

Summer 1985

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Recommended Citation

Vyse, S., Rieg, T. S., & Smith, N. F. (1985). Reinforcement-based response elimination: The effects of response-reinforcement interval and response specificity. *The Psychological Record*, 35(3), 365-376.

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Keywords

reinforcement, extinction, response, alternative behavior

Comments

Initially published in *Psychological Record*, Summer 1985, p.365-376.

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REINFORCEMENT-BASED RESPONSE ELIMINATION: THE EFFECTS OF RESPONSE-REINFORCEMENT INTERVAL AND RESPONSE SPECIFICITY

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Extinction and four reinforcement-based procedures for eliminating a response were compared in groups of 10 rats. Two procedures provided for reinforcement of a specific alternative behavior (ALT-R) while two others were differential reinforcement of other behavior (DRO) contingencies. The effect of 10-s and 1-s response-reinforcement intervals was examined with each of the ALT-R and DRO groups in (a) a training phase, in which an original response was established, (b) a response elimination phase, (c) an extinction phase, and (d) a reacquisition phase. Results indicated (a) the fastest response elimination occurred in the ALT-R 10-s group and the slowest occurred in the DRO 1-s group; (b) all reinforcement-based procedures showed an increase in original lever responses during the extinction phase, but (c) this effect was lessened for both the groups that had experienced the 10-s response-reinforcement interval; (d) all groups showed rapid recovery of the original lever responses during reacquisition, but (e) slower recovery was shown in the DRO 10-s group.

Research in the elimination of operant behavior with reinforcement has largely centered on two contingencies: differential reinforcement of other behavior (DRO) and alternative response training (ALT-R). As outlined by Uhl and Garcia (1969), DRO is defined by two temporal parameters: (a) the reinforcement-reinforcement interval, which dictates the schedule of reinforcement provided a response does not occur, and (b) the response-reinforcement interval, which delays reinforcement contingent upon responding. Zeiler (1977) has suggested an alternative description, $\bar{R} > t$, or reinforcement for response-free periods greater than the arbitrary period t , but we prefer the Uhl and Garcia (1969) definition because it is a more general statement which does not assume the two temporal parameters to be of equal length. The ALT-R schedule constitutes a concurrent operant in which a previously reinforced response (now targeted for elimination) is programmed for extinction and a second operant is reinforced.

With some exceptions, previous research has shown these two response

The first author submitted a portion of these results in partial fulfillment of the requirements of the MA degree in experimental psychology at the University of Rhode Island and presented them on April 14, 1984 at the 55th annual meeting of the Eastern Psychological Association, Baltimore, MD. The authors would like to thank Thomas Fagan, Sara Hazard, James A. Mulick, Carol Wentworth, and Beth Whaley for their contributions to this research.

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elimination procedures to decrease response rates more rapidly than simple extinction. The effectiveness of ALT-R has been demonstrated in a wide variety of between groups (Enkema, Slavin, Spaeth, & Neuringer, 1972; Leitenberg, Rawson, & Bath, 1970; Rawson & Leitenberg, 1973; Rawson, Leitenberg, Mulick, & Lefebvre, 1977) and within subjects (Lowry & Lachter, 1977; Mulick, Leitenberg, & Rawson, 1976) experiments. In contrast, the research with DRO has been more equivocal. Some studies (Uhl, 1973; Uhl & Garcia, 1969) have found DRO less effective than extinction in eliminating behavior; others have found DRO and extinction to have essentially equivalent effects (Lowry & Lachter, 1977; Pacitti & Smith, 1977); and still others have found DRO to be more effective than extinction (Johnson, McGlynn, & Topping, 1973; Topping & Ford, 1974; Zeiler, 1971).

A number of these studies have assessed the durability of response elimination effects by following this phase with a period during which all reinforcement was eliminated, and in most cases, both DRO and ALT-R have shown a rebound in original responses (Enkema et al., 1972; Leitenberg et al., 1970; Rawson et al., 1977; Uhl & Garcia, 1969; Uhl & Homer, 1974). This effect is similar to the "compensatory recovery" found in early studies of punishment (Boe & Church, 1967; Estes, 1944) and the "resurgence" effect recently identified by Epstein (1983). Only three studies have failed to show the rebound effect. Two of these (Lowry & Lachter, 1977; Mulick et al., 1976) were within subjects multiple schedule designs in which there was no recovery of responding when ALT-R or DRO components were changed to extinction. The third (Leitenberg, Rawson, & Mulick, 1975, Experiment 4) showed no rebound in extinction after extended ALT-R training.

