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Differential Reinforcement of Other Behavior: Effects of the Response-Reinforcement Interval

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DIFFERENTIAL REINFORCEMENT OF OTHER BEHAVIOR:
EFFECTS OF THE RESPONSE-REINFORCEMENT INTERVAL.

BY

THOMAS S. RIEG

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
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ABSTRACT

Forty male rats acquired a lever press response over eight sessions on a fixed interval (FI) schedule of reinforcement. After this acquisition phase subjects were randomly assigned to one of four treatment groups involving response elimination. Three of the groups received varying response-reinforcement intervals of 2, 6 and 18 seconds within a differential reinforcement of other behavior (DRO) paradigm. A reinforcement-reinforcement interval of 10 seconds was used for these animals. A control group receiving a standard extinction (EXT) contingency was also run for this 10 session treatment phase. One 15 minute reacquisition session followed the treatment sessions during which all animals were retrained on a FI 10 s schedule. During the treatment phase significant differences for the four groups were found after the first session. The DRO 2 group responded the most throughout the rest of this phase, followed by the EXT group, the DRO 6 group and finally the DRO 18 group. Significant results from the reacquisition phase were found only between minute two and five. At these times the DRO 2 group did not differ from the EXT group, but these two both were faster to reacquire the original response than both the DRO 6 and the DRO 18 group which had the slowest reacquisition. The results indicated that the longer the response-reinforcement interval the more effective the response elimination during treatment. Also,

as a measure of permanence, the longer the response-reinforcement interval the more permanent the response suppression.

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Table of Contents

	<u>page</u>
Abstract	ii
Acknowledgements	iv
Table of Contents	vi
List of Tables	vii
List of Figures	viii
Introduction	1
Method	11
Results	14
Discussion	41
References	50
Appendices	55

List of Tables

Table 1.	Means and Standard Deviations of Lever Responses during the Acquisition Phase.	15
Table 2.	Means and Standard Deviations of Lever Responses during the Treatment Phase.	20
Table 3.	Means and Standard Deviations of Natural Log Transformed Lever Responses during the Treatment Phase.	21
Table 4.	Means and Standard Deviations of Lever Responses during the Reacquisition Phase.	26
Table 5.	Means and Standard Deviations of Natural Log Transformed Lever Responses during the Reacquisition Phase.	28

List of Figures

Figure 1. Mean Lever Responses for each Group during the Acquisition Phase.	17
Figure 2. Mean Natural Log Transformed Lever Responses for each Group during the Treatment Phase.	23
Figure 3. Mean Natural Log Transformed Lever Responses for each Group during the Reacquisition Phase.	31
Figure 4. Representative Cumulative Records for Subjects' Lever Responding during the Acquisition Phase.	35
Figure 5. Representative Cumulative Records for Subjects' Lever Responding on the First Day of the Treatment Phase.	36
Figure 6. Representative Cumulative Records for Subjects' Lever Responding on the Last Day of the Treatment Phase.	39
Figure 7. Representative Cumulative Records for Subjects' Lever Responding during the Reacquisition Phase.	40

Introduction

When E.L. Thorndike put forth the law of effect he stated that rewards increase the likelihood of responses and that punishers decrease the likelihood of responses. Based on this, theoretical accounts have been proposed as to the reason for the effectiveness of punishment (Dinsmoor, 1954; 1955). Yet as early as 1944, W.K. Estes had presented empirical evidence that although punishment does suppress responding, its effects are only temporary. B.F. Skinner (1953; 1971) offers another criticism of punishment, that not only does it not remove an undesirable behavior from an organism's repertoire, but it does not offer an alternative response that would lead to reinforcement. Combined with the failure of punishment to permanently change a response (Azrin & Holz, 1966), and the recent concern as to the ethical issues involving the use of punishment (Johnston, 1972), the investigation of alternative, reinforcement based, methods for the elimination of an already established response have become more important. One such reinforcement-based response elimination procedure is 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 between response and reinforcement are (a) the response-reinforcement ($R-S^R$) interval, and (b) 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^R s should no response occur.

In 1961 Reynolds introduced the DRO contingency as a control procedure in a behavioral contrast demonstration. Since then DRO has been used for the elimination of an operant based on the presentation of a reinforcer. DRO has been used on infrahuman subjects especially in studies comparing the response elimination effects of DRO and extinction procedures (Zeiler, 1971; Uhl, 1973; Mulick, Leitenberg, & Rawson, 1976; Vyse, Rieg, & Smith, 1985). While the majority of results support the hypothesis that DRO is more efficient than extinction (Leitenberg, Rawson, & Bath, 1970; Leitenberg, Rawson & Mulick; 1975; Mulick et al., 1976; Zeiler, 1971; Johnson, McGlynn, & Topping, 1973; Vyse et al., 1985), some studies have found no significant difference between DRO and extinction (Uhl & Sherman, 1971; Topping, & Ford, 1975; Pacitti & Smith, 1977), and still others have found extinction to be more effective (Uhl, 1973; Uhl & Sherman, 1971; Uhl & Garcia, 1969; Lowry & Lachter, 1977).

