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A Comparison of Extinction and Reinforcement-Based Response Elimination Technique

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A COMPARISON OF EXTINCTION AND REINFORCEMENT-BASED
RESPONSE ELIMINATION TECHNIQUES

BY
STUART VYSE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
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IN
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Abstract

Over a period of eight daily sessions, 40 male rats acquired an operant lever response under an FI 10-sec schedule of reinforcement. Following this training the subjects were randomly assigned to one of four treatment conditions designed to eliminate this response: 1) extinction (EXT), 2) differential reinforcement of other behavior (DRO), 3) reinforcement of an alternate response (ALT-R1), or 4) reinforcement of an alternate response plus a response-reinforcement delay for the original response (ALT-R10). These four response elimination contingencies were compared under three experimental conditions: 1) a five session treatment phase in which each response elimination procedure was in effect, 2) a five session extinction phase in which no reinforcement was available for any of the four groups, and 3) a single reacquisition session in which reinforcement was reinstated for the original response. The results of the treatment phase showed the ALT-R10 procedure to be significantly more effective in eliminating the original response than either EXT or ALT-R1, and in the final session of this phase, ALT-R10 was also more effective than DRO. In the extinction

phase, subjects in all three of the reinforcement-based response elimination procedures showed a rebound in original responses resulting in a significantly higher rate of responding than for subjects in the EXT group, and ALT-R1 subjects showed significantly more original responses than either DRO or ALT-R10 subjects. Finally, ALT-R10 showed significantly fewer original responses than DRO in the first session of the extinction phase but was not significantly different from this group in the other four sessions of this phase. In the reacquisition session, the EXT group was significantly slower to recover the original response than all of the reinforcement-based treatment groups, and DRO showed significantly slower reacquisition than ALT-R1 or ALT-R10. Finally, ALT-R1 and ALT-R10 were essentially equivalent in reacquisition. The theoretical relevance of these effects for reinforcement-based response elimination procedures is discussed, as well as the implications of this research for the applied use of similar contingencies aimed at the treatment of human behavioral excesses.

Acknowledgements

This section of a graduate thesis is something of a formality, and perhaps the most traditional aspect of this formality is the acknowledgement of the assistance of the thesis committee. However in this case my remarks are not stimulated by custom. This project, whose conception and development have spanned more than a year, represents the major product of my early graduate training in psychology, but the contributions of my committee have not been limited to this research. Each of them, Jerry Cohen, James Loy, James A. Mulick, and Mark D. Rapport, has served as a mentor and colleague and has listened patiently to sad stories and improbable schemes. Special thanks go to my major professor, Nelson Smith, who has always provided me with the guidance, support, and materials to make my graduate education as comprehensive as I had the energy to make it.

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Preface

As behavioral psychology enters its seventh decade it appears to have passed into an adolescence marked both by expansion into new and diverse areas of research (Epling & Pierce, 1983) and a drifting apart of applied and basic behavioral research (Deitz, 1978; Michael, 1980). While the former is considered by most to be good news, many researchers have expressed serious concern about the latter. One of the major controversies surrounding this basic-applied schism has been the increased frequency within applied behavior analysis of studies employing package independent variables, such as "overcorrection", "response cost", and "feedback". These interventions combine a number of elements whose relation to more clearly defined experimental principles (e.g. punishment, negative reinforcement, and stimulus control) is unclear. As Deitz (1978) suggests, this development within applied research reflects a greater concern for effects upon dependent variables than for the discovery of functional relationships between independent and dependent variables.

Perhaps another aspect of this divergence of basic and applied research is the increased specialization of issues examined in current basic research journals. The advent of

research on the matching law (Herrnstein, 1961) and various forms of phylogenetic behavior has helped to drive a wedge between the two spheres by making basic research less accessible to applied professionals. Research in these areas is often concerned with theoretical issues of dubious applied significance.

Set against this background, the present graduate thesis is something of an anachronism. It is basic animal research which, while having considerable theoretical significance, is primarily an analog study directed at an applied question. The response elimination issues examined in this study are more consistent with the topics addressed in applied journals, yet this characteristic may be one of its strengths.

The growth of applied behavior analysis in the 1950's and 60's was a direct result of earlier animal research; however, in the intervening years applied research has become an independent discipline with its own unique history and methods. While the practical benefits of this applied technology have been many, the society which reinforces these advances is in part responsible for the theoretical imprecision cited by Michael (1980) and Deitz (1978). The solutions to these problems will come primarily with changes in the language, methods, and topics of applied research, but the present study represents another type of solution. By returning applied issues to the laboratory, research of

this type may provide both improved experimental control and the kind of functional analysis Michael (1980) and Deitz (1978) advocate. I hope the following pages argue convincingly for the return of applied researchers to the animal laboratory and stand as an example of effective communication between the two worlds of behavior analysis.

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Introduction

The search for effective treatments for behavioral excesses in applied psychology has led to the successful use of several punishment techniques (Lovaas & Simmons, 1969; Plogrove & Reith, 1983; Rapport, Murphy, & Bailey, 1982) as well as reinforcement procedures (Deitz & Repp, 1983) for the elimination of a response. However, current concerns about the restrictiveness of aversive procedures (Barton, Brulle, & Repp, 1983; Martin, 1975) and other, undesirable effects thought to accompany the use of punishment (Skinner, 1953) have given greater importance to research in various reinforcement-based response elimination procedures. Basic research in this area has been primarily in two parallel lines, one involving the differential reinforcement of other behavior (DRO) or omission training (OT) and the second involving the reinforcement of a specific alternative response (ALT-R).

As outlined by Uhl and Garcia (1964), DRO schedules, like free operant avoidance schedules, are defined by two temporal schedule parameters: 1) the reinforcement-reinforcement interval and 2) the response-reinforcement interval. Since the DRO contingency allows for the reinforcement of any response other than the

one targetted for elimination, the reinforcement-reinforcement interval dictates the rate of reinforcement provided the target response does not occur. The response-reinforcement interval determines the amount of time which must elapse after a response has been made before reinforcement is delivered.

DRO was first introduced as a control procedure for examining behavioral contrast in multiple schedules (Reynolds, 1961), but its response elimination effects soon engendered a new line of research (Johnson, McGlynn, & Topping, 1973; Lowry & Lachter, 1977; Mulick, 1975; Mulick & Leitenberg, 1978; Nevin, 1968; Pacitti & Smith, 1977; Topping, Larmi, & Johnson, 1972; Uhl & Garcia, 1969; and Zeiler, 1970, 1971, 1976, 1977, 1979). Most studies comparing this schedule to extinction (EXT) have shown that the DRO contingency produces more rapid response elimination (Johnson, et al, 1973; Pacitti & Smith, 1977; Topping et al., 1972; Topping & Ford, 1974) and, when reinforcement is reinstated for the target response, is more resistant to reacquisition (Pacitti & Smith, 1977; Topping et al., 1972). However most studies which follow the DRO treatment phase with a period of extinction during which no reinforcement is available have shown a characteristic rebound in the target response (Mulick, 1975; Mulick & Leitenberg, 1978; Pacitti & Smith, 1977). This effect, which is characteristic of punishment and

reinforcement-based response elimination techniques, has been labelled "compensatory recovery" (Boe & Church, 1967). Uhl and Garcia (1969, Experiment 1) found that OT produced slower response elimination in rats than EXT; however, in a second experiment Uhl and Garcia provided a brief blackout after reinforcement delivery which reversed the effectiveness of the two treatments. This result suggested that a "chaining" effect had occurred in the first study in which the delivery of reinforcement was so strongly associated with the response that early in OT the presence of food actually increased the probability of the response. Mulick and Leitenberg (1978) reported a similar chaining pattern in the responses of OT subjects.

Two multiple schedule experiments (Lowry & Lachter, 1977; Mulick, Leitenberg, & Rawson, 1976) in which single subjects were alternately exposed to several response elimination treatments per session, showed results which were in contrast to most between groups studies. In both cases ALT-R produced the most rapid response elimination while DRO and EXT showed more moderate and essentially equivalent decrements in response rate. However, the most remarkable aspect of these studies is that neither showed a rebound effect for either DRO or ALT-R during the extinction phase. These consistent results seem to indicate that the multiple schedule design is a unique case which produces different effects than between groups studies. For the

purpose of extrapolation to likely human applications of these procedures, the between groups case is more informative since rapid alternation of treatments is rare in clinical settings.

Zeiler's recent research with DRO has been involved with parametric analyses of the response-reinforcement intervals (1977) and the study of conjoint schedules in which DRO and either a fixed time schedule of food delivery (FT) or a fixed ratio schedule of reinforcement (FR) are simultaneously in effect (1977, 1979). These studies have greatly increased our understanding of the DRO contingency. The conjoint schedule studies (Zeiler, 1977, 1979) are of particular note because they more accurately simulate the applied case in which DRO is used as a treatment for the elimination of a response which, nevertheless, is still receiving reinforcement on some intermittent schedule. However, unlike the studies cited earlier, these experiments were limited to DRO and did not compare it to other response elimination techniques.

Other than DRO or OT the most frequently studied reinforcement technique for elimination of a response is alternate response (ALT-R), which normally involves the introduction of a second manipulandum in the chamber upon which responses are made contingent during the response elimination phase. Many studies have found this to be a treatment which produces more rapid elimination of the

original response than EXT (Boe, 1964; Enkema, Slavin, Spaeth, & Nueringer, 1972; Leitenberg, Rawson, & Bath, 1970; Leitenberg, Rawson, & Mulick, 1975; Lowry & Lachter, 1977; Mulick, 1975; Mulick & Leitenberg, 1978; Pacitti & Smith, 1974; Rawson & Leitenberg, 1973); however, in studies which followed ALT-R treatment with a period of no reinforcement for either response (EXT), all but the within subject studies (Lowry & Lachter, 1977; Mulick, Leitenberg, & Rawson, 1976) showed a rebound of responding similar to that found in the DRO studies. Indeed, a number of group studies (Leitenberg et al., 1970; Pacitti & Smith, 1977) have shown that when total responses in both the treatment and extinction phases are compared for both EXT and ALT-R groups no significant savings was found for ALT-R.

Recently, Epstein and his associates (Epstein, in press; Epstein & Medalie, 1983) have related this phenomenon, which is similar to the "compensatory recovery" of DRO (Boe & Church, 1967), to a principle they call "resurgence". This principle states that, "when, in a given situation, recently reinforced behavior is no longer reinforced, behaviors that were previously reinforced tend to recur" (Epstein, in press). Epstein has suggested that resurgence plays an important part in a number of problems solving activities.

The rebound effect is of theoretical importance because it is related to an early theory of punishment proposed by Estes (1944) which suggested that the punishment of a

learned response only suppresses it temporarily and that complete elimination can only come after the response has undergone the normal process of extinction. More recently this theory has been criticized on several points (see Azrin & Holz, 1966) and experimental evidence suggests that the punishment of responses with powerful electric shock can produce more permanent effects. Nevertheless, the work in ALT-R and DRO are relevant to this issue since the great majority of studies have found no significant difference in the number of responses made by ALT-R, DRO, or EXT groups when both treatment and extinction phases are combined. These results, like Estes (1944) early work in punishment, might lead to the conclusion that reinforcement-based response elimination techniques only produce a temporary suppression effect; however, Leitenberg et al. (1975) have shown that when the ALT-R treatment phase was extended for 27 days, switching to extinction did not produce a rebound in responding and a significant savings in total responses was found over the EXT group. Thus, while there is some evidence that reinforcement-based procedures can produce relatively rapid and permanent suppression, few contingencies have been found which were successful in this end.

The present study was designed to explore the elimination of a previously learned response using a contingency of reinforcement which combined some aspects of

both ALT-R and DRO. Simply stated the contingency consisted of an ALT-R procedure which included a substantial response-reinforcement interval for the original response, similar to DRO. This arrangement made reinforcement available on a fixed interval schedule for an alternate response and set up a brief interruption of this schedule each time an original response was made. It was hoped that this addition of a penalty for original responses would prevent the usual rebound during extinction and produce more durable effects in reacquisition.