Finally, several studies have further examined the durability of response elimination effects in a phase which either reinstated reinforcement for the original response or provided noncontingent reinforcement. Results with DRO generally have shown superior durability (slower recovery) than extinction (Pacitti & Smith, 1977; Uhl, 1973; Uhl & Garcia, 1969), and in a comparison of extinction, ALT-R, and DRO, Pacitti and Smith (1977) showed slower reacquisition for the DRO group and more rapid and equivalent reacquisition for both extinction and ALT-R groups.

The present study was designed to examine two important elements of the DRO and ALT-R contingencies. Previous studies of ALT-R have employed changeover delay (COD) lengths of from 0 s (Pacitti & Smith, 1977) to 5 s (Leitenberg et al., 1975) without directly examining the effect of this interruption in the schedule of reinforcement for alternative behavior contingent upon the occurrence of an original response. Since, in the context of ALT-R research, COD constitutes a response-reinforcement interval for original responses (similar to DRO), the present study examined the effects of 1-s and 10-s response-reinforcement intervals applied to both ALT-R and DRO contingencies. Thus, when ALT-R contingencies were employed, one with a 1-s COD and the other with a 10-s COD, as well as two DRO contingencies, one with a 1-s response-reinforcement interval and one with a 10-s response-reinforcement interval.

In addition, an important difference between these contingencies is the requirement of a specific response in ALT-R versus an unspecified response in DRO. Any behavior other than the original response will produce reinforcement

under DRO, but reinforcement is available only for a single operant under ALT-R. As outlined in Figure 1, the resulting four experimental conditions represent a 2×2 design with groups separated on the dimensions of specific versus nonspecific response requirement and length of response-reinforcement interval (or COD). The schedule of reinforcement was equated for all groups, and as a point of reference, a simple extinction condition was also examined.

		Response Requirement	
		Specific	Non-specific
Response-Reinforcement Interval	1-s	ALT-R(1)	DRO(1)
	10-s	ALT-R(10)	DRO(10)

Figure 1. A 2×2 diagram showing the distribution of the independent variables among the four reinforcement-based response elimination procedures. For the ALT-R conditions, a response-reinforcement interval was accomplished with a COD.

It is important to note that Uhl and Garcia (1969) studied DRO with temporal parameters of varied lengths; however, when the response-reinforcement interval was shorter than the reinforcement-reinforcement interval, the shorter interval was dominant, actually producing a higher frequency of reinforcement for responding than for not responding. In the present study, the shorter response-reinforcement interval was not dominant, but acted like a COD, merely preventing the delivery of reinforcement contiguous with an original response.

Method

Subjects

Fifty male Sprague-Dawley rats served in this experiment. Each weighed between 250 and 350 g prior to food deprivation and was individually housed with free access to water throughout the study. Before shaping, each rat was reduced to approximately 80% of his ad libitum weight and was maintained at this level throughout the experiment.

Apparatus

Two Coulbourn Model #E10-10 operant chambers in sound-attenuating housings were employed. The front panel of each chamber was equipped with two operant levers and a recessed food cup. The levers were 13.1 cm apart and 2.8 cm above the grid floor. The food cup was centered between the two levers, 1.8 cm above the grid floor. Masking noise was provided by ventilating fans,

and programming was accomplished using standard electromechanical equipment housed in an adjoining room. Noyes 45-mg precision pellets were used as reinforcers.

Procedure

Phase 1—Acquisition. Each rat was randomly assigned to one of the chambers and to a left or right original lever. Sessions were conducted daily approximately the same time. During the first session, rats were hand shaped to press the original lever. For each animal, Sessions 2 and 3 lasted 30 min, during which a fixed interval (FI) 10-s schedule of reinforcement was programmed on the original lever. Following Session 3, each session lasted 15 min. The remainder of the training phase consisted of five sessions of FI 10-s reinforcement on the original lever.