Several studies have investigated the relative permanence of the effects of DRO and extinction during an extinction period following DRO scheduling (Leitenberg et

al., 1975; Uhl & Garcia, 1969, Vyse et al., 1985), and when reinforcement is once again made available (Vyse et al., 1985). Generally, results indicate that DRO results in a greater rebound of original responding during the extinction period and in slower recovery during reacquisition when compared to extinction conditions only (Uhl, 1973; Uhl & Garcia, 1969; Topping & Ford, 1974), with support of this latter finding coming from our lab (Pacitti & Smith, 1977; Vyse et al., 1985). The relatively transient effects of DRO seen during extinction and reacquisition following DRO scheduling is similar to the phenomenon labeled "compensatory recovery" by Boe & Church (1967) commenting on early studies on punishment (see also Estes, 1944; Skinner, 1938). They argue that compensatory recovery occurs when a response is followed not by an aversive stimulus, but by a stimulus that changes the stimulus context. Church (1963) presents a hypothesis in which, for punishment to be effective it must be correlated with an instrumental response. This indicates that in order for punishment or another response elimination procedure to be effective it requires a response contingency between the instrumental response and the particular response elimination procedure (e.g., punishment). An inhibition for responding must develop based on this contingency. If this contingency and the resulting inhibition are not established the suppressive effects of the response elimination procedure will be

retarded. In the Vyse et al. (1985) study comparing the DRO 1 s and the DRO 10 s groups a greater suppression of responding in the DRO 10 s group was shown. This relatively more effective suppressive effect of the longer DRO interval may be due to the more inhibitive and contiguous relationship between responding and reinforcing consequence.

DRO has been relied on heavily as an alternative to punishment for the elimination of a response (Uhl & Sherman, 1971; Zeiler, 1971, 1979). The effectiveness of punishment as a procedure for suppressing an established response has been directly compared with DRO (Uhl & Sherman, 1971; Zeiler, 1979). These studies suggest that the parameters governing punishment are similar to those of DRO. For example, Zeiler (1979) argues that the relation of DRO to the response rate is similar to those of punishment and free shock. In this study the response dependent delay in the presentation of food suppressed the rate of responding more than response independent presentation of food. Zeiler (1976) also reports that the higher the level of shock administered the lower the frequency of responding. Similarly, in the DRO procedure the higher the frequency of food presentation (the shorter the SR-SR interval) the lower the rate of responding. The suppressive effects of punishment have been shown to last from several days with modest punishers, to near permanence when an extremely aversive punisher is used

(Azrin & Holz, 1966). Using DRO schedules similar results have been recorded, with suppression lasting through several sessions of reacquisition (Topping & Ford, 1974). In this case subjects did not respond for several sessions although reinforcement was again available contingent on responding. The more suppressive effects of punishment seem to involve the role of a temporal discriminative stimulus. In the punishment condition the subject must actively make a response in order to gain knowledge about the new contingencies. This is not the case with the DRO contingency. When reinforcement is no longer delivered according to a DRO schedule, the termination of that schedule is signaled through the absence of reinforcers. In this case the subject must not emit a response in order to determine that the DRO contingency has stopped. What seems to be necessary for learning to take place is that each response must be followed by non-reinforcement. Zeiler & Solano (1982) therefore argue that with extreme punishment, in order for the original response to increase, the suppressive effects must first dissipate, and this will necessarily take longer than in the DRO situation.

Vyse et al. (1985) and others (Mulick et al., 1976) have shown recovery of the original response if a DRO phase is followed by an extinction phase. A speculation for the reason for this recovery of responding is that the animals were prevented from experiencing extinction

conditions. That is, for the learning of extinction to take place each response must be followed by non-reinforcement (Leitenberg et al., 1975). The argument is that the effects of DRO are not permanent because its contingencies are such that the animal seldom makes the response that is being eliminated. The response is not "removed" from the subject's repertoire but is "replaced" by new or "other" responses, while the original response is never eliminated. This hypothesis also implies that the suppressive effects of DRO are observed because of stimulus control properties of the situation controlling the alternative responses as well as the reinforced increase of the other behavior. (Support for this hypothesis is given by Zeiler (1979) when he obtained equally suppressive effects for DRO and response independent reinforcement.)

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) looked at it on a minute by minute basis and Pacitti & Smith (1977) used five 12 minute intervals to study reacquisition. Vyse et al. (1985) analyzed their reacquisition data on a minute by minute basis across their five treatment groups. They found differences between the groups from minute two through minute six of reacquisition. These differences during the first few minutes of reacquisition indicate

differences when short vs 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 & Smith (1977) found an even greater resistance to the reacquisition of the original response. Four of their eight DRO animals with 20 second reinforcement-reinforcement did not respond until 36 minutes into the session.

Comparisons of DRO and extinction have yielded a wide variety of results. Reasons for the variability in the data from study to study may be accounted for by many variables. Schedules used for the acquisition of the original response have included variable interval schedules (VI) (Mulick et al., 1976), fixed interval schedules (FI) (Vyse et al., 1985), variable ratio schedules (VR) (Uhl & Sherman, 1971), differential reinforcement of low rate schedules (DRL) (Topping, Pickering, & Jackson, 1971), and concurrent schedules (CONC) (Zeiler, 1971). Another possible explanation for the variable results is that the number of available reinforcers during the treatment phase were not equated with the acquisition phase and to one another in the majority of the studies. However, Topping, Pickering, and Jackson (1972) presented data that show that even when a longer DRO schedule is used the results still produce greater response suppression than with extinction.