This aspect of the study is related to an important issue which has never been fully addressed in the alternate response literature. Since by definition the ALT-R procedure involves two manipulanda, different at least in location in the chamber, it qualifies as a special case of concurrent operant in which one manipulandum is associated with a schedule of reinforcement and the other is associated with extinction (Catania, 1966). However, as Catania (1966) has outlined in detail, a critical problem in the study of concurrent operants is the independence of the responses and the schedules of reinforcement associated with them. If the two operants are not made sufficiently independent, the close temporal relationship of reinforcement as a result of a schedule on one manipulandum and responses made on another may support superstitious responses on one or both manipulanda or a pattern of switching from one to the other.

Normally, schedules of reinforcement are made independent by programming a changeover delay (COD) (Catania, 1966) which prevents the reinforcement of a response for a brief period of time after a change from one manipulandum to another. However, this kind of independence can also be created by the physical arrangement of the manipulanda, as was the case in the present study. If the levers or keys are far enough apart, a tacit COD will be created by the time involved in moving from one to the other.

The question of independence is an important one for the alternate response literature since the length of CODs employed have ranged from none at all (Pacitti & Smith, 1977) to a very substantial 5 sec COD (Leitenberg et al., 1975). Similarly, the physical arrangement of the manipulanda has varied in different studies. Yet neither the physical or temporal independence of schedules or responses has been systematically examined in the alternate response literature.

The ALT-R procedure as studied in the animal literature is related to two applied response elimination procedures. The most common of these is differential reinforcement of incompatible behavior (DRI) (Deitz & Repp, 1983; Mulick, Schroeder, & Rojahn, 1980; Tarpley & Schroeder, 1979; Woods, 1983). As defined by Woods (1983), DRI is "a procedure in which the contingent application of a stimulus event strengthens a response which is incompatible

(physically or practically) with another, undesired response" (p. 60). For two of the subjects studied by Tarpley and Schroeder (1979), self-injurious hand-to-head hitting was reduced by reinforcing ball-trading. This was a typical and very successful application involving a physically incompatible response, except that in this case the investigators required that ball-trading occur uninterrupted for a fixed interval in order to obtain reinforcement.

Deitz and Repp (1983) have identified another applied response elimination procedure which is related to the ALT-R contingency of the experimental literature. Differential reinforcement of alternate behavior (DRA) is defined as reinforcement of a response which is not "physically or practically" incompatible with the behavior targeted for elimination. While less frequently studied, DRA procedures have also been effective in a number of cases (Deitz & Repp, 1983).

In the present study, four different response elimination procedures were compared: 1) EXT, 2) DRO, 3) ALT-R, and 4) ALT-R plus a 10 sec response-reinforcement interval. In this case the ALT-R was analogous to an applied DRI procedure since the manipulanda in this study were physically separated and a short COD was employed. The 13.1 cm distance between the levers did not make simultaneous responses physically impossible, given the

typical length of a 250 g Sprague-Dawley rat, yet such responses were extremely unlikely.

The group of primary interest was the ALT-R group in which a response on the original lever created a 10 sec delay in the availability of reinforcement on the alternate lever. In both its experimental and applied senses this contingency combined aspects of the ALT-R (or DRI) and DRO procedures. Reinforcement was available only for a specified response (as in ALT-R and DRI); however, the occurrence of an original response produced a 10 sec delay in the availability of reinforcement for the alternative response (similar to DRO). It was hoped that, like the DRO contingency, this procedure would provide a mild punishment for responses on the original lever. This penalty combined with reinforcement for a specific alternative response might result in more efficient suppression than DRO or ALT-R alone and produce the durable effect which has been observed in studies involving DRO.

In all four groups of the present study the original training was on an FI 10-sec schedule for five days, and in the three reinforcement-based treatment procedures the optimal reinforcement-reinforcement intervals were also matched at 10 sec. This arrangement equated the three groups on the potential rate of reinforcement, both during training and treatment phases.

The sequence of treatment phases included training,

response elimination treatment, extinction, and reacquisition. The extinction and reacquisition phases are included as tests of the durability of the various response elimination techniques, since during the applied use of any of these procedures it is reasonable to assume that behavior modification programs will experience brief interruptions or that on occasion inappropriate behaviors will be inadvertently reinforced. In light of this, it is important to find contingencies which produce durable suppression under conditions of extinction and reacquisition.

The present study has one primary hypothesis: the length of changeover delay of an ALT-R contingency contributes to its response elimination effects. Specifically, it is predicted an ALT-R contingency with a 10-sec changeover delay penalty will control lower rates of responding than an ALT-R contingency without a substantial penalty. This prediction is expected to hold both while the two contingencies are in effect, as well as after both have been switched to extinction. Finally, it is predicted that an ALT-R plus penalty condition will control lower rates of responding during a brief reacquisition phase. No prediction is possible regarding the relative effectiveness of either of these contingencies in comparison to DRO.

Method

Subjects

The subjects were 40 male Sprague-Dawley rats. Each weighed between 250 and 350 g prior to food deprivation and was individually housed and provided with free access to water throughout the course of the study. For three days prior to shaping, each subject was deprived of all food, and following shaping was maintained at approximately 80% of his free feeding weight throughout all phases of the experiment.

Apparatus

Two Coulbourn Instruments model # E10-10 operant chambers were employed. The front and back walls were aluminium and were 25 cm wide. The side walls were clear Plexiglas and were 30 cm wide. The chambers were 29 cm tall and each was contained in a sound attenuating housing. The front wall of each chamber was equipped with two operant levers and a food cup. The levers extended 2.0 cm into the chamber 2.8 cm above the grid floor and were 3.0 cm wide. The levers were spaced 13.1 cm apart, and the food cup was recessed in the wall of the chamber and centered between the two levers 1.8 cm above the grid floor. Masking noise was provided by ventilating fans attached to each housing, and programming was accomplished using standard electro-mechanical equipment which was kept in an adjoining

room. Noyes precision pellets were used as reinforcement.

Procedure

Prior to initial shaping each subject was handled on at least two different days and was acclimated to the experimental chamber. Immediately after his daily session each subject was returned to the animal colony and, a few hours later, was given enough rat chow to maintain him at 80% of his pre-deprivation weight.

Other than on the first shaping day, all sessions were conducted five days a week (Monday through Friday) at approximately the same time each day and lasted 15 min. On the first day of shaping, the session was conducted with the door of the housing open in order to make the subject clearly visible, but during all other sessions the housing was closed.

Shaping. The first day of shaping for each subject was conducted on a Sunday. Each subject was randomly assigned to one of the two chambers and to a left-hand or right-hand lever for original response training. Initially, hand shaping was terminated when the subject made 40 reinforced lever presses, and if this criterion was not met within 75 min the animal was replaced by another. However, early in the experiment, due to a number of failures to produce 40 lever presses within the 75 min time limit, the shaping procedures were changed. All animals were deprived of food

for four days prior to shaping, and the criterion was reduced to 30 responses within the 75 min session.

Pretraining. On the second and third days of the experiment, the subject was placed in the chamber and an FI 10-sec schedule of reinforcement was programmed on the original lever. In order to firmly establish the response, the session length on these two days was 30 min.

Phase I--Training. Following the first three sessions, the daily session length was reduced to 15 min and each subject received five days of FI 10-sec training on the original response. A criterion for response rate during Phase I was set such that any subject who did not produce an mean of 100 responses per day across the five days of this condition was eliminated and replaced. Following this preliminary training, subjects were randomly assigned to one of the four treatment groups. Each group consisted of 10 subjects.

Phase II--Treatment. This phase of the experiment lasted five days during which each subject was exposed to one of the following treatment conditions.

Extinction(EXT). Beginning on the first day of treatment each subject in this group received no reinforcement for any response.

Differential Reinforcement of Other Behavior (DRO). This group was programmed for a DRO contingency with matched 10 sec reinforcement-reinforcement and 10 sec

response-reinforcement intervals for responses on the original lever. Under this arrangement each subject received reinforcement every 10 sec as long as the original response did not occur; however, each original response which was made set up a 10 sec delay in reinforcement.

Alternate Response (ALT-R1). Under this treatment condition reinforcement was made available on the alternate lever on the same FI-10 sec schedule as was programmed on the original lever during the previous phase, and responses on the original lever were not reinforced. A 1 sec COD was programmed for responses on the original lever in order to prevent the chaining of responses or the adventitious reinforcement of switching from one lever to the other.

Alternate Response plus 10 sec penalty (ALT-R10) This treatment condition was the same as the ALT-R group with the addition of a 10 sec response-reinforcement interval for responses on the original lever. Under this arrangement each response on the original lever set up a 10 sec delay in the availability of reinforcement on the alternate lever.

Phase III--Extinction. This phase of the experiment lasted five days, during which all subjects received no reinforcement for any response.

Phase IV--Reacquisition. This phase of the experiment involved one 15 min session which was run on the day immediately following the last day of the extinction phase. During this session, an FI 10-sec schedule of reinforcement

was again programmed for responses on the original lever for all the subjects.

Results

Subject Attrition

During the course of the experiment one subject died, one was eliminated for not acquiring an average of 100 responses per day across the original training phase, and 18 subjects were eliminated for not attaining the shaping criterion in 75 min. Each of these was replaced by another animal.

Presentation of Results

The results are presented in two major sections. The first is a traditional statistical analysis of the three dependent variables (original lever responses, alternate lever responses, and reinforcement rate) which examines total frequencies of these measures across sessions or minutes. The second section consists of examples of cumulative records of moment-to-moment response patterns within sessions.

Statistical Analyses

The following section reports the results of 12 analyses of variance performed on various dependent

variables. In each case a Hartley's $F_{\max}$ or a Cochran's test of homogeneity of variance was performed on the data prior to further analysis. In each case in which significant heterogeneity of variance was found ($p < .01$) the data were transformed to minimize this problem. In four cases heterogeneity persisted after transformation. The largest $F_{\max}$ obtained on transformed data was 94.25 ($df = 20, 9$), relative to a critical value of 15.3 ($df = 10, 9$), and in one case a Cochran's C of .070 was obtained, relative to a critical value of .059 ($df = 60, 9$). Given the relatively moderate levels of heterogeneity and evidence that the analysis of variance is robust to violations of this assumption (Boneau, 1960; Glass, Peckham, & Saunders, 1972; Ramsey, 1980), ANOVA's were undertaken on the transformed data in each case.

In every instance where simple effects tests were performed, the Satterthwaite method (Winer, 1971) was used to estimate the degrees of freedom for the denominator.

In every case but one, the analyses of variance reported here are two factor designs involving one between subjects factor consisting of the response elimination treatment conditions and one within subjects factor consisting of the various levels of sessions or time. Since subjects are considered an additional randomized factor nested within the between subjects factor (Cohen, 1981; Winer, 1971), these constitute mixed design multifactor

analyses. In each case the within subjects factor had either 5 or 15 levels, and the between subjects factor had either 3 or 4 levels. In one case, data was summed across several levels of the within subjects factor in order to create a simple one way between groups design.

Original Lever Analyses

Phase I--Training

Table 1 shows the means and standard deviations of original responses for each treatment group across the five days of the training phase, and Figure 1 depicts of the means for each group for this phase. In this case the Hartley's test was nonsignificant ($F_{\max}(20, 9) = 15.17, p > .01$).

Following the Hartley's test a 4x5 mixed design ANOVA was performed (see summary table presented in Appendix A). The analysis yielded a significant effect of sessions ($F(4, 144) = 38.66, p < .001$), no significant effect of treatments ($F(3, 36) = 1.25$), and no treatment by sessions interaction ($F(12, 144) = 1.39$). Figure 1 shows a general upward trend for all groups. While the means across groups differ by as much as 110 responses in session five, the large standard deviations in Table 1 illustrates why such a difference is nonsignificant. As a result, the equivalence of original training across in Phase I was established.

The effect sizes for this design were estimated by calculating Omega squared values for each effect. For the training phase the obtained values were .002 for treatment, .423 for sessions, and .013 for treatment x sessions interaction, indicating that, while the majority of variance in this analysis is due to error, the increase in response rate for all groups across sessions accounted for over 40% of the variance.