Phase 2—Response elimination. Following Phase 1, rats were randomly assigned to one of five response elimination groups: (a) ALT-R with a 1-s CO (ALT-R(1)), (b) ALT-R with a 10-s COD (ALT-R(10)), (c) DRO with a 1-s response-reinforcement interval (DRO(1)), (d) DRO with a 10-s response-reinforcement interval (DRO(10)), and (e) simple extinction (EXT). The schedule of reinforcement for each of the four reinforcement-based procedures were identical FI 10-s contingencies, which, for the DRO groups, was equivalent to other studies employing DRO with 10-s reinforcement-reinforcement intervals (e.g., Uhl & Garcia, 1969), and in each case, reinforcement was no longer available for responses on the original lever. Under the ALT-R conditions, reinforcement was dependent upon responses on the alternative lever, whereas under DRO reinforcement was dependent upon the nonoccurrence of original lever responses. As a result, the four reinforcement-based groups corresponded to the four conditions outlined in Figure 1, each of which was equated with respect to potential rate of reinforcement. This phase continued for five daily sessions.

Phase 3—Extinction. This phase lasted five sessions, during which reinforcement was available for any of the rats.

Phase 4—Reacquisition. This phase consisted of a single session in which for all rats, a FI 10-s schedule of reinforcement was reinstated contingent upon original lever responses. Response rates during this session were recorded minute-by-minute.

Results

Figure 2 shows the means for total log original lever responses for each group during Phases 1, 2, and 3. Acquisition data are shown beginning with the fourth session of Phase 1, since that was the point at which the 15-min session began. Log response rates are shown because the data from Phases 2, 3, and 4 were transformed to obtain homogeneity of variance prior to statistical analysis.

Phase 1—Acquisition. Total original lever responses for each group were analyzed in a 5 x 5 analysis of variance with repeated measures across sessions. It revealed a significant session effect, $F(4, 180) = 43.14, p < .001$, nonsignificant group, $F(4, 45) = 1.15$, and group x session effects, $F(16, 180) = 1.14$. These results indicated that all groups showed a significant increase

original lever responses across the five sessions of Phase 1, but that there were no significant differences in response rates across the groups at any point. Throughout Phase 1, original lever rates were equivalent for each group.

Phase 2—Response elimination. As in Phase 1, the common log transformed

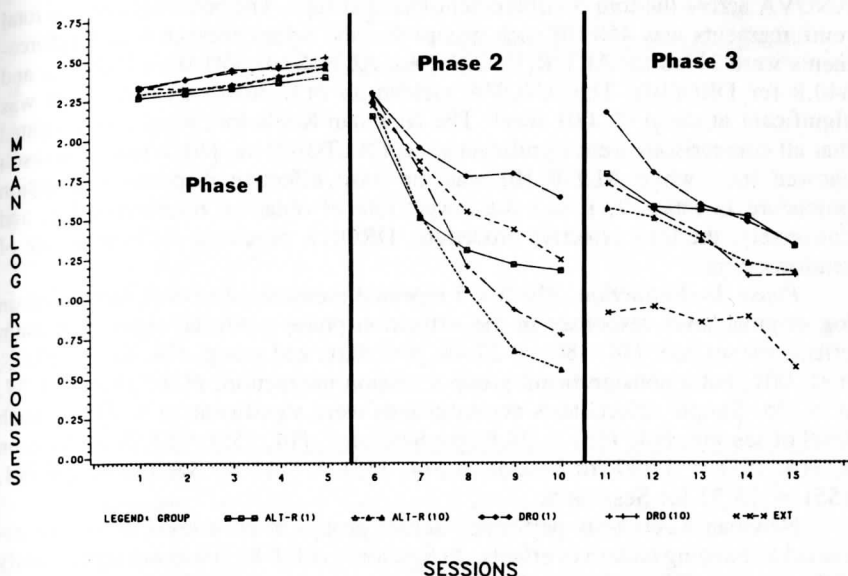


Figure 2. Mean rates of log original lever responses per session for each of the five response elimination groups under the conditions of training (Phase 1), response elimination (Phase 2), and extinction (Phase 3).