Studies comparing the various response elimination techniques have used both between subjects and within subjects design (Vyse et al., 1985; Zeiler, 1977). However, data coming from the same lab using between subject comparisons (Topping & Larimi, 1973) and within subject designs (Topping & Ford, 1975) show identical results. The effectiveness of DRO has been demonstrated in a wide variety of species of animals leading to conclusion that species is not an important variable in the production of DRO effects.

At present only one study has come close to investigating 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. In this contingency the required time for not responding was divided into separate units such that the total DRO interval remained constant. This resulted in conditions with multiple DRO units which when summed equaled a total response-reinforcement time of 30 sec. For example, reinforcement was available on a FR 10 (DRO 3) schedule, or a FR 3 (DRO 10) schedule, or a FR 1 (DRO 30) schedule. The data indicate that the shorter the time unit of the DRO the lower was the response rate. There seems to be room for more studies investigating the effects of varying response-reinforcement intervals. The

proposed study will directly investigate different DRO intervals using a between subjects design.

Many different reinforcement-reinforcement intervals have been used in the literature. Intervals which have been studied have included, 10 and 30 s within the same study (Uhl & Garcia, 1969), 32 s (Lowry, & Lachter, 1977), 20 s and 30 s in the same condition (Mulick et al., 1976), or even a VI 3 min schedule (Reynolds, 1961). The present study investigated the effects of varying the length of the response-reinforcement interval in relation to an absolute length of time of the reinforcement-reinforcement interval. By using an FI 10 s reinforcement-reinforcement interval compared to response-reinforcement intervals of shorter and longer durations, inferences could be drawn as to the effect of the relative length of the response-reinforcement interval and its relation to the reinforcement-reinforcement interval.

This study was designed to compare three values of the $R-S^R$ intervals (DRO 2 s, DRO 6 s, DRO 18 s) 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 eight seconds 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 seconds before the next reinforcer was scheduled. For the DRO 18 animals, any response during the reinforcement-reinforcement increased their effective response-reinforcement interval by 18 to 28 sec. An extinction control group was also run. Of primary interest was the relation between the three DRO groups in reference to the extinction group during the treatment phase and the reacquisition phase. It was expected that the longer the response-reinforcement interval the greater the suppressive effect.

The experimental phases followed an acquisition, treatment, and reacquisition sequence. 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 (1976; 1977) it was hypothesized that the difference in the total DRO interval would make a difference between the groups. Predictions were that the DRO 18 group would show significantly greater suppression of responding than the other three groups. Another hypothesis was made in regard to the reacquisition data. Data from Vyse et al. (1985) shows that differences would occur in 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. The prediction here was that the animals receiving the longest response-reinforcement interval would show the slowest reacquisition of lever responding during this last phase.

Method

Subjects

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

Apparatus

Two Coulbourn Instruments model #E10-10 operant chambers were employed, each in sound attenuating enclosures. The front and the back walls of the operant chambers were 25 cm wide and made of aluminium. The side walls were made of clear Plexiglas and were 30 cm wide. The interior of the chamber was 29 cm high. 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 a ventilation fan attached

to each chamber. Programming was accomplished through the use of software written by the author 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 selected to serve in one of the four treatment conditions and were randomly assigned to one of the two experimental chambers. Two food pellets were placed in the food cup and the animal was required to remain in the chamber for 10 min with the house lights on. After the second day of food deprivation and until the end of the study, each subject was returned to his home cage in the colony and fed enough to maintain him at 80% of his free feeding weight.

Shaping. During shaping each subject was placed in the chamber with the door of the external housing open in order to make the animal clearly visible to the experimenter during this process. Hand shaping continued until the subject had made 30 lever responses or a 75 min period had passed. Upon meeting the 30 response criterion on a cfr schedule of reinforcement the subject was removed from the chamber and returned to the colony. Subjects not meeting this criterion within 75 min they were discarded from the study and replaced.

Pre-acquisition. On the second and third days of the experiment the subjects were placed in the experimental chamber for 30 min on an FI 10 s schedule of reinforcement.

Acquisition. During the acquisition phase of the experiment the subjects were allowed to respond for food on an FI 10 sec schedule. This phase consisted of five sessions each 15 min in length. In this phase a criterion was used such that each subject had to average at least 100 responses per day across the five days in order to be included in the study.

Treatment. This phase of the experiment consisted of 10 sessions in which each subject was exposed to one of the treatment conditions: (a) DRO 2, (b) DRO 6, (c) DRO 18, and (d) EXT. With the DRO contingencies the reinforcement-reinforcement (S^R-S^R) interval was always 10 seconds. Thus, with this contingency reinforcement occurred every 10 s if the subject did not make the previously reinforced response, in this case lever pressing. However, if the subject emitted a response the response-stimulus ($R-S^R$) interval was in effect. This caused an additional delay besides the 10 s reinforcement-reinforcement interval until the next reinforcement occurred. This delay was 2 s for the DRO 2 group, 6 s for the DRO 6 group and 18 s for the DRO 18 group. The extinction group received a regular extinction

procedure where reinforcement was no longer presented whether a response occurred or not.