Table 1

Means and Standard Deviations of Total Original Lever Responses for Each Group Across the Five Sessions of the Original Training Phase

Group	Sessions				
	1	2	3	4	5
EXT					
Mean	221.20	219.80	227.20	261.90	296.50
S. D.	78.27	83.24	85.38	102.96	106.43
ALT-R1					
Mean	184.00	197.10	211.60	231.00	246.60
S.D.	41.14	53.40	58.81	63.90	51.04
ALT-R10					
Mean	200.50	207.90	229.30	250.30	294.40
S. D.	62.99	61.15	80.69	58.22	100.46
DRO					
Mean	221.20	246.40	287.10	317.10	356.60
S. D.	102.87	77.01	128.34	160.26	151.80

Figure 1. Graph of the mean total original lever responses per session for each treatment group across the five sessions of the Training phase.

Phase II--Treatment

Table 2 shows the means and standard deviations for total responses for each group for the five sessions of the treatment phase. In this case an $F_{\max}$ test revealed significant heterogeneity of variance ($F_{\max}(9, 20) = 1,193.59, p < .01$). As a result, a common log transformation was performed in order to equalize variances across cells (Winer, 1971). The means and standard deviations of the log transformed data are presented in Table 3. A test of homogeneity of variance on these data was nonsignificant ($F_{\max}(9, 20) = 16.23, p > .01$) therefore the following analyses were performed on the transformed data.

A 4x5 mixed design ANOVA was performed on the log transformed treatment phase data, and the summary table for this analysis is presented in Appendix B. The main effect for sessions was significant at the $p < .001$ level ($F(4, 144) = 10.98$), and this is reflected in Figure 2, where a plot of the transformed means shows a rapid decline across sessions for all groups. The treatments effect and sessions x treatments interaction effect were also significant at the $p < .01$ level ($F(3, 36) = 6.08$ and $F(12, 144) = 2.63$, respectively).

In order to determine the relative value of each

treatment at various points in time, simple effects tests were performed at each level of sessions. Simple effects tests for sessions 1 and 2 proved to be nonsignificant ($F(3, 152) = 0.33$ and $F(3, 152) = 2.23$, respectively). At session 3, the simple effects test was significant ($F(3, 152) = 2.80$, $p < .05$), and a Newman-Kuels follow-up test found all pairwise comparisons significantly different from one another except that DRO was not different from either ALT-R1 or ALT-R10. At session 4, the simple effects test was again significant ($F(3, 152) = 7.18$, $p < .01$), and the Newman-Kuels follow-up revealed all groups were significantly different except that DRO was still not different from ALT-R10. Finally, in the last session the simple effects test was again significant at the $p < .01$ level ($F(3, 152) = 7.05$) and follow-up tests revealed all comparisons were significantly different except that now EXT and ALT-R1 were not different.

The Omega squared values for the treatment phase were .025 for treatments, .604 for sessions, and .033 for treatments x sessions interaction. These figures suggest that the majority of the variance in this phase was due to the downward trend in log responses for all groups, and while the significant treatments and treatments x sessions effects are of major interest, they combine to account for only 5.8% of the variance.

Table 2

Means and Standard Deviations of Total Responses for
Each Group Across the Five Sessions of the
Treatment Phase

Group	Session				
	1	2	3	4	5
EXT					
Mean	175.40	76.80	39.20	29.60	27.60
S.D.	77.14	33.82	20.77	16.81	30.98
ALT-R1					
Mean	143.40	42.60	23.10	17.70	17.20
S.D.	44.11	40.37	13.86	10.08	13.06
ALT-R10					
Mean	194.70	57.50	17.00	10.60	9.70
S.D.	100.21	47.15	13.60	18.52	22.83
DRO					
Mean	247.10	100.10	17.80	12.50	6.60
S.D.	210.44	122.91	12.51	10.09	6.10

Table 3

Means and Standard Deviations for the Common
Log Transformed Total Responses for
Each Group Across the Five Sessions of the
Treatment Phase

Group	Session				
	1	2	3	4	5
EXT					
Mean	2.21	1.86	1.54	1.43	1.24
S.D.	0.20	0.18	0.27	0.23	0.48
ALT-R1					
Mean	2.14	1.50	1.30	1.21	1.17
S.D.	0.13	0.38	0.31	0.26	0.29
ALT-R10					
Mean	2.24	1.51	1.05	0.66	0.54
S.D.	0.21	0.62	0.54	0.62	0.59
DRO					
Mean	2.29	1.80	1.19	0.92	0.76
S.D.	0.31	0.43	0.27	0.54	0.36

Figure_2. Mean common log transformed total original lever responses per session for each group across the five sessions of the treatment phase.

Phase III--Extinction

The means and standard deviations for total responses for each group during the five sessions of the extinction phase are presented in Table 5. A Hartley's $F_{\max}$ test was performed on these data revealing significant heterogeneity of variance ($F_{\max}(9, 20) = 68.01, p < .01$). As a result, a common log transformation (Winer, 1971) was performed, and the resulting transformed response means and standard deviations are presented in Table 6. An $F_{\max}$ test of these data proved nonsignificant ($F_{\max}(9, 20) = 15.94, p > .01$); as a result, the following analyses were performed on the transformed data. The 4x5 mixed design ANOVA summary table for the log transformed responses in extinction is presented in Appendix C. Both main effects of treatments and sessions were significant at the $p < .001$ level ($F(3, 36) = 17.49$ and $F(4, 144) = 14.67$, respectively) and there was no significant sessions x treatments interaction ($F(12, 144) = 0.90$). This pattern is reflected in Figure 3, a graph of the means for each group across the five sessions of Phase III. The plot shows a general downward trend for all groups with a consistently lower rate of total log responses for the EXT group.

Simple effects tests were performed at all levels of sessions for the extinction phase. All five simple effects tests were significant at the $p < .01$ level ($F(3, 127) = 13.17$ at session 1; $F(3, 127) = 7.37$ at session 2; $F(3,$

127) = 7.76 at session 3; $F(3, 127) = 5.53$ at session 4; and $F(3, 127) = 9.12$ at session 5).

Newman-Kuels follow-up tests revealed a varying pattern of results across sessions. At session 1, DRO was not significantly different from ALT-R1, but all other pairwise comparisons were significant. At session 2, EXT was significantly different from all other groups ($p < .01$), but no other comparisons were significant. Finally, for sessions 3 through 5, DRO vs. ALT-R10 was nonsignificant with all other groups significantly different at $p < .05$. This pattern indicates that at all points EXT maintains a lower rate of log responses, and that for sessions 1 and 2 none of the reinforcement techniques is any more effective than any other. For sessions 3 through 5 ALT-R1 emerges as clearly less effective than the other two reinforcement-based response elimination techniques with ALT-R10 slightly more effective than DRO, based on the results of session 1.

The Omega squared values for this analysis were .187 for treatments, .207 for sessions, and .045 for the sessions $\times$ treatment effect. This indicates that the treatment effect, which was of greatest experimental interest, accounts for approximately 21% of the variance in this design.

Table 4

Means and Standard Deviations of Total Responses for
Each Group Across the Five Sessions of the
Extinction Phase

Group	Sessions				
	1	2	3	4	5
EXT					
Mean	10.20	10.70	11.30	8.20	4.20
S. D.	7.18	12.09	12.94	8.22	4.64
ALT-R1					
Mean	67.20	46.10	38.60	37.10	25.40
S. D.	36.59	36.06	19.48	23.90	17.12
ALT-R10					
Mean	44.90	40.50	30.90	24.90	23.00
S. D.	31.91	30.74	24.37	20.81	23.76
DRO					
Mean	56.40	39.50	25.00	15.20	14.30
S. D.	28.60	22.45	9.30	8.07	8.82

Table 5

Means and Standard Deviations of Common Log
Transformed Total Responses for each Group during the
Five Sessions of the Extinction Phase

Group	Sessions				
	1	2	3	4	5
EXT					
Mean	0.90	0.94	0.84	0.88	0.56
S.D.	0.45	0.31	0.54	0.25	0.40
ALT-R1					
Mean	1.77	1.57	1.54	1.50	1.32
S. D.	0.26	0.23	0.23	0.28	0.34
ALT-R10					
Mean	1.56	1.49	1.36	1.21	1.15
S.D.	0.34	0.37	0.40	0.51	0.48
DRO					
Mean	1.71	1.54	1.39	1.13	1.14
S. D.	0.21	0.25	0.14	0.33	0.21

Figure_3. Mean common log transformed total original lever responses per session for each group across the five sessions of the extinction phase.

Phase IV--Reacquisition

The means and standard deviations for the minute-by-minute totals for each group during the reacquisition phase are presented in Table 6. In this case, the $F_{\max}$ test of homogeneity of variance was significant ($F_{\max}(9, 60) = 117.51, p < .01$), and as in the previous cases, a common log transformation was performed yielding the new means and standard deviations presented in Table 7. Here the $F_{\max}$ was also significant ($F_{\max}(9, 20) = 23.9$).

The summary table of the mixed design ANOVA for the common log transformed data is presented in Appendix D. In this case the main effect for treatments was nonsignificant ($F(3, 36) = 1.25, p > .05$) and both the main effect for time and the treatments x time interaction effects were significant at the $p < .001$ level ($F(14, 504) = 42.20$ and $F(42, 504) = 2.95$, respectively).

A graph of the means of the common log transformed data for the reacquisition phase is presented in Figure 4. At minute 1, no significant differences between groups were found ($F(3, 86) = 2.16, p > .05$); however, at minutes 2, 3, and 4, significant differences were found at the $p < .01$ level ($F(3, 86) = 7.13$ at minute 2, $F(3, 86) = 7.30$ at minute 3, and $F(3, 86) = 5.52$ at minute 4). No other significant differences were found. The F value for minute 5 was 1.82 and for minute 6 was 1.66 ($df = 3, 86; p > .05$). Beyond minute 6 all F values were less than 1.00.

Newman-Kuels follow-up test were performed across treatments for minutes 2, 3, and 4. At minutes 2 and 3, all pairwise comparisons were found to be significant ($p < .01$ at minute 2 and $p < .05$ at minute 3). Finally, at minute 4, all group comparisons were significantly different from one another ($p < .01$ except for EXT vs. DRO ($p < .05$)).

Given the pattern of means shown in Figure 4, these results indicate that reacquisition proceeded very rapidly for all groups, but that in the first few minutes of the session some differences occurred between groups. The primary result was that subjects in both ALT-R1 and ALT-R10 groups were consistently quicker to reacquire the original lever response than subjects in either the DRO or EXT groups. A second and slightly less robust result was that, in two of the three minutes where significant differences were found, DRO showed a significantly higher rate of response than EXT.

In order to assess the practical significance of the effects found in Phase IV, Omega squared values were calculated for each effect. The nonsignificant treatments effect yielded a value of .01, and the time effect and time x treatments interaction were .41 and .08 respectively. This pattern of results indicates that, while the interaction effect found in minutes 2 through 4 was of considerable theoretical importance, it represents only 8% of the variance in this design.

