animals increased their response rates over the 5 days of this phase. Mean response rates were similar to Experiment 1.

Treatment phase. Because an F_{max} test revealed violations in homogeneity of variance, a natural log transformation was performed before the data were analyzed. The group by session interaction effect was found to be significant, $F(27, 324) = 4.79$, as was the main effect for group, $F(9, 324) = 90.35$, and sessions, $F(3, 36) = 36.51$. Figure 3 shows a general decrease in responding over the 10 sessions. Follow-up simple effects tests were performed for each session. Significant differences were found only for Sessions 5 through 10.

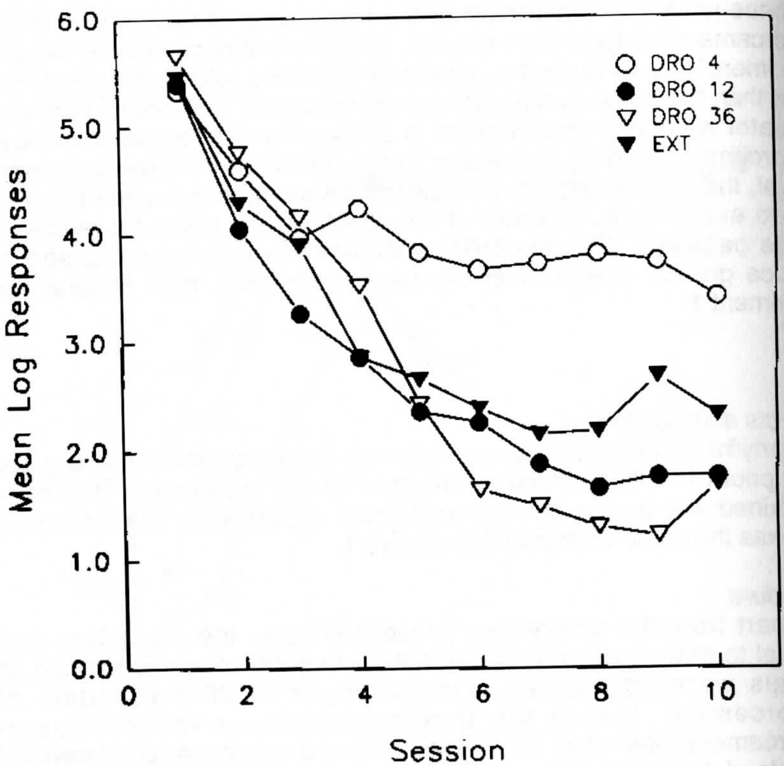

Figure 3. Natural log transformed means for lever responding for each group across the 10-session treatment phase during Experiment 2.

Newman-Keuls tests showed that responding in the DRO 4 group remained consistently greater than that of the other three groups for much of this phase. Also, during Session 6 the DRO 12 and EXT groups were not different from one another, during Session 7 all groups except the DRO 4 were equivalent, and finally, during the last session the DRO 12 and EXT groups were not different from one another.

Reacquisition phase. A natural log transformation was conducted on these data after an F_{max} test revealed violations of homogeneity for these data. See Figure 4 for the mean lever responses for the four groups during this phase. An ANOVA calculated with these data revealed a nonsignificant group main effect, a significant sessions main effect, $F(14, 504) = 52.38$, and a significant groups by sessions interaction effect, $F(42, 504) = 2.25$. Simple effects were shown to be significant for Minutes 3, 4, 5, and 6. Newman-Keuls tests for these 4 min showed the DRO 36 group to respond consistently less than the other three groups. During Minutes 3 and 6 the DRO 12 and EXT groups were not different from one another but were both responding less than the DRO 4 and as already stated more than the DRO 36 groups.