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

Results

Subject Attrition

Over the course of the experiment seven subjects were eliminated due to experimenter error and 13 subjects were rejected for not meeting the shaping criterion within 75 min. All of these subjects were replaced with other animals so that the data from 40 subjects were used for data analysis.

Statistical Analyses

Acquisition Phase. Table 1 shows the means and standard deviations for lever responses during the five days of the acquisition phase. Figure 1 displays the means for each group during this phase. A Hartley's test for homogeneity was computed for this data and found not to be significant, [$F_{\max}(20,9) = 15.30, p > .01$].

A 4x5 (groups x sessions) ANOVA was performed on the acquisition data (see Appendix A for the summary table). The analysis indicated a significant effect for sessions [$F(4,144) = 45.151, p < .05$], no significant effect

Table 1

Means and Standard Deviations of Responses for Each Group
During the Acquisition Phase

Group		Sessions				
		1	2	3	4	5
DRO 2	<u>M</u>	244.20	273.20	317.30	313.00	387.90
	<u>SD</u>	83.65	100.41	107.60	109.82	144.29
DRO 6	<u>M</u>	264.90	310.60	383.60	366.50	417.60
	<u>SD</u>	79.20	77.60	130.23	126.52	123.26
DRO 12	<u>M</u>	246.40	278.70	333.60	345.10	403.90
	<u>SD</u>	132.30	142.76	169.02	213.78	238.16
EXT	<u>M</u>	295.80	323.00	371.50	394.60	442.20
	<u>SD</u>	178.26	147.52	119.50	137.87	97.47

Figure 1. Means for lever responding for each group across the five sessions during the acquisition phase.

for treatment groups [$F(3,36) = .406, p > .05$], and no significant interaction effect [$F(12,144), p > .05$]. As can be seen in Figure 1 there is a marked increase in mean lever responding for all four groups over the five sessions. The lack of significant differences for the group treatment effect establishes the equivalence of the four groups' responding during this phase.

Omega squared values were computed for this design in order to determine effect sizes. For the acquisition phase the values for treatment groups were .035, .124 for sessions, and .006 for the group x session interaction. This indicated that while the majority of variance was due to error, most of the variance accounted for was due to the increasing response rate over the five sessions.

Treatment Phase. The means and standard deviations for lever responses of each group during the treatment phase are presented in Table 2. An $F_{\max}$ test on these data showed violations of homogeneity, [$F_{\max}(40,9) = 1647.28, p < .01$]. A natural log transformation was conducted on the data in order to equalize variances (Winer, 1971). The means and standard deviations for the transformed data are represented in Table 3. A test for homogeneity on the transformed data again indicated heterogeneity in the data, [$F_{\max}(40,9) = 19.04, p < .01$]. However, studies by Box (date) indicate that ANOVA is robust for minor violations in its underlying assumptions. For this reason all further data was

analyzed using this natural log transformed data, reported in Table 3.

A 4x10 (groups x sessions) ANOVA was computed on the transformed data (the summary table can be found in Appendix B). Both the main effect for treatment group and sessions were found to be significant, [$F(3,36) = 5.797$, $p < .05$ and $F(9,324) = 98.014$, $p < .05$ respectively]. The treatment group by session interaction was also significant [$f(9,324) = 4.865$, $p < .05$]. This data is depicted in Figure 2 where an early gradual decrease in responding over sessions is seen, and a final leveling out of the rate of responding.

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. The simple effects test on session 1 was found to be nonsignificant [$F(3,126) = .073$, $p > .05$]. The remaining nine simple effects test for sessions two through 10 were all found to be significant at the $p < .05$ level [$F(3,126) = 2.736$] for session 2; [$F(3,126) = 7.772$] for session 3; [$F(3,126) = 7.741$] for session 4; [$F(3,126) = 7.856$] for session 5; [$F(3,126) = 5.925$] for session 6; [$F(3,126) = 7.215$] for session 7; [$F(3,126) = 6.295$] for session 8; [$F(3,126) = 5.529$] for session 9; and [$F(3,126) = 7.404$] for session 10. Newman-Kuels follow up tests for each significant simple effects test found differences between

Table 2

Means and Standard Deviations of Lever Responses for Each Group During the Treatment Phase

Group	Sessions				
	1	2	3	4	5
DRO 2					
M	259.60	174.30	130.80	121.10	102.60
SD	140.43	114.09	91.87	96.52	96.91
DRO 6					
M	227.60	45.90	40.90	47.00	20.70
SD	103.60	39.44	31.73	31.78	16.25
DRO 18					
M	216.50	62.60	25.30	11.30	5.00
SD	103.79	39.39	47.40	16.94	3.46
EXT					
M	260.90	121.50	136.10	58.30	34.00
SD	91.58	63.56	102.33	38.47	17.56
Group	6	7	8	9	10
DRO 2					
M	84.40	67.90	58.60	51.40	58.50
SD	76.07	51.36	54.31	40.07	52.64
DRO 6					
M	30.10	20.80	17.40	25.30	21.90
SD	33.81	25.17	17.31	26.75	23.42
DRO 18					
M	9.70	7.80	5.60	4.30	3.40
SD	16.91	12.37	8.02	3.68	3.53
EXT					
M	42.20	40.30	47.60	26.90	26.40
SD	33.39	29.34	64.96	22.72	21.22