Table 6

Means and Standard Deviations of Total Original Lever Responses per Minute for Each Group During the Fifteen Minutes of the Reacquisition Phase

Min.	Group							
	EXT		ALT-R1		ALT-R10		DRO	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	1.40	3.78	4.00	4.76	5.80	7.07	1.70	2.16
2	3.20	5.61	9.30	7.40	18.10	19.58	5.30	6.32
3	6.30	7.96	17.80	11.02	20.60	21.11	7.10	7.82
4	7.20	7.91	20.70	10.01	19.50	16.60	11.02	10.17
5	12.30	9.07	15.80	9.82	23.60	20.07	13.00	12.18
6	15.60	9.92	21.60	7.68	22.50	23.45	12.10	10.29
7	18.20	8.73	19.60	7.06	23.40	21.64	13.30	11.92
8	18.30	8.86	18.20	8.23	23.50	19.43	13.60	9.06
9	21.00	10.08	18.20	8.46	26.40	22.52	17.30	9.42
10	18.20	8.31	21.60	8.75	25.10	19.81	18.20	11.65
11	17.60	8.57	19.40	7.15	23.10	16.97	16.50	9.05
12	19.60	7.31	19.80	10.00	25.50	20.21	20.60	11.58
13	19.70	7.13	18.10	7.75	25.30	18.61	19.20	9.85
14	22.30	7.71	17.40	4.74	25.10	18.04	18.30	11.58
15	17.20	7.77	18.50	6.93	26.50	19.62	19.40	9.85

Table 7

Means and Standard Deviations of Common Log Transformed
Total Original Lever Responses per Minute for
Each Group During the Reacquisition Phase

Min.	Group							
	EXT		ALT-R1		ALT-R10		DRO	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	0.16	0.37	0.50	0.44	0.56	0.55	0.30	0.35
2	0.33	0.49	0.89	0.36	1.09	0.48	0.56	0.50
3	0.53	0.60	1.22	0.21	1.11	0.53	0.64	0.55
4	0.63	0.57	1.30	0.20	1.15	0.48	0.84	0.57
5	0.93	0.54	1.17	0.22	1.21	0.51	0.87	0.61
6	1.07	0.47	1.33	0.16	1.16	0.52	0.94	0.48
7	1.20	0.34	1.29	0.14	1.21	0.50	1.00	0.44
8	1.18	0.43	1.25	0.16	1.21	0.50	1.08	0.33
9	1.23	0.45	1.25	0.18	1.29	0.50	1.17	0.36
10	1.22	0.29	1.32	0.19	1.25	0.50	1.15	0.45
11	1.22	0.24	1.29	0.15	1.23	0.49	1.16	0.35
12	1.28	0.18	1.28	0.18	1.25	0.50	1.25	0.33
13	1.29	0.18	1.25	0.16	1.26	0.50	1.24	0.27
14	1.34	0.15	1.25	0.12	1.27	0.49	1.21	0.26
15	1.21	0.23	1.27	0.14	1.28	0.51	1.23	0.29

Figure 4. Mean common log transformed total original lever responses per min for each treatment group across the 15 mins of the reacquisition phase.

Savings Analysis

Since Leitenberg, et al. (1975) and Pacitti and Smith (1977) analyzed total original lever responses across both the treatment and extinction phases in order to determine whether any of the reinforcement-based procedures produced a significant "savings" in total responses emitted across these phases, a similar analysis was performed for the data collected in the present study. Table 8 shows the means and standard deviations for total original lever responses for each group across Phases II and III. A Hartley's test of homogeneity of variance proved nonsignificant ($F_{\max}(4, 9) = 7.04$) as did the analysis of variance for differences between groups ($F(3, 36) < 1.00$; see summary table, Appendix E) indicating no difference in total responses.

Table 8

Means and Standard Deviations for Total Original
Lever Responses for each Group Across Phases II and III

	Group			
	EXT	ALT-R1	ALT-R10	DRO
Mean	393.20	458.40	453.70	534.5
S.D.	135.27	125.78	121.48	322.35

Alternate Lever Analyses

While responses on the original lever was the dependent variable of major importance, an analysis of responses on the alternate lever was undertaken in order to gain a better understanding of the preceding results.

Phase I--Training

The means and standard deviations for alternate lever responses for each group across the five sessions of the training phase are presented in Table 9. The Hartley's test for these data was significant ($F_{\max}(20, 9) = 84.45$); however, after common log transformation a second test was no longer significant ($F_{\max}(20, 9) = 5.18$). The transformed means and standard deviations are presented in Table 10.

The mixed design analysis of variance for the common log transformed total alternate lever responses per session for each group across the five sessions of the training phase produced no significant effects. The F values for the treatments and sessions effects were less than one, and the F for the treatment x sessions interaction effect was 1.22 ($df = 12, 144$; $p > .05$). The summary table for this analysis is presented in Appendix F.

Table 9

Means and Standard Deviations for Total Alternate
Lever Responses for each Group Acrosss the Five
Sessions of the Training Phases

Group	Session				
	1	2	3	4	5
EXT					
Mean	7.10	10.10	5.90	6.40	4.30
S.D	11.44	14.52	8.56	9.82	7.20
ALT-R1					
Mean	2.60	2.30	3.00	2.40	3.80
S.D.	2.41	2.31	2.40	1.58	3.79
ALT-R10					
Mean	2.20	2.20	1.40	2.80	2.20
S.D.	3.58	2.86	1.58	2.82	3.68
DRO					
Mean	2.90	3.80	2.00	3.00	2.00
S.D.	4.04	8.43	3.74	6.48	3.40

Table 10

Means and Standard Deviations for Common Log
Transformed Alternate Lever Responses across the
Five Sessions of the Training Phase

Group	Session				
	1	2	3	4	5
EXT					
Mean	0.51	0.70	0.51	0.51	0.35
S.D.	0.60	0.57	0.56	0.58	0.57
ALT-R1					
Mean	0.44	0.44	0.51	0.47	0.52
S. D.	0.36	0.26	0.32	0.27	0.42
ALT-R10					
Mean	0.32	0.35	0.29	0.46	0.31
S.D.	0.40	0.39	0.31	0.34	0.40
DRO					
Mean	0.41	0.34	0.29	0.32	0.31
S. D.	0.41	0.49	0.38	0.44	0.38

Phase II--Treatment

The means and standard deviations for total alternate lever responses per session in the five sessions of the treatment phase for each of the four treatment groups is presented in Table 11. Once again the Hartley's test of homogeneity of variance was significant ($F_{\max}(20, 9) = 9,449.03$). A common log transformation of these data produced the means and standard deviations presented in Table 12. An $F_{\max}$ test of the transformed data was still significant ($F_{\max}(20, 9) = 94.25$).

The summary table for the mixed design analysis of variance of the common log transformed alternate lever responses during the treatment phase is presented in Appendix G. Both main effects and the interaction effect were significant beyond the $p < .001$ level ($F(3, 36) = 38.90$ for treatments, $F(4, 144) = 9.59$ for sessions, and $F(12, 144) = 8.00$ for sessions x treatments interaction). A graph of the mean rate of alternate lever responses for each group across the five sessions of Phase II is presented in Figure 5, which shows a rapid increase in log response rate for the ALT-R1 and ALT-R10 groups with relatively low, even rates of responding in the other two groups.

Simple effects tests conducted at all levels of sessions yielded significant differences at the $p < .01$ level ($F(3, 86) = 8.54$ at session 1; $F(3, 86) = 15.53$ at session 2; $F(3, 86) = 28.56$ at session 3; $F(3, 86) = 38.82$

at session 4; and $F(3, 86) = 44.43$ at session 5).

Newman-Kuels follow-up tests at each level of sessions revealed a changing pattern of differences among treatment groups. At session 1 and 2, all treatments were significantly different from each other ($p < .05$) except for the EXT vs. DRO comparisons. At session 3, all four groups were significantly different from each other at the $p < .05$ level. At sessions 4 and 5, ALT-R1 and ALT-R10 were no longer significantly different from one another, and at session 5 EXT and DRO were once again not significantly different. All other comparisons in the last two sessions were significantly different from one another ($p < .05$).

Finally Omega square values were calculated for the treatment, sessions, and treatment x sessions effects. The values obtained were .25 for treatments, .09 for sessions, and .21 for treatments x sessions. These results suggest that the largest part of the variance in this design can be attributed to the treatment and treatment x sessions effects, reflecting the increasing rate of log responses for the ALT-R1 and ALT-R10 groups.

Table 11

Means and Standard Deviations of Total Alternate
Lever Responses for each Group During the
Five Sessions of the Treatment Phase

Group	Sessions				
	1	2	3	4	5
EXT					
Mean	7.20	9.70	5.50	4.90	2.30
S. D.	9.69	7.73	6.17	6.40	2.21
ALT-R1					
Mean	69.60	180.50	212.20	238.10	263.20
S. D.	35.82	79.15	54.84	55.02	55.81
ALT-R10					
Mean	32.30	134.90	213.80	311.20	352.00
S. D.	35.08	172.65	180.46	215.20	205.95
DRO					
Mean	7.70	9.90	15.50	6.30	6.60
S. D.	8.56	16.09	27.24	7.65	7.06

Table 12

Means and Standard Deviations of Common Log
Transformed Total Alternate Lever Responses
During the Five Sessions of the Treatment Phase

Group	Sessions				
	1	2	3	4	5
EXT					
Mean	0.66	0.89	0.57	0.56	0.42
S.D.	0.50	0.40	0.52	0.47	0.33
ALT-R1					
Mean	1.71	2.16	2.31	2.37	2.41
S.D.	0.52	0.41	0.13	0.10	0.09
ALT-R10					
Mean	1.12	1.51	2.01	2.33	2.46
S.D.	0.75	0.93	0.77	0.53	0.32
DRO					
Mean	0.72	0.74	0.74	0.58	0.66
S.D.	0.47	0.53	0.70	0.56	0.50

Figure 5. A graph of mean common log transformed alternate lever responses for each group during the five sessions of the treatment phase.

Phase III--Extinction

The means and standard deviations for total alternate lever responses for each group across the five sessions of the extinction phase are presented in Table 13. Again a Hartley's test of homogeneity of variance was significant ($F_{\max}(20, 9) = 1,763.24$). A common log transformation of these data produced homogeneity ($F_{\max}(20, 9) = 11.54$), and the following analysis was performed on the transformed data. The means and standard deviations for total common log responses is presented in Table 14.

Figure 6 is a graph of the means for total log alternate lever responses for each group during the five sessions of the extinction phase. The analysis of variance summary table for these data is presented in Appendix H. The analysis reveals significant effects for treatments ($F(3, 36) = 68.21, p < .001$, sessions ($F(4, 144) = 24.11, p < .001$, and sessions $\times$ treatments ($F(12, 144) = 2.76, p < .01$).

All five simple effects tests across groups at each level of sessions revealed significant effects at the $p < .001$ level ($F(3, 125) = 55.11$ at session 1; $F(3, 125) = 38.19$ at session 2; $F(3, 125) = 34.24$ at session 3; $F(3, 125) = 21.68$ at session 4; and $F(3, 125) = 16.73$ at session 5).

Newman-Kuels follow-up tests produced a fairly consistent pattern of differences between groups. In

sessions 1 through 4, all pairs were significantly different from one another ($p < .05$) except the ALT-R1 vs. ALT-R10 comparison. By session 5, all pairs were significantly different from one another ($p < .05$). This result suggests that ALT-R1 and ALT-R10 maintained a consistently higher rate of log alternate lever responses than the other treatment groups and that the DRO group showed a consistently higher rate than the EXT group.

Finally, the effect sizes for this analysis were estimated by calculating the appropriate Omega squared values. They were: .391 for the treatments effect, .179 for the sessions effect, and .041 for the sessions x treatments interaction. This result indicates that the most important ingredient in this analysis was the group effect, which accounted for approximately 40% of the variance.

Table 13

Means and Standard Deviations for Total
Alternate Lever Responses for Each Group
During the Five Sessions of the
Extinction Phase

Group	Sessions				
	1	2	3	4	5
EXT					
Mean	2.30	2.70	2.40	2.60	2.20
S.D.	2.21	3.09	3.24	3.81	5.27
ALT-R1					
Mean	148.90	76.00	51.40	27.80	25.40
S.D.	62.10	30.83	18.02	15.59	20.06
ALT-R10					
Mean	156.80	82.00	75.50	34.10	14.70
S.D.	92.97	66.51	57.81	18.89	8.39
DRO					
Mean	18.30	11.40	13.10	6.90	5.70
S.D.	16.72	10.62	15.22	4.63	6.48

Table 14

Means and Standard Deviations of Common Log
Transformed Alternate Lever Responses for each
Group Across the Five Session of the
Extinction Phase

Group	Sessions				
	1	2	3	4	5
EXT					
Mean	0.42	0.41	0.35	0.35	0.25
S. D.	0.33	0.40	0.41	0.43	0.41
ALT-R1					
Mean	2.14	1.85	1.69	1.41	1.29
S. D.	0.19	0.20	0.16	0.21	0.36
ALT-R10					
Mean	2.13	1.81	1.75	1.46	1.14
S. D.	0.26	0.32	0.38	0.33	0.22
DRO					
Mean	1.05	0.90	0.93	0.77	0.67
S. D.	0.55	0.47	0.47	0.42	0.38

Figure 6. Mean log transformed total alternate lever responses per session for each group across the five sessions of the extinction phase.