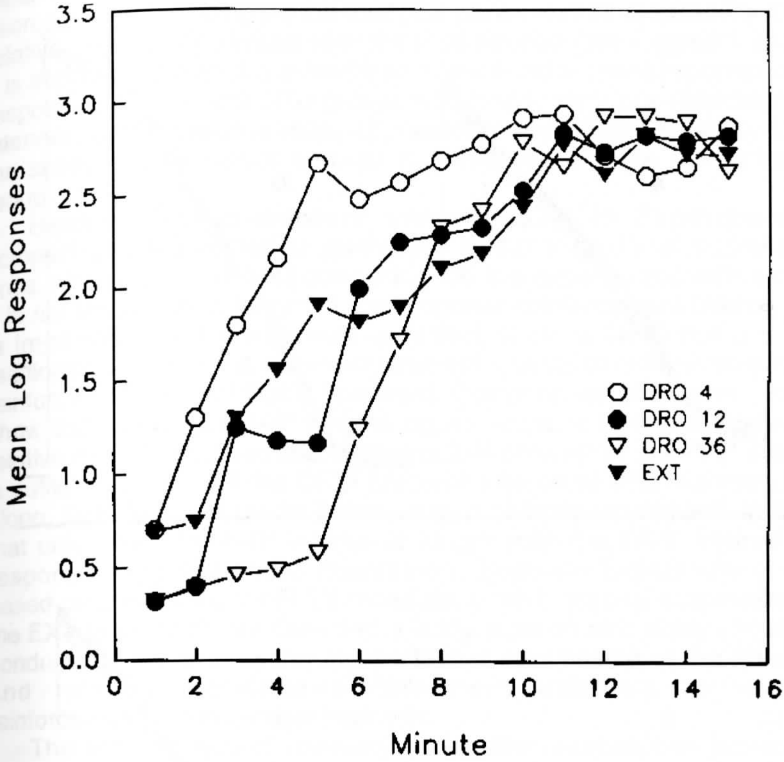

Figure 4. Natural log transformed means for lever responding for each group across the 15 min of the reacquisition phase during Experiment 2.

Lever Response Pattern Analysis

Records a, b, c, and d in Figure 5 typify responding by subjects during the reacquisition phase. Each record represents the responding of one of the subjects in each of the four treatment groups. The records were selected on the basis of being representative of all animals (total session responses within 10% of mean) in that group. Record a is that of a DRO 2 animal, b that of a DRO 6, c of a DRO 18, and d of an EXT animal. It is evident that the animals in all groups, with the exception of those from the DRO 18 group (Record c), finished the reacquisition session responding at rates close to those characteristic of animals on an FI schedule. The difference is that all subjects began responding much later in the session during reacquisition than during an acquisition day. The curves also show that after fewer than five reinforcements most of the subjects were responding at rates usually observed after prolonged exposure to an FI schedule. The extinction animal (Record d) recovered especially quickly, after only two reinforcements. The lower