Table 3

Means and Standard Deviations of Natural Log Transformed
Lever Responses for Each Group During the Treatment Phase

Group	Sessions				
	1	2	3	4	5
DRO 2					
M	5.43	4.94	4.60	4.51	4.24
SD	.54	.77	.85	.87	.95
DRO 6					
M	5.32	3.48	3.20	3.63	2.76
SD	.53	.97	1.40	.79	.94
DRO 18					
M	5.28	3.99	2.40	1.91	1.58
SD	.47	.58	1.33	1.12	.78
EXT					
M	5.52	4.69	4.70	3.91	3.42
SD	.33	.52	.69	.64	.58
Group	6	7	8	9	10
DRO 2					
M	4.06	3.95	3.79	3.63	3.72
SD	.98	.81	.78	.94	.92
DRO 6					
M	2.83	2.38	2.62	2.72	2.58
SD	1.20	1.44	.81	1.17	1.19
DRO 18					
M	1.78	1.58	1.42	1.37	1.14
SD	.98	1.08	.96	.89	.92
EXT					
M	3.47	3.51	3.16	2.90	3.03
SD	.84	.67	1.27	1.21	.82

Figure 2. Means for lever responding for each group across the 10 sessions during the treatment phase.

all four groups at each session except during sessions 2 and 3 where the DRO 2 and EXT groups were not different, and for session 9 where the DRO 6 and EXT groups were not different from one another but were different from all the others.

Omega squared computations for this analysis were .251 for the treatment group effect, .315 for the sessions effect, and .041 for the treatment groups x sessions interaction effect. This indicates that while the treatment group effect accounted for a large portion of the variance, the sessions effect accounted for the majority of the variance and is due to the gradual decrease in mean responding over the 10 sessions.

Reacquisition Phase. Both means and standard deviations for the minute by minute total response rates for each group during the reacquisition phase are presented in Table 4. An $F_{\max}$ test of homogeneity of variance was found to be significant for these data, [$F_{\max}(9,60) = 1439.619, p < .01$]. A natural log transformation was performed and the means and standard deviation are reported in Table 5. Again a $F_{\max}$ test was found to be significant [$F(9,60) = 35.521, p < .01$]. All further analyses were performed on the natural log transformed data.

A 4x15 (groups x minutes) ANOVA was computed on the transformed minute by minute data (see Appendix C for the summary table). The main effect for groups was found to

be significant [$F(3,36) = 4.802, p < .05$], as was the main effect for minutes [$F(14,504) = 52.595, p < .05$]. The group by minute interaction effect was found to be non significant [$F(42,504) = 1.347, p > .05$]. The means of the natural log transformed data are presented in Figure 3.

Simple effects tests were performed for each minute during this phase. Again for each simple effects test computed, the Satterthwaite method (Winer, 1971) was used to compute the degrees of freedom for the denominator. The simple effects test for minute 1 was found to be nonsignificant [$F(3,183) = 2.663, p > .05$]. For the next four minutes the tests were significant, [$F(3,183) = 5.136, p < .05$] for minute 2; [$F(3,183) = 4.942, p < .05$] for minute 3; [$F(3,183) = 2.790, p < .05$] for minute 4; and [$F(3,183) = 2.745, p < .05$] for minute 5. The 10 remaining simple effects tests were all found to be nonsignificant, [$F(3,183) = .914, p > .05$] for minute 6; [$F(3,183) = 2.136, p > .05$] for minute 7; [$F(3,183) = 1.024, p > .05$] for minute 8; [$F(3,183) = 1.475, p > .05$] for minute 9; [$F(3,183) = 1.219, p > .05$] for minute 10; [$F(3,183) = .832, p > .05$] for minute 11; [$F(3,183) = .749, p > .05$] for minute 12; [$F(3,183) = 1.157, p > .05$] for minute 13; [$F(3,183) = .930, p > .05$] for minute 14; and [$F(3,183) = 1.350, p > .05$] for minute 15.

Follow-up Newman-Kuels tests were computed for minutes 2, 3, 4, and 5. At minute 2 comparisons indicated

Table 4

Means and Standard Deviations of Lever Responses for Each Group During the Reacquisition Phase

Group	Sessions				
	1	2	3	4	5
DRO 2					
M	3.80	8.00	13.60	14.20	24.90
SD	3.39	6.00	10.34	6.71	11.06
DRO 6					
M	1.40	4.60	8.80	16.60	19.70
SD	1.96	3.63	4.89	13.74	11.41
DRO 18					
M	.40	.80	2.50	6.90	8.70
SD	.52	1.23	2.84	8.92	6.40
EXT					
M	4.10	14.20	23.20	21.90	29.10
SD	4.56	14.26	13.94	13.94	15.84
Group	6	7	8	9	10
DRO 2					
M	20.10	21.80	18.90	20.30	20.60
SD	8.80	7.21	7.80	5.58	7.38
DRO 6					
M	21.10	20.60	21.80	23.60	19.40
SD	10.73	7.76	12.66	9.67	10.93
DRO 18					
M	14.40	11.20	15.80	16.20	15.40
SD	10.17	10.00	14.54	11.92	12.39
EXT					
M	26.40	28.30	25.80	31.30	29.90
SD	15.46	19.01	14.69	13.14	13.71