original lever responses from the response elimination phase were analyzed in a 5×5 ANOVA with repeated measures across sessions. In this case, all three effects were significant at the $p < .001$ level, $F(4, 45) = 8.16$ for group, $F(4, 180) = 106.02$ for session, and $F(16, 180) = 3.87$ for group \times session. Simple effects tests performed across groups at all levels of session showed no significant differences between response elimination procedures at Session 1, $F(4, 146) = .34$, but significant differences at the $p < .01$ level for Sessions 2 through 5, $F(4, 146) = 3.94$ at Session 2, $F(4, 146) = 7.79$ at Session 3, $F(4, 146) = 18.07$ at Session 4, and $F(4, 146) = 17.26$ at Session 5. Newman-Kuels follow-up tests were performed across groups at Sessions 2 through 5. At Session 2, both ALT-R groups were significantly different from the other three groups, but there were no other significant comparisons. At Session 3, all groups were significantly different from one another, except that DRO(10) was not different from either ALT-R group. At Session 4, all groups were significantly different from one another, and at Session 5, only EXT and ALT-R(1) were not significantly different.

This pattern of results indicated that, at least in Sessions 4 and 5, ALT-R(10) was the most effective response elimination procedure in Phase 2. From most to least effective, the remaining groups were DRO(10), ALT-R(10), EXT, and

DRO(1). A noteworthy result in Phase 2 was the slow decrement in responding shown by the DRO(1) procedure, which maintained a significantly higher rate of response than simple extinction in Sessions 3 through 5.

In order to examine the effect of reinforcement on the behavior observed in this phase, total reinforcements obtained in Phase 2 were analyzed in a one-way ANOVA across the four reinforcement-based groups. The potential average total reinforcements was 450 for each group, and the actual average total reinforcements were 317.8 for ALT-R(1), 221.3 for ALT-R(10), 441.0 for DRO(1), and 340.8 for DRO(10). The ANOVA yielded an $F(3, 36)$ of 21.96, which was significant at the $p < .001$ level. The Newman-Kuels follow-up test indicated that all comparisons were significant except ALT-R(1) vs. DRO(10). This result showed that, while ALT-R(10) was the most effective response elimination procedure in Phase 2, it had the lowest rate of obtained reinforcements, and conversely, the least effective procedure, DRO(1), produced the highest rate of reinforcement.

Phase 3—Extinction. The 5×5 repeated measures ANOVA performed on log original lever responses in the extinction phase produced significant main effects for session, $F(4, 180) = 27.48$, $p < .001$, and group, $F(4, 45) = 20.03$, $p < .001$, but a nonsignificant group \times session interaction, $F(16, 180) = 1.57$, $p > .05$. Simple effects tests across groups were significant, $p < .01$, at each level of session, $F(4, 155) = 28.62$ for Session 1, $F(4, 155) = 53.29$ for Session 2, $F(4, 155) = 11.97$ for Session 3, $F(4, 155) = 9.11$ for Session 4, and $F(4, 155) = 13.53$ for Session 5.

Newman-Kuels tests performed across groups at each level of session revealed a changing pattern of effects. At Session 1, ALT-R(1) was not significantly different from DRO(10) but all other comparisons were significant. At Session 2, the ALT-R groups were not different from each other or from DRO(10), but all other comparisons were significant. Finally, for Sessions 3 through 5, ALT-R(1) and DRO(1) were not significantly different from each other, nor were ALT-R(10) and DRO(10). All other comparisons were significantly different.

These results revealed two effects. First, as found in other studies, all reinforcement-based procedures showed substantial recovery of the original response which was maintained at rates above that of the EXT group throughout Phase 3. Second, while, in Sessions 1 and 2, the rank ordering of reinforcement based groups, from most to least effective, was approximately that found at the end of Phase 2, by Session 3, all significant differences between these four groups were correlated with response-reinforcement interval and uncorrelated with the specificity of the response reinforced in Phase 2.

Phase 4—Reacquisition. As in Phases 2 and 3 the data from the reacquisition phase were transformed to produce homogeneity of variance. The common log original response rates for each minute of the reacquisition phase are presented in Figure 3. In this case, a 5×15 ANOVA with repeated measures across minute yielded significant effects for minute, $F(14, 630) = 54.14$, $p < .001$, and group \times minute interaction, $F(56, 630) = 2.31$, $p < .001$. The group effect was nonsignificant, $F(4, 45) = 1.12$. Simple effects tests across groups at each level of minute revealed significant differences at the $p < .01$ level for Min 1 through 6, $F(4, 625) = 4.16$ at Min 1, $F(4, 625) = 13.98$ at Min 2, $F(4, 625) = 14.4$

at Min 3, $F(4, 625) = 11.12$ at Min 4, $F(4, 625) = 4.06$ at Min 5, and $F(4, 625) = 15.35$ at Min 6. The F value obtained at Min 7 was 1.87 ($df = 4, 625$; $p > .05$) and for Min 8 through 15, $F(4, 625) < 1.00$.