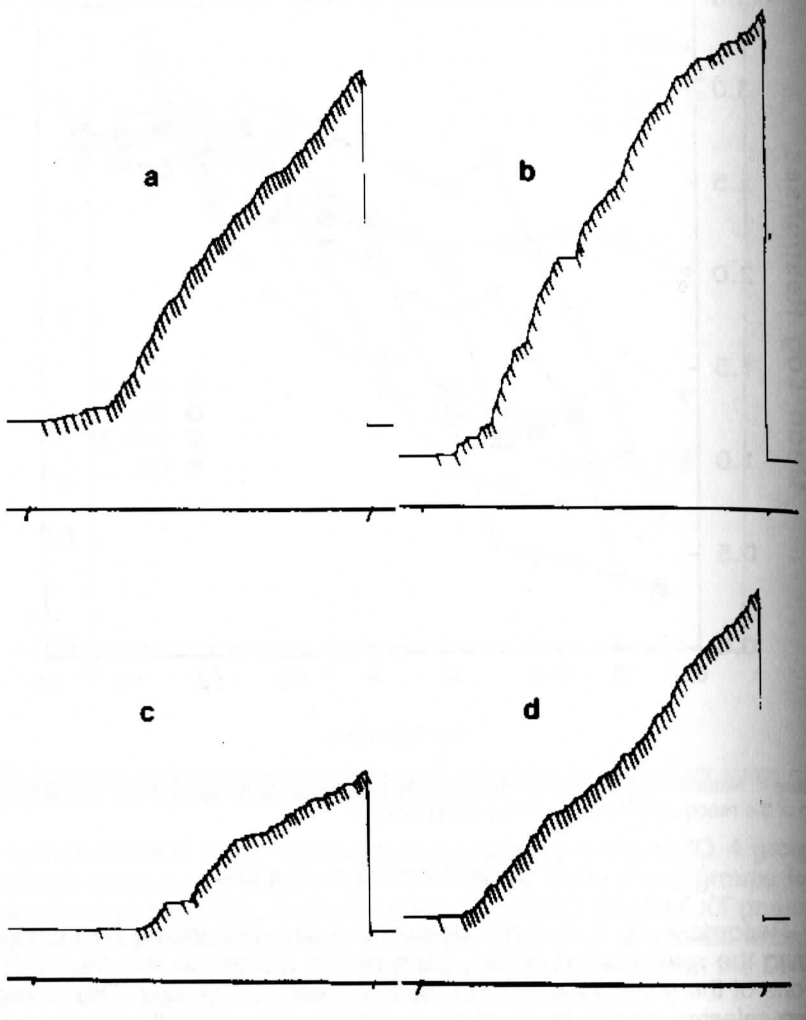

Figure 5. Representative cumulative records for subject's lever responding during the one-session reacquisition phase. Session length is 15 min. Cumulative Record a represents DRO 2, Record b represents DRO 6, Record c represents DRO 18, and Record d represents EXT.

rates of responding seen in Figure 5 then reflect the fact that the subjects did not begin responding until several minutes into the session.

Discussion

An interesting finding in the treatment phases of the first two experiments is the consistent differences and rank ordering in terms of mean lever responding for the four groups. Most important is the gradual decrease in responding for the four groups, as well as the stability in the relative order for the groups after the third session (see Figures 1 and 3). It is important to note the extreme and continued efficient suppression of responding seen in the DRO groups with longer response-reinforcement intervals. Unlike previous research, however, (see Pacitti & Smith, 1977) the shortest DRO groups showed less suppression than the extinction group.

Because all parameters were doubled in Experiment 2, comparisons are limited to qualitative rather than direct quantitative ones. Nonetheless, results comparing the two experiments indicate that it is not the absolute length of the response-reinforcement interval that is important for the suppressive effect seen in DRO but it is the relationship of the response-reinforcement interval to the reinforcement-reinforcement interval that is important. Comparisons of Figures 1 and 3 show that the longer R-S^R lengths do not produce further suppression relative to EXT. Furthermore, it seems that only when the R-S^R interval is sufficiently long will the DRO procedure be more effective than EXT alone. Data from the reacquisition phases of both experiments indicate that only when the R-S^R interval is longer than the S^R-S^R interval will response suppression be maintained. Because Experiment 2 was based on a much leaner FI 20 schedule, a more gradual suppression of the EXT group might be expected. Finally, a parametric study should be conducted to determine the most effective relationship of the absolute and relative response-reinforcement intervals to various reinforcement-reinforcement intervals.

The order in rate of recovery during the reacquisition session is comparable to that of the level of suppression in responding found during the treatment phase. Although during reacquisition, these are only temporary differences in response rates for the four groups, the results are similar. Differences during reacquisition were found only during the first 5 and 6 min of the session for Experiments 1 and 2 respectively. The results of the longer DRO groups, with the longest response-reinforcement interval, show the slowest reacquisition to asymptotic rates and clearly establishes the greater response suppression for this condition. It is important to remember, though, that after Minutes 5 and 6 no differences existed between the groups' responding.

Experiment 3

The analyses from the acquisition phases of the previous two experiments showed that all groups were responding at equivalent rates prior to exposure to the treatment condition. This was necessary to establish in order to draw conclusions from the effectiveness of each treatment condition. Several researchers have argued that at least initially, the particular dependency the subject was exposed to would affect response patterns when that dependency was changed (Lattal, 1972; Rescorla & Skucy, 1969; Rieg, Smith, Russo, & Vyse, 1987; Zeiler, 1968). That is, the baseline schedule during an acquisition phase will determine the degree to which responding will be affected during a treatment phase. Therefore, the purpose of the third experiment was to determine if the use of a fixed-ratio base schedule during acquisition would affect the pattern or degree of response suppression during treatment or reacquisition. An FR 20 schedule was used for acquisition followed in treatment by three groups with DRO intervals of 2, 6, and 18 s and an extinction group. During the reacquisition phase reinforcement was again made contingent on responding using an FR 20 schedule of reinforcement.

Method

Subjects and Apparatus

Forty naive Sprague-Dawley male rats weighing between 250 g and 350 g were used in this experiment. The apparatuses were the same as those in the first two experiments.

Procedure

During the five-session acquisition phase all subjects were trained to press on an FR 20 schedule of reinforcement. During treatment the schedules that the four groups of animals were exposed to were identical to those in Experiment 1. These consisted of a DRO 2, DRO 6, and DRO 18 contingency and a standard EXT schedule. For the DRO animals, a 10-s reinforcement-reinforcement interval was employed. Reacquisition consisted of one 15-min phase in which data were recorded on a minute-by-minute basis and animals were reinforced on an FR 20 schedule.