Group	Sessions				
	11	12	13	14	15
DRO 2					
<u>M</u>	17.40	20.00	21.00	20.30	22.40
<u>SD</u>	8.46	7.01	6.73	9.58	5.40
DRO 6					
<u>M</u>	21.60	24.70	23.10	21.00	21.70
<u>SD</u>	12.59	9.63	12.71	11.05	7.29
DRO 18					
<u>M</u>	16.90	19.40	17.40	18.40	16.40
<u>SD</u>	12.26	13.88	14.38	19.73	12.43
EXT					
<u>M</u>	29.30	30.60	32.50	27.80	32.00
<u>SD</u>	11.06	11.82	12.94	11.63	9.31

Table 5

Means and Standard Deviations of Natural Log Transformed
Lever Responses for Each Group During the Reacquisition
Phase

Group	Sessions				
	1	2	3	4	5
DRO 2					
M	1.34	2.01	2.41	2.61	3.14
SD	.74	.67	.85	.54	.55
DRO 6					
M	.59	1.50	2.06	2.58	2.93
SD	.78	.73	.87	.86	.44
DRO 18					
M	.28	.42	1.03	1.54	1.94
SD	.36	.58	.70	1.11	1.00
EXT					
M	1.33	1.98	2.70	2.70	2.96
SD	.78	1.49	1.44	1.29	1.39
Group	6	7	8	9	10
DRO 2					
M	2.97	3.06	2.90	3.03	3.01
SD	.44	.44	.47	.28	.42
DRO 6					
M	3.00	3.00	3.01	3.13	2.89
SD	.45	.44	.52	.43	.53
DRO 18					
M	2.34	2.04	2.35	2.42	2.43
SD	1.15	1.19	1.20	1.20	1.06
EXT					
M	2.92	2.91	3.08	3.35	3.30
SD	1.25	1.34	.79	.61	.62

Group	Sessions				
	11	12	13	14	15
DRO 2					
M	2.80	2.99	3.05	2.97	3.13
SD	.51	.35	.29	.46	.25
DRO 6					
M	2.97	3.16	3.04	2.98	3.07
SD	.59	.47	.59	.50	.35
DRO 18					
M	2.57	2.69	2.56	2.49	2.54
SD	1.03	1.07	1.06	1.14	1.02
EXT					
M	3.28	3.36	3.42	3.25	3.46
SD	.69	.51	.51	.54	.30

Figure 3. Means for lever responding for each group during each minute of the reacquisition phase.

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 the DRO 18 group differed from the other three groups. As can be seen in Figure 3, lever responding recovered within the first five minutes of this session. However, the data also indicate that the DRO 18 group reacquired the responding at a much slower rate than the DRO 2 and EXT groups.

Again Omega squared values were calculated for this analysis. The values for the group effect was .091, for the minute main effect it was .327, and for the group by minute interaction effect the value was .006. This indicated that most of the accounted for variance (32%) was due to the increase of responding over the minutes. The patterns of most interest, the interaction and group main effects accounted for only 9% of the variance in this analysis.

Lever Response Pattern Analysis

The following is an interpretation of the cumulative records obtained in the course of the experiments. Due to the abundance of records available and the limited space available in this report only a representative sample will be presented here. Each record therefore reflects a typical pattern of responding for an animal in any one group. In most cases the record was chosen from the end

of each phase in order to better demonstrate that group of animals' particular shape of responding at stable state.

Records a, b, c, and d in Figure 4 typify responding by subjects on the fifth day of the acquisition 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 the animals in that group. The responding seen on each record is representative for the response pattern observed for that group. Record a is that of a DRO 2 animal, b that of a DRO 6, c of a DRO 18, and d an EXT animal. The upper line shows the lever responding over time. In all of these records a steeper line indicates a higher rate of responding while a shallower line represents a slower rate of responding. The downward slashes on the top line indicate the delivery of a reinforcer. The lower line represents the passage of time, 15 minutes in this case, while the two slashes on this line mark the beginning and end of each session. Although the records in the acquisition phase do not show the distinct scalloping effect characteristic of fixed interval schedules, this may be explained by the fact that the 10's interval used may not have been long enough for this specifically characteristic pattern to emerge (Ferster & Skinner, 1957).

Figure 5 shows individual cumulative records for subjects on the first day of the treatment phase. Records

Figure 4. Representative cumulative records for subjects' lever responding during the acquisition phase.

Figure 5. Representative cumulative records for subjects' lever responding on the first day of the treatment phase.

e, f, g, and h show records for subjects from the DRO 2, DRO 6, DRO 18, and EXT groups respectively. It is evident when looking at the first three records that with higher response-reinforcement intervals fewer reinforcements are received. This can be explained by the fact that in this condition responding causes the imposition of the response-reinforcement interval to the S^R-S^R interval. Record h shows the typical extinction curve (Skinner, 1938) with an initial burst of responding early in the session and a gradual decrease in the frequency of responding later in the session.