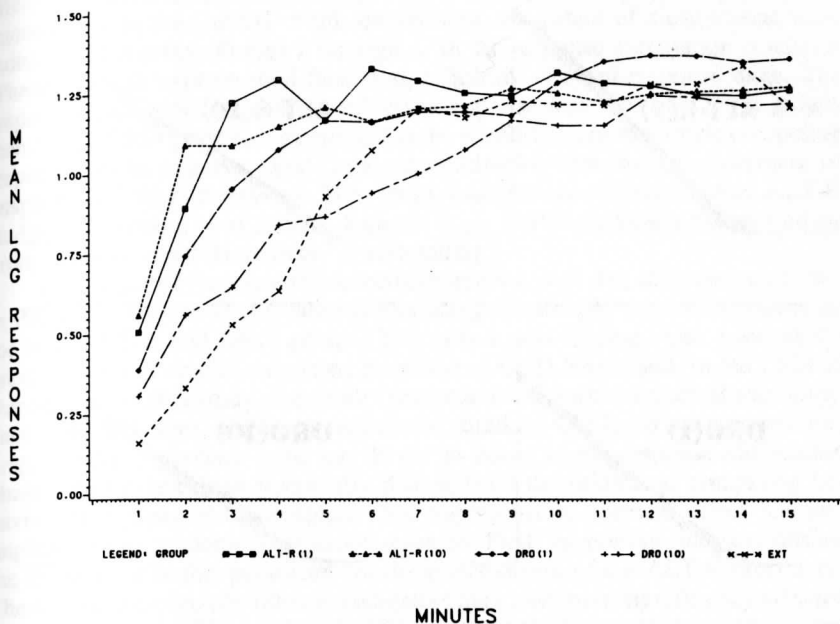


Figure 3. Mean rates of log original lever responses per minute for each of the five response elimination groups during the reacquisition session (Phase 4).

Newman-Kuels tests performed across groups at Min 1 through 6 revealed several transitory relationships and one relatively consistent result. While EXT and DRO(10) were significantly different from each other only at Min 2, for the 4-min period of Min 2 through Min 5, both controlled significantly slower reacquisition than any other group. The only other significant effect which was maintained for longer than a single minute was the difference between DRO(1) and ALT-R(1) in Min 2 and 3.

To further analyze this slower reacquisition for EXT and DRO(10), cumulative records for the reacquisition session were examined (see Figure 4). Records were selected on the basis of two criteria: (a) representativeness of shape and (b) closeness to the mean rate of response for each group during Min 3, which was the point at which the differences observed between both EXT and DRO(10) and the other response elimination groups were most pronounced. In each case, records are presented for rats for which rate of response was less than .5 SDs from the mean for each group at Min 3.

The response patterns reveal two important effects. First, for both ALT-R rats and the EXT rat, no more than two reinforcements were required to bring the original response rate back to steady levels comparable to those seen at the end of acquisition (Phase 1). In contrast, the DRO(10) animal, and to a lesser

extent the DRO(1) animal, had a more gradual increase in original lever responding, shown by the gently increasing slope over the first minutes of the session. A second important pattern is shown in the EXT rat's cumulative record. This