Phase IV--Reacquisition

The means and standard deviations for total alternate lever responses per minute for each group across the 15 mins of the reacquisition phase are presented in Table 17. Because several cells had standard deviations of zero, the Hartley's $F_{\max}$ test was not an appropriate test of homogeneity of variance. As a result, a Cochran's test was performed on the data in Table 15, yielding a $C(60, 9)$ value of .200 which was significant. A common log transformation was performed on the alternate lever reacquisition data, and the means and standard deviations for the resulting data are presented in Table 16. A Cochran's test was performed on the transformed data and, in this case, produced a $C(60, 9)$ of .070, which is still significant. A graph of the mean common log transformed alternate lever responses per minute for Phase IV is presented in Figure 7.

The mixed design ANOVA summary table for the analysis of total log transformed alternate lever responses per minute is presented in Appendix I. Significant effects were obtained for treatments $F(3, 36) = 3.35, p < .05$, time ($F(14, 504) = 4.25, p < .001$), and time x treatments ($F(42, 504) = 2.68, p < .001$).

Simple effects tests were performed across groups at all levels of time, and where significant differences were found, Newman-Kuels follow-up tests were done to locate differences between means. Simple effects tests at minutes

1 and 2 produced F values of 14.01 ($df = 3, 275$; $p < .01$) and 7.70 ($df = 3, 275$; $p < .01$) respectively. Newman-Kuels tests revealed that, in both cases, all pairs of group means were significantly different from one another except for the DRO vs. ALT-R10 comparison for minute 1 and DRO vs. EXT for minute 2.

At minute 3, the simple effects test was not significant ($F(3, 275) = 1.90$, $p > .05$). However, minutes 4 through 8 were significant at the $p < .05$ level ($F(3, 275) = 3.96$ at minute 4, $F(3, 275) = 2.92$ at minute 5, $F(3, 275) = 3.20$ at minute 6, $F(3, 275) = 2.83$ at minute 7, and $F(3, 275) = 3.34$ at minute 8). At minutes 9 through 15, simple effects tests yielded no significant differences. For minute 9, $F(3, 275) = 1.46$ ($p > .05$), and for minutes 10 through 15, all F values were < 1.0 . A Newman-Kuels follow-up test at min 4 revealed that all group comparisons were significant ($p < .05$) except DRO vs. EXT and ALT-R1 vs. ALT-R10. For both minutes 5 and 6, ALT-R10 was significantly different from all other groups ($p < .05$), but no other comparisons were significant. At minute 7, all pairs were significantly different except DRO vs. EXT and ALT-R1 vs. EXT. Finally, at minute 8, all groups were significantly different from each other ($p < .05$) except DRO vs. EXT and ALT-R1 vs. ALT-R10.

Omega squared values were calculated to determine the effect size of the alternate lever analysis in the

reacquisition phase. The values were .010 for treatments, .063 for time, and .098 for time x treatments. In this case the interaction effect, which was of primary interest, represented approximately 10% of the total variance.

Table 15

Means and Standard Deviations of Total Alternate
Lever Responses for each Group Across the
Fifteen Minutes of the Reacquisition Phase

Min	Group							
	EXT		ALT-R1		ALT-R10		DRO	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	0.10	0.32	5.10	4.86	2.30	3.53	0.20	0.42
2	0.20	0.63	4.50	5.30	2.60	4.30	0.10	0.32
3	0.80	1.75	2.00	2.16	2.70	5.23	0.90	1.72
4	0.10	0.32	1.50	2.01	3.30	8.03	0.00	0.00
5	0.10	0.32	0.60	1.07	4.60	10.97	0.10	0.32
6	0.20	0.42	0.50	0.97	4.60	10.50	0.20	0.63
7	0.20	0.42	0.80	1.75	3.40	7.73	0.00	0.00
8	0.00	0.00	2.30	3.89	1.40	3.44	0.00	0.00
9	0.10	0.32	1.80	3.91	0.00	0.00	1.80	5.69
10	0.00	0.00	0.40	0.52	0.10	0.32	1.00	2.83
11	0.10	0.32	0.20	0.63	0.10	0.32	0.80	2.53
12	0.20	0.63	0.40	0.70	0.40	1.26	0.30	0.67
13	0.00	0.00	0.40	0.52	0.40	1.26	0.90	2.51
14	0.10	0.32	0.10	0.32	0.20	0.42	0.90	2.51
15	0.20	0.63	0.00	0.00	0.10	0.32	0.80	2.53

Table 16

Means and Standard Deviations of Common Log Transformed Total Alternate Lever Responses for each Group Across the Fifteen Minutes of the Reacquisition Phase

Min	Group							
	EXT		ALT-R1		ALT-R10		DRO	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	0.03	0.10	0.70	0.27	0.31	0.43	0.06	0.13
2	0.05	0.15	0.51	0.50	0.31	0.45	0.03	0.10
3	0.14	0.29	0.36	0.34	0.33	0.42	0.17	0.29
4	0.03	0.10	0.28	0.33	0.32	0.45	0.00	0.00
5	0.03	0.10	0.14	0.23	0.33	0.53	0.00	0.10
6	0.06	0.13	0.12	0.21	0.36	0.53	0.05	0.15
7	0.06	0.13	0.14	0.29	0.32	0.48	0.00	0.00
8	0.00	0.00	0.31	0.42	0.18	0.36	0.00	0.00
9	0.03	0.10	0.12	0.40	0.03	0.00	0.13	0.40
10	0.03	0.00	0.05	0.16	0.03	0.10	0.10	0.32
11	0.03	0.10	0.05	0.16	0.03	0.10	0.10	0.32
12	0.05	0.15	0.11	0.18	0.07	0.22	0.08	0.17
13	0.00	0.00	0.12	0.16	0.07	0.22	0.12	0.31
14	0.03	0.10	0.03	0.10	0.06	0.13	0.12	0.31
15	0.05	0.15	0.00	0.00	0.03	0.10	0.10	0.30

Figure 7. Mean common log transformed total alternate lever responses per minute for each group across the fifteen minutes of the reacquisition phase.

Reinforcement Rate Analyses

In order to assess the contribution of the amount of obtained reinforcement to the effectiveness of each reinforcement-based procedure, an analysis of total reinforcements per session was undertaken for Phases I and II, as well as reinforcements per minute in Phase IV.

Phase I--Training

Table 17 shows the means and standard deviations for total reinforcements per session for each treatment group across the five sessions of the training phase. A Hartley's test of homogeneity of variance yielded a value of $F_{\max}(20, 9) = 13.43$, which was nonsignificant. The analysis of variance for these data produced nonsignificant effects for treatments and sessions $\times$ treatments interaction (both F values < 1.0) and a significant effect for sessions ($F(4, 144) = 40.83, p < .001$). The summary table for this analysis is presented in Appendix J. This result established that, like the previous two dependent variables, no significant differences in rate of reinforcement were observed across groups at any point in Phase I.

An Omega square value was calculated for the single significant effect, yielding .37 for sessions.

Table 17

Means and Standard Deviations for Total Reinforcements
For each Group Across the Five Sessions of the
Training Phase

Group	Session				
	1	2	3	4	5
EXT					
Mean	69.30	72.90	74.80	77.10	80.90
S.D.	8.30	11.36	8.60	8.77	6.33
ALT-R1					
Mean	68.70	71.90	74.20	77.10	80.30
S.D.	4.37	7.00	5.33	3.72	4.24
ALT-B10					
Mean	69.80	73.00	75.80	78.40	80.50
S.D.	11.52	5.81	3.42	3.13	5.46
DRO					
Mean	68.60	74.10	76.30	79.30	81.70
S.D.	10.00	7.64	10.36	6.38	4.47

Phase II--Treatment

The means and standard deviations for total reinforcements per session for the ALT-R1, ALT-R10, and DRO groups are presented in Table 21. A Hartley's test of homogeneity of variance for these data was significant ($F_{\max}(15, 9) = 81.69, p < .01$). An arcsin transformation was performed on these data (after dividing each value by 90, the total possible reinforcements per session, to produce proportions), and the transformed values are presented in Table 19. The $F_{\max}$ for these data was 30.16 ($df = 15, 9$), which was still significant at the $p < .01$ level.

Appendix K shows the summary table for the 3 x 5 mixed design analysis of variance of arcsin transformed reinforcement rate during the five sessions of the treatment phase for the three reinforcement-based procedures. The effects for treatments and sessions were both significant ($F(2, 27) = 7.68$ for treatments ($p < .01$) and $F(4, 108) = 97.15$ for sessions ($p < .001$), but there was no significant sessions x treatments interaction ($F(8, 108) = 1.08, p > .05$).

The results of the analysis of variance are confirmed

by Figure 8, a plot of the mean arcsin transformed rate of reinforcement for the three reinforcement-based response elimination procedures across the five sessions of Phase III. The general trend for all groups is upward with an apparently lower rate for the ALT-R10 group across all levels of sessions.

Simple effects tests were performed across groups at each level of sessions in order to determine whether the apparent differences in Figure 8 were significant. At sessions 1 through 3, these tests were significant at the $p < .01$ level ($F(2, 111) = 9.30$ at session 1; $F(2, 111) = 7.12$ at session 2; and $F(2, 111) = 8.71$ at session 3). At session 4, there were significant differences at the $p < .05$ level ($F(2, 111) = 3.42$), and no significant differences were found at session 5 ($F(2, 111) = 2.31$).

Newman-Kuels follow-up tests indicated that at session 1 all groups were significantly different from one another ($p < .05$) and that the same was true at sessions 3 ($p < .01$) and 4 ($p < .01$). However, at session 2, DRO was not significantly different from ALT-R1. This pattern of results indicates a consistently lower rate of reinforcement for ALT-R10 than for either DRO or ALT-R1 (through session four). In addition, for three of the five sessions, DRO obtained a significantly higher rate of reinforcement than ALT-R1. By session 5 all groups obtained equivalent rates of reinforcement.

The Omega squared values for this analysis were .024 for treatments, .701 for sessions, and .001 for sessions x treatments. These results indicated that, while the significant treatment effect was of primary interest, it represented only 2% of the variance in this analysis.

Table 18

Means and Standard Deviations of Total Reinforcements
Per Session for the Three Reinforcement-based
Response Elimination Procedures Across the Five
Sessions of the Treatment Phase

Group	Session				
	1	2	3	4	5
ALT-R 1					
Mean	29.50	60.70	71.30	77.20	79.10
S.D	12.08	18.87	10.77	3.64	4.35
ALT-R 10					
Mean	8.20	30.80	48.60	63.80	69.90
S.D.	11.41	32.90	30.01	24.82	20.93
DRO					
Mean	38.00	60.90	78.80	81.10	82.00
S.D	16.36	20.75	7.70	7.22	7.76

Table 19

Means and Standard Deviations of Arcsin
Transformed Total Reinforcements per Session
For the Three Reinforcement-based Response
Elimination Procedures Across the Five
Sessions of the Treatment Phase

Group	Session				
	1	2	3	4	5
ALT-R1					
Mean	0.34	0.76	0.93	1.04	1.08
S.D.	0.14	0.25	0.17	0.08	0.10
ALT-R10					
Mean	0.09	0.39	0.62	0.85	0.96
S.D.	0.13	0.42	0.40	0.37	0.36
DRO					
Mean	0.44	0.78	1.10	1.16	1.21
S.D.	0.20	0.31	0.22	0.18	0.27

Figure 8. Mean arcsin transformed total reinforcements per session for each of the three reinforcement-based response elimination procedures across the five sessions of the treatment phase.

Phase IV--Reacquisition

Table 20 shows the means and standard deviations for reinforcements per minute for all groups across the 15 min of the reacquisition phase. The Hartley's test of homogeneity of variance for these data was again significant ($F_{\max}(60, 9) = 35.66, p < .01$). An arcsin transformation was performed on these data (after dividing each value by 6, the total possible reinforcements per min, to create proportions), and the resulting means and standard deviations are presented in Table 21. The $F_{\max}$ value for these data was 15.90 ($df = 60, 9$), which was nonsignificant.

The mixed design analysis of variance summary table for arcsin transformed reinforcements per min for each group across the 15 mins of Phase IV is presented in Appendix L. The treatment effect was nonsignificant ($F(3, 36) = 1.02$), but both the time and time x sessions effects were significant at the $p < .001$ level ($F(14, 504) = 29.36$ and $F(42, 504) = 1.95$, respectively).