Records i, j, k, and l in Figure 6 show response records for animals during the final session of the treatment phase. Again records are presented in the DRO 2, DRO 6, DRO 18, and EXT sequence. By this session all subjects' responding had decreased drastically as can also be seen in Figure 2. When comparing records i and k it is noticeable that while the DRO 2 condition only altered the time to the next reinforcer very little (from 10 to 12 seconds), the DRO 18 condition more than doubled the time to the next reinforcer (from 10 to 28 seconds) should a response be emitted early within the reinforcement-reinforcement interval.

Figure 7 shows cumulative records for a subject from each treatment group during the reacquisition phase. They are presented in the same order as those above. It is evident that all animals with the exception of the DRO 18

Figure 6. Representative cumulative records for subjects' lever responding on the last day of the treatment phase.

Figure 7. Representative cumulative records for subjects' lever responding during the reacquisition phase.

group (record o) finished the session with total responding close to that of the final day of the acquisition phase (see Figure 4). Because this schedule is the same as that of the acquisition phase a direct comparison between records m, n, o, and p can be made with records a, b, c, and d. The most obvious difference is that all subjects began responding much later in the session during the reacquisition phase. This pattern is parallel to that of Figure 3. The curves also show that after only two or three reinforcements the subjects had recovered responding to rates observed prior to the treatment phase. The lower rates of responding then seen in Figure 3 reflect the fact that the subjects did not begin responding until several minutes into the session. This is especially true for the DRO 18 animals and their consistently lower response rates during the first five minutes of this session.

Discussion

The results of the present experiment replicate those of previous studies by 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 seconds this study extends our knowledge as to the effects of the response-reinforcement interval. Although originally it was hypothesized that

the DRO procedure would "eliminate" the original response the data from the reacquisition phase show that the DRO contingency had not eliminated the responding but rather caused a "suppression" of responding.

An interesting finding in the treatment phase was the clear 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 session three (see Figure 2). While the DRO 2 group continued to respond at higher rates than the EXT group both the DRO 6 and DRO 18 groups responded less than the EXT group. It is important to note the extreme and continued efficient suppression of responding seen in the DRO 18 group. Unlike previous research, however, the shortest DRO group showed less suppression than the extinction group (see Pacitti & Smith, 1977).

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 five minutes of the session. The results of the DRO 18 group, with the longest response-reinforcement interval, show the slowest reacquisition to asymptotic rates and clearly establishes

the greater response suppression for this condition. Important to remember though, is the finding that after minute five no differences existed between the groups' responding.

When responding began, the rates tended to be typical of those of the last day of acquisition. This indicates that the original lever response was not "eliminated" but that merely a suppression of responding had occurred during the treatment phase (Boe & Church, 1967). A possible explanation for the lower rates of the DRO 18 group is that whereas the DRO 2 and DRO 6 group experienced reinforcement-reinforcement intervals of maximally 12 s and 16 s the longest reinforcement-reinforcement interval for the DRO 18 group was 28 s. During the reacquisition phase it was not uncommon to see the first response of subjects in the DRO 18 group occurring several minutes into the session (see cumulative record p on Figure 7).

The rapid recovery of all animals during the third phase to rates close to those of the final day of acquisition can be explained by the fact that, because of the FI 10 sec schedule usually only one response had to be emitted by a subject in order for reinforcement to occur. This first response, followed immediately by reinforcement, then 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 five minutes of this phase indicate differences in the interval from the beginning of the session to the first response.

Several interesting findings are apparent when looking at the actual cumulative records obtained during this study. The records of the acquisition phase support the analyses performed on the data. No obvious differences between the four groups were found during the acquisition phase (see Figure 4). However, striking differences can be seen on the first day of the treatment phase (see Figure 5) and reflect the differences in each groups particular contingencies. Because the DRO 2 group's (see record e) contingency allowed for responding until eight seconds into the reinforcement-reinforcement interval before the additional response-reinforcement interval was incurred, this schedule allowed for high rates of responding early in the reinforcement-reinforcement interval leading to eventual reinforcement. For the DRO 6 animals responding in the first four seconds of the reinforcement-reinforcement interval did not change the perceived reinforcement-reinforcement interval. This necessarily led to longer periods where the animal received no reinforcement (see record f). The same is true for the DRO 18 animals where any response during the reinforcement-reinforcement interval led to the additional

response-reinforcement interval. Over the course of the treatment phase and by day 10 of this phase (see Figure 6) responding had decreased for all animals with only occasional short bursts of responding for the DRO 6 and DRO 18 animals (records j and k). Throughout this phase the extinction animals showed standard extinction curves (Ferster & Skinner, 1957) showing a gradual decrease in responding over the 10 sessions. The cumulative records for the reacquisition phase (Figure 7) show a delayed start of responding for the DRO 6, DRO 18 and EXT animals (records n, o, and p respectively). It is interesting to note the gradual increase in responding in the DRO 18 group once responding does again occur. This observation is similar to that of previous studies (Vyse et al., 1985).

Based on the 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 sec each for response elimination to be most effective. The results of the present study clearly do not support Uhl's recommendation. Although the present study used a S^R-S^R interval of 10 seconds and $R-S^R$ intervals both shorter and longer than the S^R-S^R the finding here was that the length of the DRO in relation to the reinforcement-reinforcement interval plays an important role in response suppression when compared to EXT. Both of the Uhl studies used only one response-reinforcement length which was equal to the

response-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.