Results

Acquisition phase. No statistically significant differences in the frequency of original lever responding were found between the groups during the acquisition phase nor was the interaction effect significant. The main effect for sessions was significant, $F(4, 144) = 13.15$, reflecting increasing response rates over the five sessions. The group means were much higher than in the two previous experiments (ranging from 535 to 594 responses) which was to be expected.

Treatment phase. Data for the 10-session treatment phase were transformed using a natural log transformation caused by violations of homogeneity of variance. These data are shown in Figure 6. All three effects for this analysis were found to be significant with a group main effect of $F(3, 36) = 21.31$, a session main effect of $F(9, 324) = 44.12$, and an interaction effect of $F(27, 324) = 4.88$. Simple effects tests for these data indicated differences during the entire phase. Newman-Keuls

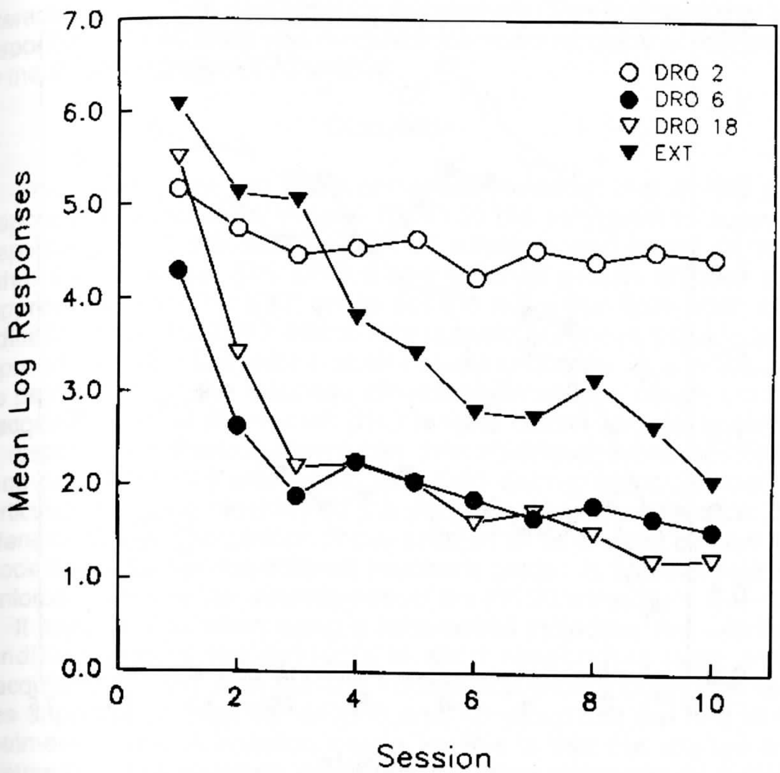

Figure 6. Natural log transformed means for lever responding for each group across the 10-session treatment phase during Experiment 3.

follow-up tests showed that the DRO 2 group remained significantly above the EXT group after the third session and the EXT group responded more than the other three during only the first session. The DRO 6 and DRO 18 groups did not differ from one another after the third session. However, after the third session the EXT group responded more than both the DRO 6 and DRO 18 groups.

Reacquisition phase. The data from the reacquisition phase are found in Figure 7. The ANOVA performed on these data yielded a significant main effect for groups, $F(3, 36) = 11.48$, and a significant main effect for minutes, $F(14, 504) = 14.65$. Because there was no significant interaction effect, $F(42, 504) = .81$, the main effects were analyzed using a Newman-Keuls follow-up test. Again the effect of interest was the differences between groups while the differences in the minutes main effect was attributed to an increased response rate through the course of this phase. The DRO 2 group recovered responding the most quickly and was significantly different than the other