Simple effects tests were performed at each level of time in order to determine whether there were any significant differences in rate of reinforcement across groups. At minute 1, there were no significant differences ($F(3, 514) < 1.00$), but at minutes 2 through 4, the F values were significant at the $p < .01$ level, and at minute 4, there were significant differences at the $p < .05$ level ($F(3, 514) = 8.70$ at minute 2; $F(3, 514) = 4.04$ at minute

3; $F(3, 514) = 3.00$ at minute 4). From minutes 4 through 15, there were no other significant differences. At minutes 5 and 6, the F values were 1.89 and 1.98 respectively ($df = 3, 514$; $p > .05$). From minutes 7 through 15, the F values were less than one, except that at both minutes 12 and 14 a value of 1.07 was obtained ($df = 3, 514$; $p > .05$).

Newman-Kuels follow-up tests performed across groups at minutes 2 through 4 revealed a fairly consistent pattern of means. At minute 2, all groups were significantly different at the $p < .01$ level, except that the ALT-R1 vs. ALT-R10 comparison was significant at the $p < .05$ level. At both minutes 3 and 4, all groups were significantly different from one another at the $p < .01$, except that neither the EXT vs. DRO or the ALT-R1 vs. ALT-R10 comparisons were significant.

The Omega squared values for this analysis were .000 for treatments, .383 for time, and .033 for time x treatments. As in previous reacquisition phase analyses, these results indicated that the interaction effect, which was of primary experimental interest, represented only 3.8% of the variance.

Table 20

Means and Standard Deviations for Total Reinforcements
Per Session for Each Group Across the Fifteen Minutes
Of the Reacquisition Phase

Min.	Group							
	EXT		ALT-R1		ALT-R10		DRO	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	0.70	1.64	2.00	1.82	1.90	1.97	1.00	1.15
2	1.10	1.66	3.60	1.90	4.30	1.77	2.00	2.16
3	2.10	2.51	4.70	0.95	4.20	1.81	2.40	2.06
4	2.60	2.46	5.00	0.47	4.50	1.71	3.20	2.25
5	3.70	2.11	5.10	0.74	4.50	1.78	3.40	2.41
6	4.40	2.01	5.30	0.48	4.80	1.81	3.80	1.81
7	4.80	1.55	5.10	0.57	4.60	1.78	4.50	1.78
8	4.70	1.89	5.10	0.74	4.60	1.78	4.50	1.27
9	5.00	1.82	4.70	0.67	4.90	1.79	4.90	1.66
10	5.00	1.49	5.40	0.84	4.80	1.81	4.90	1.79
11	5.20	1.03	5.30	0.67	5.00	1.82	4.70	1.42
12	5.50	0.71	5.30	0.48	4.60	1.71	5.00	1.15
13	5.20	0.79	5.60	0.52	5.00	1.88	5.20	1.23
14	5.80	0.42	5.20	0.92	5.10	1.85	5.10	0.99
15	5.00	0.94	5.40	0.52	4.80	1.75	4.90	0.88

Table 21

Means and Standard Deviations for Arcsin
Transformed Total Reinforcements per Minute for each
Group Across the Fifteen Minutes of the
Reacquisition Phase

Min	Group							
	EXT		ALT-R1		ALT-R10		DRO	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	0.13	0.32	0.36	0.35	0.35	0.37	0.17	0.20
2	0.20	0.30	0.76	0.52	0.91	0.46	0.41	0.51
3	0.47	0.63	0.98	0.35	0.86	0.42	0.45	0.40
4	0.54	0.56	1.02	0.21	0.95	0.44	0.65	0.51
5	0.75	0.48	1.11	0.33	0.98	0.49	0.73	0.59
6	1.00	0.57	1.16	0.28	1.09	0.50	0.73	0.37
7	1.09	0.48	1.08	0.27	1.01	0.48	0.96	0.45
8	1.07	0.52	1.11	0.33	1.01	0.48	0.88	0.26
9	1.18	0.51	0.91	0.16	1.12	0.49	1.15	0.51
10	1.14	0.45	1.28	0.38	1.09	0.50	1.12	0.49
11	1.21	0.41	1.19	0.33	1.18	0.51	0.99	0.40
12	1.31	0.34	1.16	0.28	0.98	0.44	1.10	0.38
13	1.17	0.36	1.34	0.30	1.21	0.54	1.21	0.42
14	1.45	0.25	1.17	0.37	1.24	0.52	1.15	0.39
15	1.09	0.36	1.22	0.30	1.06	0.46	1.03	0.32

Figure 9. Mean arcsin transformed reinforcements per minute for each group across the 15 mins of the reacquisition phase.

Response Pattern Analysis

The cumulative records presented in this section were selected on the basis of two criteria: 1) the representativeness of the curves of these records relative to others under the same experimental conditions and 2) the number of original lever responses shown. In each case the total original responses for each cumulative record shown in this section is less than .5 standard deviations from the mean of the cell from which it is drawn.

Records a. and b. in Figure 10 show typical response patterns at the end of Phase I. The upper line represents cumulative original lever responses over time, and should be interpreted by its relative slope. A steeper slope represents a higher rate of responding, while a shallower slope represents a lower rate. Each downward slash of this line indicates the delivery of a reinforcement. The lower line is an event record of responses on the alternate lever. Records a. and b. show a steady, moderate rate of responding on the original lever and little or no responding on the alternate lever. The records show little of the scalloping effect characteristic of fixed-interval schedules, perhaps due to the very brief 10-sec interval and the fact that by this point optimal performance had not been reached, as indicated by the increasing means for original lever responses in Table 1.

Records c. through f. show curves produced on the first session of each treatment condition. Record c. shows the EXT condition and a typical extinction curve (Skinner, 1938) with a relatively high rate of unreinforced responding early in the session, gradually tapering off to a much lower rate near the end of the session.

Record d. shows the initial session of an ALT-R1 subject. Early in the session the curve is very similar to the extinction curve in c., but after approximately five minutes of the session had passed, an alternate lever response is made and reinforced and responding soon switches to that manipulanda (as indicated by the increasing density of slash marks on the lower line). This switch to the alternate lever produces a flatter top to the original lever curve than the extinction curve in c.

Record e. in Figure 11 shows the initial treatment session of an ALT-R10 subject. It appears very similar to the ALT-R1 subject of d., except that the switch to the alternate lever occurs later in the session. This was a fairly typical effect of the 10-sec COD. As can be seen in e., the first two responses on the alternate lever went unreinforced because the 10-sec changeover requirement had not been met. This is in contrast to d., where the initial alternate lever responses were reinforced.

Record f. shows the initial Phase II session of a DRO subject. Here there was little increase in alternate lever

responses (as reflected by the few slashes on the lower line), but as the subject paused during runs of responses on the original lever, the 10 sec response-reinforcement interval was met and reinforcement was delivered (shown by slash marks on the upper line). Since the DRO contingency required a lack of responding on the original lever to obtain reinforcement, slashes on the upper line only occur after flat spaces of no responding.

Records g. through h. show response patterns for subjects in the last session of Phase II. Here each treatment condition has been in effect for five sessions, and the cumulative records show very low levels of original lever responses. In g. the EXT subject shows the shallow curve typical of the later stages of extinction (Skinner, 1938). Records h. and i. (ALT-R1 and ALT-R10 respectively) show relatively high, steady rates of responding on the alternate lever, and a regular rate of reinforcement. Both show very low rates of original lever responses with slightly fewer responses for the ALT-R10 subject. Finally, in j. a typical DRO subject shows very low levels of both original and alternate lever responses and a steady pattern of reinforcement. Here, too, the rate of original lever responses is less than in either the EXT or ALT-R1 subjects.

Figure 12 shows typical cumulative records for each group during the first session of the extinction condition,

Phase III. Record k. shows an EXT subject continuing to extinguish to lower levels of original lever responses. In l. through n., the subjects from the three reinforcement-based procedures responded for the first time under conditions in which no reinforcement was available at all, and in each case the rates of original lever responses were much higher than at the end of the treatment phase (see Figure 11, g. through j.). Both the ALT-R1 (l.) and ALT-R10 (m.) subjects showed high rates of alternate lever responding, but in this case the pattern is less consistent, reflecting much shifting back and forth between the two levers. In the ALT-R10 subject, changeovers between levers appear to have been less frequent, but in both cases runs of responding on the alternate lever were often followed by bursts on the original lever. The DRO subject shows a fairly typical, though more shallow extinction curve with a few bursts on the alternative lever. As in the previous two cumulative records, there is a significant rebound in original lever responding compared to levels produced at the end of Phase II (see Figure 11, record i.).

Figure 13 shows representative cumulative records for subjects from each treatment group during the reacquisition session, Phase IV. In this case, records were selected on the basis of their closeness to mean rates of original lever responding in minute 3 of Phase IV, since this was the first minute in which significant differences between groups were

found. The curves are remarkable in that, with the possible exception of record r., no more than two responses were required before very steady rates of original lever responding were regained at levels almost identical to those seen at the end of the training phase (see Figure 10, records a. and b.). This pattern is consistent with the immediate reconditioning after extinction reported by Skinner (1938). In the ALT-R1 (p.) and ALT-R10 (q.) subjects, reacquisition occurred after a single response. For the EXT subject, reacquisition was complete after the second response, but in this case the first response was not made until over a minute into the session, and then the second response occurred approximately a minute after the first. This pattern suggests that the statistically significant lower levels of responding in the EXT group during the early minutes of Phase IV reflect the very low levels of responding produced by this group after 10 sessions of extinction. As shown in the statistical analysis of Phase III, all three of the reinforcement-based procedures showed significantly higher rates of original lever responses at the end of the extinction phase. Finally, record r. (DRO) is of particular interest because it shows a more gradual rate of reacquisition. Original lever responses were made at the beginning of the session, but in this case the rate of response showed a slightly more gradual reacquisition, as characterized by a steepening

curve at the beginning of the session. Unlike the other three subjects whose former rates were regained almost immediately, record r. seems to reflect a slight resistance to reacquisition in the early minutes of the session.

Figure 10. Cumulative records of subjects in Phases I and II. Records a. and b. show typical subjects during the final session of the training phase. Record c. shows an EXT subject during the first session of the treatment phase, and record d. is of an ALT-R1 subject also in the first session of the treatment phase.

Figure 11. Records e. and f. show ALT-R10 and DRO subjects, respectively, during the first session of Phase II. Records g. through j. are example cumulative records of subjects from each of the treatment groups during the last session of the treatment phase. Record g. is an EXT subject, record h. is an ALT-R1 subject, record i. is an ALT-R10 subject, and record j. is a DRO subject.

Figure 12. Representative cumulative records of subjects from each treatment group during the first session of the extinction phase. Record k. is an EXT subject, record l. is an ALT-R1 subject, record m. is an ALT-R10 subject, and record n. is a DRO subject.

k

l

m

n

Figure 13. Representative cumulative records of subjects from each treatment group during the reacquisition phase. Record o. is an EXT subject, record p. is an ALT-R1 subject, record q. is an ALT-R10 subject, and record r. is a DRO subject.

Discussion

This research has produced a number of noteworthy results. One of the most interesting of these is the effectiveness of the ALT-R10 procedure in Phase II. DRO controlled a consistently low rate of responding in the last three sessions of this condition, but in sessions three and four ALT-R10 was equally effective and in session five was even more effective. It is surprising that ALT-R1 produced consistently higher rates of responding in light of previous research showing a quicker initial treatment effect for ALT-R1 than for DRO (Mulick & Leitenberg, 1978; Mulick, et al., 1976). The DRO and ALT-R10 groups were the two reinforcement-based groups for which a specific contingency was programmed for responses on the original lever (other than the brief 1 sec COD for ALT-R1), and the results of Phase II suggest that this aspect of these contingencies had an important effect. Particularly striking is the comparison between ALT-R1 and ALT-R10. These two procedures were exactly the same, except that the COD for the ALT-R10 group was extended to 10 sec, providing a longer penalty (in the form of an interruption in the schedule of reinforcement on the alternate lever) for responses on the original lever. Nevertheless, as Figure 2 shows, this relatively subtle

difference in the contingencies produced a reliably lower rate of responding for ALT-R10 at sessions three through five. That this additional penalty had a bearing on the results for this phase is confirmed by the reinforcement rate analysis, which indicated a lower rate of reinforcement for ALT-R10 across all levels of sessions (see Figure 8).