Several studies have pointed out that the effectiveness of DRO when compared to EXT was that, during DRO, the response of not responding or the response alternate to responding is strengthened while during EXT response suppression without the conditioning of other behaviors occurs (Zeiler, 1971; Uhl & Garcia, 1969). This line of logic would necessarily argue 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. Again the results of the present study suggest that only when the response-reinforcement interval is sufficiently long will the DRO subjects reacquire the original response more slowly than the EXT animals.

Generalizations from basic animal research to the applied literature are generally frowned upon. However, as Epling and Pierce (1986) point out, what is needed to link the two is a heightened awareness by the basic researcher of the issues within the human literature that

will yield an understanding of all operant behavior. It is for this reason that several points need to be made with regard to the present study. To our knowledge no one has analyzed the effects different response-reinforcement intervals have on human responding. As stated above most studies involving DRO have been comparisons between omission training (OT) or DRO and other response eliminating procedures (see below).

The effectiveness of any one DRO procedure compared to other response elimination procedures such as extinction and punishment procedures have yielded as many conclusions as there are studies. Whereas some studies have found DRO to be more effective than extinction (O'Neil, White, King, & Carek, 1979) others have found EXT to be more effective (Redd, 1986) and others have found punishment to be more effective in comparisons between DRO and punishment (Barrett, Matson, Shapiro, & Ollendick, 1981). Still other response elimination procedures have been used in comparisons with the effectiveness of DRO. The method of alternative response training has been found to be more effective than DRO. In comparisons with time out, DRO has been shown to be less effective (Roberts, Hatzenbuehler, & Bean, 1981). Response cost has also been shown to be more effective (Sindelar, Honsaker, & Jenkins, 1982; Johnson, McGlynn & Topping, 1973), as have response contingent interruptions of the ongoing behavior (Azrin, Besalel, & Wisotzet 1982).

Another series of studies has achieved results showing no differences between DRO and extinction (Heidon, & Jensen 1984), punishment (Thompson, Iwata, & Poyner 1979), and overcorrection (Rapoff, Altman, & Christophersen, 1980).

The results of the present experiment clearly show that the DRO 18 group's responding was more suppressed than the EXT group during both the treatment and reacquisition phase. If the differences in the length of the response-reinforcement interval do indeed make a significant difference in the suppression of an already established response this would necessarily allow for the questioning of the validity of applied studies using DRO as a comparison procedure for whatever behavior the researcher or therapist is trying to eliminate. The effectiveness of the DRO procedure in any of the above referenced studies could have been changed in comparison to that of the other response elimination procedures had a different response-reinforcement interval been used. It would be interesting to closely review the above cited applied reports and to determine what reinforcement-reinforcement intervals were used with what response-reinforcement intervals. If response-reinforcement intervals were used that were shorter than the reinforcement-reinforcement interval the external validity of the conclusions of these studies could be seriously questioned.

An obvious conclusion from the present experiment is that the longer the response-reinforcement interval the greater the suppression of responding observed, as well as the slower the reacquisition of lever responding once reinforcement is once again made contingent on lever responding. One question that the present study does not answer is whether it is the $R-S^R$ to the S^R-S^R ratio that is important in causing response suppression or whether it is the absolute length of these intervals that is causing the greater suppression. A conceivable followup study would therefore use the same design with each interval being twice as long. For example, DRO intervals of 4, 12, and 36 seconds could be used with a reinforcement-reinforcement interval of 20 seconds. A second issue that may make the present results particular to the present study is the effect of the base schedule which the animals experience during the acquisition phase. An important question would therefore be, what would happen if an interval schedule such as the FI 10 s used during acquisition in the present study were replaced with a ratio schedule while the $R-S^R$ and S^R-S^R intervals remained the same.

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Appendix A

Mixed Design Analysis of Variance Summary table for
Lever Responses During the Acquisition phase

Source	Sum of Squares	<u>df</u>	Mean Square	<u>F</u>
Between				
Group	103402.109	3	34467.370	.406
Error	3056361.380	36	84898.927	
Within				
Sessions	537260.362	4	134315.090	45.151
Group x				
Sessions	11981.455	12	998.455	.336
Error	428366.197	144	2974.765	
Total	4137372.500	199		

Appendix B

Mixed Design Analysis of Variance Summary Table for
Natural Log transformed Lever Responses During
the Treatment Phase

Source	Sum of Squares	<u>df</u>	Mean Square	<u>F</u>
Between				
Group	236.288	3	78.763	14.486
Error	195.7269	36	5.437	
Within				
Sessions	280.070	9	31.119	89.116
Group x				
Sessions	45.835	27	1.698	4.865
Error	113.025	324	.349	
Total	870.943	399		

Appendix C

Mixed Design Analysis of Variance Summary Table for
Natural Log transformed Lever Responses During
the Reacqauition Phase

Source	Sum of Squares	<u>df</u>	Mean Square	<u>F</u>
Between				
Group	79.115	3	26.372	4.802
Error	197.700	36	5.492	
Within				
Sessions	229.000	14	16.357	52.595
Group x				
Sessions	17.602	42	.419	1.347
Error	156.604	504	.311	
Total	680.020	599		