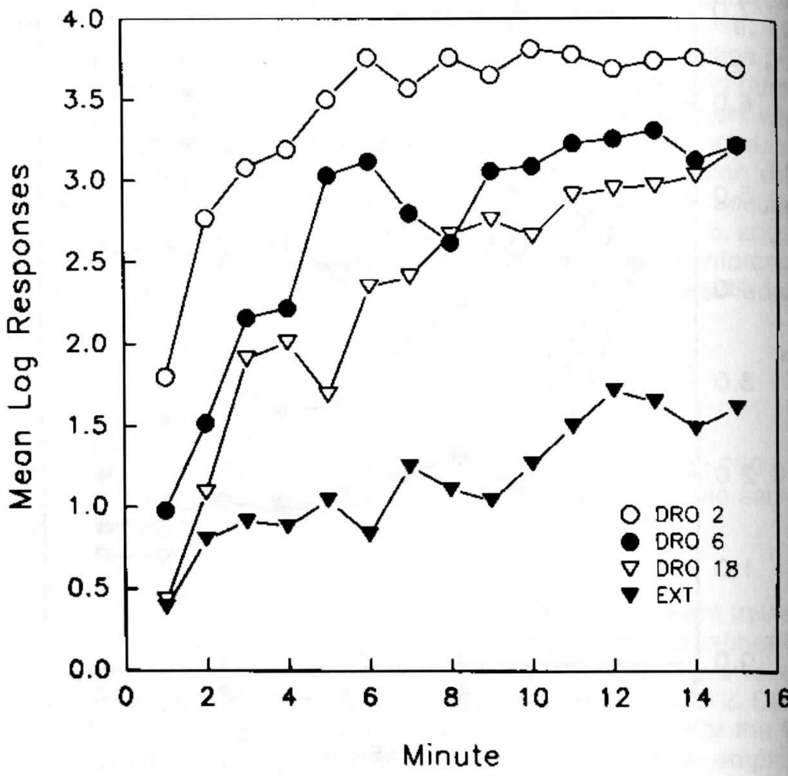

Figure 7. Natural log transformed means for lever responding for each group across the 15 min of the reacquisition phase during Experiment 3.

groups except during Minute 5 and the last five minutes of this phase. Except during Minutes 5 and 6, the DRO 6 and DRO 18 groups were not significantly different from one another. Finally, from the third minute through the end of this phase the EXT group responded significantly less than the other three groups.

An analysis of the cumulative records obtained during reacquisition for the three experiments indicated that the differences during reacquisition in response suppression might be caused by varying delays to the first reinforced response for the four groups. An analysis for data from this experiment was computed to determine if there were significant differences between the four groups once the animals had been reinforced for responding again. The data therefore consisted of the minute-by-minute response data for the first five minutes after the first reinforcer had been delivered. Because some of the animals in various groups made no responses at all during this phase, this analysis was based on unequal sample sizes. Neither the main effects nor the interaction effect was significant for this analysis. This indicates that after responding started there was no difference in the recovery of responding by the different treatment conditions.

Discussion

The results from the treatment phase indicated that a very short response-reinforcement interval (DRO 2) did very little to suppress responding when the base acquisition schedule was based on ratios rather than intervals. The DRO 6 and DRO 18 groups showed more suppression than the EXT group but did not differ from each other indicating that the DRO effect may asymptote more quickly when imposed on an FR than when on an FI base schedule. As a measure of the permanence of the response elimination procedure, results from the reacquisition phase indicate all DRO lengths tested were less effective as response suppression techniques than traditional extinction. Finally, once reinforcement was again received during reacquisition, the particular treatment received by the subjects made no difference. The difference in the reacquisition phase seemed to be caused by how long it took the subject in the different treatment groups to achieve their first reinforcement upon the reinstatement of the FR 20 schedule.

It appears that when using a ratio-based schedule, the extinction condition causes the subjects to start responding later in the reacquisition phase than the DRO conditions even though they were less suppressed than the DRO 6 and 18 groups at the end of the treatment phase. A possible cause for this is that the change from treatment to reacquisition (involving the discontinuation of the R-R reinforcers) was more noticeable than the change from extinction to reacquisition.

General Discussion

The results of the present experiments showed that longer response-reinforcement intervals caused a greater suppression of responding than did shorter response-reinforcement intervals. Although originally it was hypothesized that the DRO procedure would "eliminate" the original response, the data from the reacquisition phases show that the DRO contingency had not eliminated the responding but rather caused a "suppression" of responding.