The analysis of rebound effects during Phase III follows very closely the effects of Phase II. First, a significant rebound was shown for all reinforcement-based procedures, and this effect was reflected in rates of original lever responding which were much greater than the EXT group at all levels of sessions. This result is consistent with the majority of previous studies (e.g. Leitenberg, et al., 1975; Pacitti & Smith, 1977) except that in this case the rebound was maintained across more sessions, possibly due to the fixed-interval training schedule in combination with a relatively short (15 min.) session length in this research. Of greater experimental interest is the superiority of ALT-R10 and DRO over ALT-R1. Here, as in Phase II, the two reinforcement-based procedures involving a penalty for original lever responses controlled lower rates of responding than ALT-R1 in sessions three through five. There was no significant difference between these two procedures except that in the initial session of the extinction phase ALT-R10 produced fewer original lever responses than either ALT-R1 or DRO. As in the previous

phase this result confirms the greater response elimination effect of ALT-R10 and DRO, and suggests that, at least under treatment and extinction conditions, the ALT-R10 procedure is slightly more effective than DRO. (This conclusion is based on the results of Phase II session five and Phase III session one.)

The results in Phase IV were somewhat different from previous conditions. In the reacquisition phase, differences between groups were transitory, appearing only in minutes 2, 3, and 4, but for this brief period the superiority of the DRO procedure was clearly demonstrated. Subjects in the EXT group, as discussed in the response pattern analysis, had reached a very low rate of responding by the end of Phase III (a mean of 4.20 responses per session by session 5) and reacquired the original lever response slower than subjects in any other group. Nevertheless, DRO subjects showed a consistently lower rate of responding than subjects under either of the other reinforcement-based procedures in minutes 2 through 4. This result is consistent with Pacitti and Smith (1977) who found DRO subjects more resistant to reacquisition than those under two counter conditioning procedures similar to the present ALT-R1.

The number of original lever responses for ALT-R1 and ALT-R10 were significantly different in minutes 2 through 4, but because ALT-R10 showed a higher rate at minute 2 and

ALT-R1 showed higher rates at minutes 3 and 4, no consistent difference between the two was produced. Nevertheless, the alternate lever analysis for this phase suggests an explanation for this pattern of results. As Figure 7 indicates, the ALT-R1 group began Phase IV with a high rate of alternate lever responses which showed a steady and rapid decline through minute 5. In contrast, ALT-R10 began the session with a relatively low rate of alternate lever responses which showed a gradual increase to a peak at minute 5 and 6 before decreasing again through minute 9. While ALT-R1 and ALT-R10 showed no significant differences in rate of alternate lever responses at minutes 3 and 4, ALT-R1 did show a significantly higher rate at minute 2, the point at which that group showed a lower rate of original lever responses than ALT-R10.

The relatively late burst of alternate lever responding in the ALT-R10 group produces another important difference between this response elimination procedure and any of the others examined in this study. While the original lever analysis in Phase IV produced no significant differences beyond minute 4, at minutes 5 through 7, ALT-R10 controlled a significantly higher rate of alternate lever responding than any other group. As a result, this group produced more lever responses in general (including both original and alternate lever responses) than any other group during the period of minutes 2 through 7. Once again the relatively

subtle difference between ALT-R1 and ALT-R10 (a 10 sec COD) has produced a surprisingly dramatic difference in effects.

This collection of results suggests a number of conclusions. Perhaps the most important is the superiority of DRO as a response elimination procedure. It produced rates of responding almost as low as any other response elimination procedure during Phases II and III and showed slower reacquisition in Phase IV. This resistance to reacquisition is of particular interest because it reveals a functional difference between DRO and DRI (DRI here is used in either its more common sense (Woods, 1982, similar to the present ALT-R1) or in the sense of Tarpley & Schroeder (1979) which is similar, though not exactly comparable, to the present ALT-R10). Woods (1982) has suggested that there is no difference between the two contingencies, arguing that research in superstitious and schedule-induced behavior indicates that specific incompatible responses are conditioned in DRO. However the equivalence of these two contingencies is an empirical question, and the results of Phase IV show a clear point of separation. While the ALT-R10 and DRO groups were nearly equivalent through the treatment and extinction conditions, the DRO group showed significantly slower reacquisition.

A possible explanation for this slower reacquisition is the essential difference between this contingency and the others examined here. The only requirement for

reinforcement under the DRO condition was the nonoccurrence of an original lever response for a 10 sec period. All other behavior was reinforced. While superstitious and schedule induced responses might be expected to develop, random variations in these responses, which would also be reinforced (provided they did not involve original lever responses), make this contingency different from DRI (ALT-R1 and ALT-R10). A number of responses are reinforced, while only one is not. In the FI training condition and in both the ALT-R1 and ALT-R10 treatment conditions only specific responses were reinforced. While other research has shown that the topography of the response has little bearing on ALT-R's effectiveness (Leitenberg et al., 1975; Pacitti & Smith, 1977), the present study and others (Pacitti & Smith, 1977) suggest that the single response (ALT-R) vs. any response but a single response (DRO) distinction between these contingencies can have an important impact.

A second major finding of this research is that, as in previous studies (Leitenberg, et al., 1975), none of the reinforcement-based procedures resulted in a "savings" of total original lever responses when both treatment and extinction phases were combined. This result is consistent with the Estes (1944) theory of punishment; however, as discussed above, this theory is no longer widely accepted (Azrin & Holz, 1966). Furthermore, the results of the "savings" analysis appear to depend upon a number of

conditions, such as session length and the number of sessions run in both the treatment and extinction phases. In the present study, no attempt was made to extend either Phase II or III until subjects in any or all groups were completely extinguished.

Finally, the finding of greatest experimental interest was the effect of the lengthened COD on the performance of the ALT-R10 group. While Catania (1966) showed the dramatic effects the addition of a COD can have on concurrent schedules, the present study established that this effect can be maintained after the schedule has been switched from conc FI 10-sec EXT to conc EXT EXT. This was reflected in the data for the ALT-R10 group, where the additional requirement of a 10 sec period free of original responses had an important effect in Phases II and III.

A Few Words About Terminology

The present study has maintained the use of the term alternate reinforcement (ALT-R1 and ALT-R10) because it is firmly connected with this line of response elimination research. However, in the interest of accuracy, a more general description of the various contingencies might have been more useful. Translation into the more widely used language is easily accomplished.

In the case of the EXT group, the terminology is straightforward. For purposes of experimental interest,

responses on both manipulanda were measured, but the lack of any reinforcement history on the alternate lever exposes the EXT group to a simple FI 10-sec schedule in Phases I and IV and an extinction schedule in Phases II and III.

While it might be argued that DRO is a concurrent schedule in which the second response is reinforced but not measured, this research and current usage would present it as a single operant contingency. As a result the DRO group was exposed to FI 10-sec in Phases I and IV, DRO 10-sec in Phase II, and extinction in Phase III.

The addition of an FI 10-sec schedule of reinforcement on the alternate lever for the ALT-R1 and ALT-R10 groups makes these concurrent schedules from Phase II through Phase IV. The groups were exposed to a simple FI 10-sec schedule in Phase I, a conc FI 10-sec EXT schedule in Phase II, a conc EXT EXT schedule in Phase III, and a conc EXT FI 10-sec schedule in Phase IV. The essential difference between the two schedules is the length of the COD.

Alternate Reinforcement and the Matching Law

The plethora of current research on, or influenced by, the matching law (Herrnstein, 1961) all but obligates the discussion of its relation to any study involving concurrent operants. In his initial investigation, Herrnstein (1961) found that the number of responses a subject makes on one of two concurrent schedules can be accurately predicted from

the number of responses made on the other schedule and the relative rate of reinforcement available on each schedule. The specific mathematical formulation is:

$$\frac{R1}{R1 + R2} = \frac{r1}{r1 + r2}$$

Here R1 and R2 represent the frequency of response on each schedule and r1 and r2 represent the rate of reinforcement on each schedule. It has also been shown (de Villiers, 1977) that the amount of time spent responding on each schedule can be predicted by this formula and that the relative delay of reinforcement or amount of reinforcement can be used as predictors. A wide variety of factors can affect the accuracy of this formula (producing "undermatching" or "overmatching"), but under a number of conditions it produces accurate predictions (de Villiers, 1977).

However, the matching law applies only to concurrent schedules which have been brought to optimal, steady-state performance and has fostered a "molar" approach to behavior, which is concerned with the mathematical description of steady-state behavior (Catania, 1979). This new perspective has been lamented by those who promote a more "molecular" analysis of patterns of responding, both early and late in the conditioning process (Michael, 1979; Skinner, 1976).

The present study is in the molecular tradition. In

its simplest form, the matching law would make no differential prediction of relative response rates for either the ALT-R1 or ALT-R10 groups. While the length of COD has been identified as an important determinant of the accuracy of predictions based on the matching law (de Villiers, 1977), the applied goals of this study demanded a more molecular examination. Response elimination procedures similar to those studied in this research are often applied to human behaviors which have serious personal and social consequences (e.g. self-injurious or aggressive behavior in mentally retarded clients). Given this type of application, research in response elimination should be concerned with rates of response at all stages in the conditioning process. As a result, a session-by-session and moment-by-moment analysis was appropriate for the current research.

Some Applied Implications of this Research

There are two major results of this study which may have significance for applied psychology. First, the effectiveness of DRO as a response elimination procedure was demonstrated in Phases II and IV. Particularly noteworthy was the DRO group's slower reacquisition of the original response in Phase IV. These results suggest that DRO should be an effective response elimination procedure for applied use. Interestingly, while DRO is widely used, the majority of applied research studies examining this contingency have

employed it in combination with with other procedures, such as time out (Woods, 1983). This suggests that DRO's effectiveness in animal studies may be due, in part, to peculiarities of the laboratory which are not characteristic of applied settings. In addition, Lindsley (personal communication, November 7, 1983) has argued against applications of DRO on the grounds that it does not develop new behavior. He suggests that behavior analysts apply the "dead man test," which holds that, if a dead man could receive reinforcement under the designed contingency, then it cannot be reinforcing new behavior. While Lindsley's objection to DRO appears to be based primarily on professional and ethical concerns for the careful choice of applied interventions, it is a view shared by many applied psychologists (Deitz & Repp, 1983).

The second finding of importance for the clinical use of response elimination procedures was the effectiveness of the ALT-R10 procedure in Phase II. Its superiority to DRO in session five and to ALT-R1 in sessions three through five have valuable implications for the application of DRI procedures. This research suggests that response elimination procedures which combine reinforcement of an incompatible response with a response-reinforcement interval (like DRO) may prove to be equal to or more effective than DRI or DRO alone. Such a procedure would be similar to, though not exactly comparable with, the DRI procedure used

by Schroeder and Tarpley (1979). Finally, while ALT-R10 showed more rapid reacquisition than DRO in Phase IV, it may be more palatable for clinicians since it allows for the choice of incompatible behaviors which have educational or adaptive value.

Limits to the Applied Implications of this Research

While the stated goals of this research included the hope that it would add to a body of knowledge which might lead to more effective treatment of behavioral excesses in human beings, there are a number of issues which limit its applied significance.

First and perhaps most obviously, this is animal research which cannot be easily applied to humans. Research on fixed interval responding in humans (Poppen, 1982) has indicated that, while these schedules show a consistent scalloped pattern in a wide variety of animal species, human subjects with well developed verbal repertoires rarely show the familiar scalloped pattern. As a result, the contingencies studied here may have more relevance for the severely and profoundly mentally retarded and other non-verbal populations than for verbal subjects.

A second limitation is created by differences between response elimination reinforcement contingencies as they have been studied here and as they are likely to be encountered in applied settings. In this study the original

response was trained under an FI 10-sec schedule in Phase I and was switched to EXT in the treatment and extinction phases. This is a hypothetical and questionably valid course of contingencies in natural settings. In many cases the contingencies of reinforcement which support an undesirable behavior are unknown to the clinician. In addition, even if the majority of reinforcement for a response is eliminated through differential reinforcement procedures, the multiple sources of reinforcement in natural settings make it probable that reinforcement will still be available for the target response on some unknown schedule.