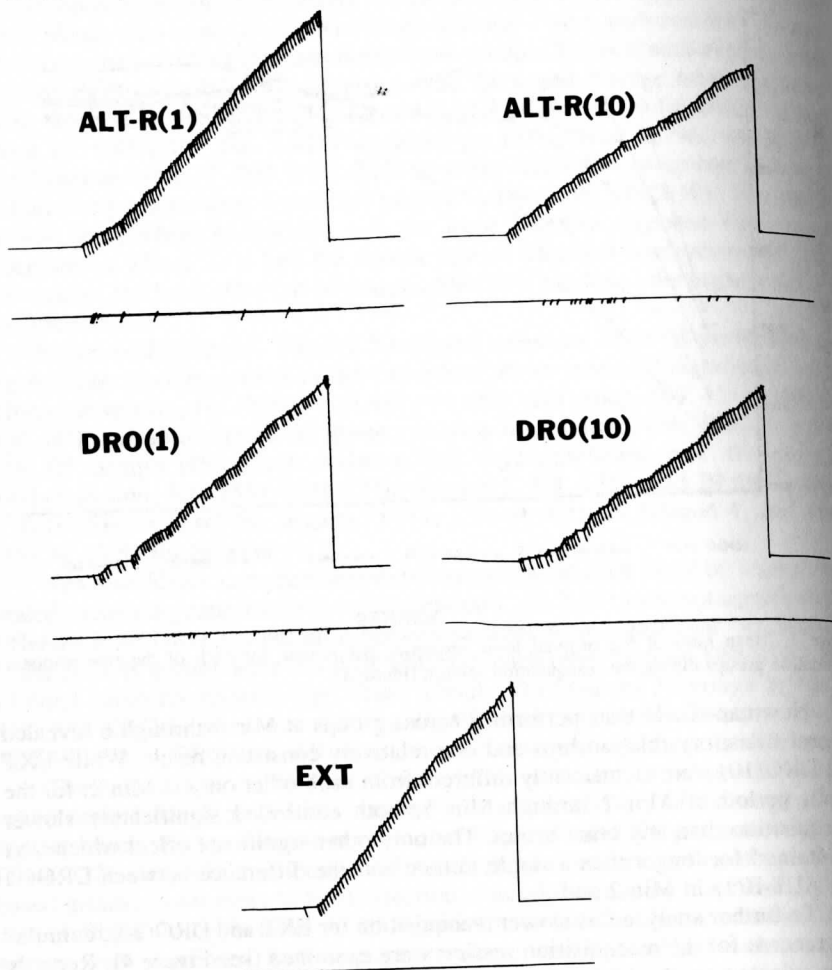


Figure 4. Representative cumulative records produced by rats from each of the response elimination groups during the reacquisition session (Phase 4). The horizontal line below each cumulative record is an event record of responding on the alternative lever.

animal made its first original lever response later in the session than any of the other animals. The later emission of this rat's first and second responses suggest that the slower recovery of the EXT group in Phase 4 may have been due to the relatively lower rates of responding obtained by this group at the end of the previous phase. (The mean absolute response rates per session for each group at the end of Phase 3 (extinction) were 4.20 for EXT, 25.42 for ALT-R(1), 23.00 for ALT-R(10), 29.20 for DRO(1), and 14.30 for DRO(10).)

Discussion

The present results suggest that reinforcement-based response elimination effects are dependent upon both response specificity and response-reinforcement interval, but in the context of this experiment, the extent of these effects were quite different across Phases 2 through 4. In the response elimination condition (Phase 2), both experimental factors significantly affected response rates. The response specificity factor produced lower response rates for the ALT-R groups than for the DRO groups, suggesting that the reinforcement of a single competing response produces more rapid response elimination than the reinforcement of unspecified "other" behaviors. This result was consistent with previous ALT-R studies (Leitenberg et al., 1970; Rawson et al., 1977) in which this procedure produced very rapid decrements in responding.

The length of response-reinforcement interval was also an important factor in Phase 2, with the longer interval producing more rapid response elimination for both ALT-R and DRO groups. This was a new finding since none of the previous ALT-R studies examined the effect of COD length and, in the Uhl and Garcia (1969) DRO study, the shorter response-reinforcement interval was dominant over the longer reinforcement interval (unlike a COD). In the present case, original lever responses were less likely to occur in the response elimination phase if they were kept temporally distant from the reinforced competing behavior, regardless of topography. This response-reinforcement effect has two implications for response elimination research. First, the present study establishes the importance of this parameter for the effectiveness of the ALT-R procedure. The rapid effects seen by other investigators may have been significantly affected by the length of COD employed. Second, the response-reinforcement interval is also an important determinant of the response elimination effects of DRO. While the DRO(10) group's rate of original lever responding declined rapidly in Phase 2, the DRO(1) group showed a higher rate than simple extinction. Since this contingency required no specific alternative response and maintained only a 1-s response-reinforcement interval, many reinforcements were delivered temporally (and undoubtedly *physically*) proximate to original lever responses. Iversen (1984) has shown that the reinforcement of responses that are physically or functionally related to previously reinforced lever responses, such as food cup entry, can be sufficient to produce increases in lever responding. In the present case, a similar response generalization effect may have served to produce higher rates of responding for the DRO(1) group.