Based on a classic study comparing DRO with EXT (Uhl & Garcia, 1969), Uhl (1973) states that parameter values for the R-S^R and S^R-S^R should be 20 s each for response elimination to be most effective. The results of the present studies clearly do not support this recommendation. Although the present studies used a S^R-S^R interval of 10 and 20 s and R-S^R intervals both shorter and longer than the S^R-S^R the present data indicate that the length of the DRO in relation to the reinforcement-reinforcement interval plays an important role in response suppression when compared to EXT. The most important finding when comparing the levels of suppression of Experiments 1 and 2 is that it is the relationship of the length of the R-S^R to the S^R-S^R interval that is responsible for the suppressive effects of DRO rather than the absolute length of either the R-S^R or the S^R-S^R interval.

It is important to consider that both of the Uhl studies used only one response-reinforcement length that was equal to the reinforcement-reinforcement length. Therefore, conclusions about the effectiveness of DRO as a response elimination procedure compared to EXT are ambiguous at best. That is, DRO's effectiveness as a response reduction technique cannot be adequately evaluated when only one response-reinforcement interval is used.

It has been suggested that the effectiveness of DRO compared to EXT was caused by the strengthening of response alternates, whereas during EXT response suppression without the conditioning of other behaviors occurs (Uhl & Garcia, 1969; Zeiler, 1971). This explanation leads to the prediction that when a reacquisition period is presented to the animal, slower reacquisition of responding should be seen in the animals previously exposed to the DRO contingency when compared to EXT animals because, these animals would have the "other" response to unlearn (extinguish). The results of the present FI studies suggest that only when the response-reinforcement interval is long enough to delay the first response beyond what is typical of EXT animals will the DRO subjects reacquire the original response more slowly than the EXT animals.

The idea of greater response suppression with an R-S^R longer than the S^R-S^R interval may be analogous to some of the interval relationships found in Sidman avoidance. Within the Sidman paradigm, greater responding is achieved when the response-shock delay interval is longer than the shock-shock interval (Sidman, 1962). Data from Experiments 1 and 2 indicate that greater response suppression is obtained with longer R-S^R intervals, and qualitative comparisons between Experiments 1 and 2 (Figures 1 and 2) indicate that the R-S^R interval should be close to twice the S^R-S^R interval to produce a robust reduction in responding. Before unequivocal conclusions are made about the relationship between these two intervals, a parametric study must be conducted varying each interval within one experiment.

Once responding began during the reacquisition phases in all three experiments, the rates tended to be typical of those of the last day of acquisition. This indicates that the original lever response was not "eliminated" or unlearned but that it had merely suppressed during the treatment phase (Boe & Church, 1967). When reinforcement is no longer delivered according to a DRO schedule, the termination of that schedule is signaled through the absence of reinforcers. What seems to be necessary for a permanent change to take place is that each response must be followed by nonreinforcement, and that in order for the original response to increase, the suppressive effects must first dissipate, and this typically takes longer in the DRO situation.

The rapid recovery of all the FI-based animals during reacquisition to rates close to those of the final day of acquisition can be explained by the fact that, with an FI 10 or 20 schedule, the first response emitted by a subject during this session was often made after the interval and therefore reinforced. This first response, followed immediately by reinforcement, served as a discriminative stimulus indicating that food reinforcement was again available contingent on lever pressing and not on emitting some "other" response. The differences seen during the first 5 minutes of this phase indicate differences in the interval from the beginning of the session to the first response.

Although direct generalizations from basic animal research to human applications are not popular, the results from this particular series of experiments may yield important applied implications. To our knowledge no one has previously examined the effects of different response-reinforcement intervals on human responding. As stated above most applied studies involving DRO have been comparisons between omission training (OT) or DRO and other response eliminating procedures.

Several applied implications result from the findings of the present studies. First, greater suppressive effects can be achieved with longer DRO intervals up to at least twice the length of the reinforcement-reinforcement interval. Also, when the DRO contingency is no longer in effect such as during the reacquisition phases used in these studies, again slower recovery from suppression is seen with longer response-reinforcement intervals. Furthermore, the effectiveness of DRO can be enhanced when salient response alternates are reinforced (Bouton & Swartzentruber, 1991) and ideally these should be continued beyond the therapeutic setting.

Finally, the base schedule that was maintaining the subject's behavior prior to treatment needs to be considered to predict the suppressive effects of DRO on response recovery. For those using DRO in an applied setting it is important to determine whether the schedule that was maintaining the client's behavior prior to intervention was under the control of an interval or a ratio contingency. If it was an interval schedule that was maintaining that behavior, a DRO procedure should be used. However, if the behavior was under the control of a ratio schedule the most durable treatment would probably be an extinction contingency.

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