If we abbreviate the unknown contingencies of reinforcement as UC1 (during original training, or pre-treatment) and UC2 (during treatment) a more accurate scheme of the applied contingencies can be described. (Note: in some situations UC1 might equal UC2, but advances in behavior analysis make it likely that they will not.) The majority of applied behavioral treatments involve both procedures for obtaining reinforcement for incompatible behavior and efforts aimed at the limiting of reinforcement obtained through the undesired response. Under this arrangement Phase I for all treatment conditions would be a simple UC1 schedule. In the DRO condition, Phase II would involve a conjoint schedule (conj DRO UC2) in which both schedules operate simultaneously on the same manipulanda. This is similar to the conjoint DRO schedules studied by

Zeiler (1976; 1977). For both ALT-R1 groups, the present terminology would produce a conc ALT-R UC2 schedule in Phase II rather than the present conc ALT-R EXT. Finally, the present analysis of the original response makes the EXT group in this study of questionable value as a control condition. In addition, if the EXT group is not a valid control, then Phase III and the "savings" analysis are also tests of questionable relevance to the probable applications of these contingencies in natural settings.

Finally, a third limitation to the applied significance of this research is concerned with the relative effort of responses in natural settings. The relative effort of a response is a variable which can have important effects on response rate (Chung, 1965) and intensity (Skinner, 1938). However, effort is rarely studied in the laboratory and, perhaps as a result, does not play a prominent part in many theories of learning. Nevertheless, it should play an important part in the analysis of concurrent operants in both experimental and applied contexts.

The study of concurrent operants in the laboratory has almost without exception involved responses of equal effort, either because a single manipulanda was used in conjunction with a changeover key or because two identical keys or levers were used. Yet Chung's (1965) study of single and concurrent operants showed that, when the effort requirements were increased, response rates decreased.

Therefore, the effort involved in each response is an important consideration in the study of concurrent operants. In addition, effort seems to be important in changeover behavior. While this aspect of effort has been studied infrequently (various schedules of fixed ratio CODs--which could be interpreted as requiring varying amounts of effort--have been studied (Pliskoff & Fetterman, 1981)), it is a relevant factor for concurrent operants. The effort of changeovers can be varied through fixed ratio CODs (requiring a number of consecutive responses on the new manipulanda before its schedule goes into effect), manipulating the force requirement on the changeover key, or by moving the manipulanda apart. If, as in the present study, the manipulanda are physically separated, two effects result: (a) the effort requirement for changeovers increases as a function of the animal's weight and the distance between the two operants and (b) a COD is created by the time delay inherent in travelling from one manipulanda to another. Experimentally, the effort of changeovers and length of COD could be varied independently using the single key procedure by controlling the effort on the changeover key and the length of the COD, but when the distance between manipulanda is varied a positive, dependent relationship exists between COD length and effort. Greater distance creates longer CODs and greater effort.

While these issues are not widely discussed in basic

research on concurrent operants, their importance becomes obvious when placed in a real world context. In natural settings, organisms are confronted with many concurrent operants; however, they rarely involve equal effort. In addition, "changeover" force requirements and CODs can vary. Deitz and Repp (1983) have used the terms DRI, for differential reinforcement of incompatible responses (meaning, in this case, physically incompatible), DRA, for differential reinforcement of alternate behavior which is not incompatible (similar to the ALT-R of basic research literature (Leitenberg et al., 1970)), and have argued for the superiority of DRI without providing adequate analysis of the functional relationship between two. However, in light of the forgoing discussion of effort and concurrent operants a plausible interpretation can be presented using existing terminology.

The difference between DRA and DRI appears to be analogous to moving the manipulanda farther apart. If two responses are physically incompatible, changing over from one to the other is affected by both increased effort and increased delay of reinforcement. Whereas in the DRA procedure, both operants are simultaneously available and, the only variables affecting response rate are the effort and schedules of reinforcement for each operant. The present research has shown in an animal experiment that given two physically incompatible responses in a context

similar to DRI (ALT-R1 and ALT-R10) the addition of a long COD can significantly increase response elimination effects.

Conclusions

This research has made two contributions to our knowledge of response elimination contingencies. The first of these concerns the length of COD employed in the ALT-R treatment condition. The longer COD of the ALT-R10 group produced significantly fewer original lever responses than the ALT-R1 group in three sessions of Phase II and all five sessions of Phase III. These results indicate that the greater delay to reinforcement correlated with responding on the original lever for the ALT-R10 group had a significant effect both during the treatment phase and after reinforcement was no longer available for any response. This consistent superiority of the ALT-R10 group did not hold in Phase IV where the reacquisition curves for each group were essentially the same. An important suggestion of these effects is that the results of previous studies, in which a variety of COD lengths have been used, may have been influenced by this variable. The extent to which COD can influence conclusions about the ALT-R procedure was dramatized by the finding that a 1 sec COD produced a treatment which was consistently less effective than DRO, yet a 10 sec COD produced a treatment which was marginally more effective than DRO.

The second contribution of this research is concerned with the relative effectiveness of DRO and ALT-R10. Consistent with previous research (Pacitti & Smith, 1977), the DRO group was extremely effective. Of the 11 points at which significant differences were found, DRO was only surpassed by a reinforcement-based procedure twice. This groups slower reacquisition of the original response in Phase IV was particularly noteworthy and, as discussed above, may have been due to the essential nonresponse contingency of this procedure.

In comparison, the ALT-R10 procedure was either superior to or not significantly different from DRO through Phases II and III, indicating that the ALT-R procedure combined with a DRO-like response-reinforcement interval results in a response elimination procedure which is more effective than either ALT-R without the COD or DRO alone. The exception to this pattern came in Phase IV, where ALT-R10 showed more rapid recovery of the original response than DRO.

Finally, the conclusions to be drawn from these major findings can be briefly summarized in two concise statements. First, since the essential difference between the ALT-R1 and ALT-R10 contingencies was the length of COD, the present research has demonstrated that, while this distinction is of importance under conditions of treatment and extinction, it is less important in reacquisition.

Second, since the essential difference between DRO and ALT-R10 was that in one condition reinforcement was available for any behavior other than the original response and in the other reinforcement was only available for the alternate response, this distinction was shown to be of marginal importance under treatment and extinction conditions, but of greater importance in reacquisition. Taken together, these results and conclusions suggest that the present research has summarized the functional effects of the two characteristics which separate the ALT-R and DRO contingencies: 1) the single alternate response versus any response other than the original response distinction and 2) the presence or absence of a response-reinforcement penalty for original responses.

In addition to these experimental findings, the present research has given strong evidence for the efficacy of applied response elimination procedures which combine differential reinforcement for responses which are incompatible with the target behavior (DRI) with a response-reinforcement delay interval contingent upon occurrence of the target behavior (similar to DRO). Such a contingency appears to control low rates of responding similar to those associated with DRO, yet it allows for the building of alternate, desirable behavior. While a number of factors impede the easy extrapolation from laboratory research with other species to clinical use with humans,

historically, the development of behavior modification techniques for the reduction of behavioral excesses has been tied to earlier animal research in punishment and reinforcement-based response elimination (Reese, 1978). As a result, behavioral treatments based on the findings reported here may lead to useful applications in a variety of field settings.

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Appendix A

Mixed Design Analysis of Variance Summary Table
For Total Original Lever Responses for Each Group
Across the Five Sessions of the Training Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Treatments	134,212.30	3	44,737.43	1.25
Error	1,292,146.66	36	35,892.96	
Within				
Sessions	220,417.83	4	55,104.46	38.66***
Sessions x				
Treatments	23,851.13	12	1,987.59	1.39
Error	205,249.44	144	1,425.34	

*** $p < .001$

Appendix B

Mixed Design Analysis of Variance Summary Table for
Common Log Transformed Total Responses During the
Treatment Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Treatments	5.17	3	1.72	6.08**
Error	10.22	36	0.28	
Within				
Sessions	43.94	4	10.98	90.64***
Sessions x				
Treatments	3.82	12	0.32	2.63**
Error	17.45	144	0.12	

** $p < .01$ *** $p < .001$

Appendix C

Mixed Design Analysis of Variance Summary
Table for the Common Log Transformed Total
Responses for Each Group Across the Five
Sessions of the Extinction Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Treatments	14.65	3	4.88	17.49***
Error	10.05	36	0.28	
Within				
Sessions	4.80	4	1.20	14.67***
Sessions x				
Treatments	0.97	12	0.08	0.99
Error	11.77	144	.08	

*** $p < .001$

Appendix D

Mixed Design Analysis of Variance Summary Table for
Total Original Lever Responses per Minute for each
Treatment Group Across the Fifteen Minutes of the
Reacquisition Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Treatments	5.84	3	1.95	1.25
Error	55.98	36	1.56	
Within				
Time	35.66	14	2.55	42.20***
Time x				
Treatments	7.49	42	0.18	2.95***
Error	30.42	504	0.06	

*** $p < .001$

Appendix E

Analysis of Variance Summary Table for Total
Original Lever Responses Across Both the
Treatment and Extinction Phases

Source	Sum of Squares	df	Mean Square	F
Between Treatments	100,547.30	3	33,515.77	0.88
Error	1,375,048.60	36	38,195.79	

Appendix F

Mixed Design Analysis of Variance Summary Table
For Log Transformed Total Alternate Lever Responses for
Each Group Across the Five Sessions of the
Training Phase

Source	Sum of Squares	<u>df</u>	Mean Square	<u>F</u>
Between				
Treatments	1.28	3	0.43	0.58
Error	26.49	36	0.73	
Within				
Sessions	0.19	4	0.48	0.91
Sessions x				
Treatments	0.77	12	0.06	1.22
Error	7.57	144	.05	

Appendix G

Mixed Design Analysis of Variance Summary Table
For the Common Log Transformed Alternate Lever
Responses for Each Group Across the Five
Sessions of the Treatment Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Treatments	98.74	3	32.91	38.90***
Error	30.46	36	0.84	
Within				
Sessions	4.96	4	1.24	9.59***
Sessions x				
Treatments	12.42	12	1.03	8.00***
Error	18.62	144	0.13	

*** $p < .001$

Appendix H

Mixed Design Analysis of Variance Summary
Table for Common Log Transformed Total Alternate
Lever Responses for each Group Across the
Five Sessions of the Extinction Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Treatments	62.16	3	20.72	68.21***
Error	10.94	36	0.30	
Within				
Sessions	8.39	4	2.10	24.11***
Sessions x				
Treatments	2.88	12	0.24	2.76**
Error	12.52	144	0.09	

** $p < .01$ *** $p < .001$

Appendix I

Mixed Design Analysis of Variance Summary Table for
Log Transformed Total Alternate Lever Responses in the
Reacquisition Phase

Source	Sum of Squares	<u>df</u>	Mean Square	<u>F</u>
Between				
Treatments	3.19	3	1.06	3.35*
Error	11.42	36	0.32	
Within				
Time	2.98	14	0.21	4.25**
Time x				
Treatments	5.64	42	0.13	2.68**
Error	25.26	504	0.05	

* $p < .05$ ** $p < .01$

Appendix J

Mixed Design Analysis of Variance Summary Table for
Total Reinforcements per Group Across the Five Sessions
Of the Training Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Treatments	67.14	3	22.38	0.12
Error	6,669.62	36	185.27	
Within				
Sessions	3,271.33	4	817.83	40.83***
Sessions x				
Treatments	39.79	12	3.31	0.17
Error	2,884.08	144	20.03	

*** $p < .001$

Appendix K

Mixed Design Analysis of Variance Summary Table
For Arcsin Transformed Total Reinforcements per
Session for the Three Reinforcement-based
Response Elimination Procedures Across the Five
Sessions of the Treatment Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Treatments	3.38	2	1.69	7.68**
Error	5.94	27	0.22	
Within				
Sessions	12.49	4	3.12	97.15***
Sessions x				
Treatments	0.28	8	0.03	1.08
Error	3.47	108	0.03	

** $p < .01$

*** $p < .001$

Appendix L

Analysis of Variance Summary Table for
Total Arcsin Transformed Reinforcments per
Minute for Each Group Across the Fifteen
Minutes of the Reacquisition Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Treatments	3.78	3	1.26	1.02
Error	44.41	36	1.23	
Within				
Time	42.89	14	3.06	29.36***
Time x				
Treatments	8.53	42	0.20	1.95***
Error	52.59	504	0.10	

*** $p < .001$