The Phase 3 results established the importance of response-reinforcement interval in the maintenance of response elimination effects. While all reinforcement-based procedures showed the characteristic resurgence of original lever responses seen in other between-groups studies (Leitenberg et al., 1970; Rawson et al., 1977; Uhl & Garcia, 1969), the groups that had experienced longer response-reinforcement intervals, ALT-R(10) and DRO(10), showed consistently lower rates of responding in the later sessions of this condition. The power of temporal contiguity in reinforcing and maintaining behavior has been demonstrated in numerous experimental contexts, but the present study has helped to enumerate one of the effects of temporal discontinuity in controlling low rates of responding. When reinforcement was delivered more distant in time from

previously reinforced original lever responses, these responses were less likely to occur in extinction. This effect was maintained over three sessions and occurred whether or not the topography of reinforced alternative response in Phase 2 was specified.

The more gradual reacquisition of original lever responding by the DRO(10) group in Phase 4 revealed an interaction between the nonspecific response requirement of DRO and the longer response-reinforcement interval. While both the longer response-reinforcement interval groups, ALT-R(10) and DRO(10), had obtained equal original response rates at the end of the extinction phase, they showed very different rates of recovery in the early minutes of the reacquisition phase. In this case, the reinforcement of unspecified responses temporally separated from the previously reinforced original lever responses in Phase 2 produced more gradual reacquisition when reinforcement was again made contingent upon the original lever in Phase 4. This result showed that a history of reinforcement for several topographies, which, for the DRO(10) group, were temporally (and perhaps physically) removed from the original lever, produced a different pattern of reacquisition. For ALT-R rats, the reintroduction of reinforcement in Phase 4 produced some alternation between levers early in the session (as seen in the event records of Figure 4), and it is probable that a similar alternation between previously reinforced topographies occurred in DRO rats. If so, it appears that the multiple topographies of the DRO(10) group persisted through the early minutes of Phase 4, briefly interfering with original lever responding. DRO(1) showed a relatively rapid reacquisition, similar to that seen in the ALT-R groups, indicating that the slower reacquisition under DRO reported by other investigators (Pacitti & Smith, 1977; Uhl, 1973; Uhl & Garcia, 1969) and seen here in the DRO(10) contingency, is dependent upon the length of the response-reinforcement interval.

In summary, the present study in the elimination of operant behavior leads to three conclusions. First, the Phase 2 results indicated that both the factors of (a) the specificity of the reinforced alternative behavior and (b) the length of the response-reinforcement interval for the behavior to be eliminated are important to the observed rate of decrease. The reinforcement of a single alternative response (ALT-R) produces more rapid effects than the reinforcement of unspecified "other" behaviors (DRO), and reinforcement of alternative responses temporally distant from the behavior targeted for elimination, through the use of a longer response-reinforcement interval, also results in superior response elimination. Second, when reinforcement is removed for both alternative and original behavior (Phase 3), only the response-reinforcement interval factor affects the rate of responding. All reinforcement-based response elimination contingencies produce a resurgence of the original behavior, but lower rates of responding were observed in rats that had experienced a longer response-reinforcement interval during response elimination. Therefore the temporal discontinuity of currently reinforced behavior with previously reinforced behavior significantly influences the latter's strength when neither is reinforced. Third, Phase 4 showed that, when reinforcement is reinstated contingent upon original responses, the two experimental factors interacted to produce significantly slower recovery under a contingency which combined the reinforcement of unspecified alternative behavior with longer response-reinforcement interval. Under response elimination contingency

cies involving either a single alternative response or a shorter response-reinforcement interval, original behavior returned more rapidly. This result indicates that when currently reinforced behavior has unspecified, and possibly multiple, topographies and is temporally distant from originally reinforced behavior, the reacquisition of original behavior is slowed.

It is noted that the significant differences found in Phase 2 between groups having specific and nonspecific response requirements could not have been predicted by current quantitative theories of reinforcement which suggest that the source of alternative reinforcement is not a determinant of response rate in either single or concurrent schedules (de Villiers, 1977; Herrnstein, 1970). However, these theories are molar formulations based on examinations of steady-state behavior, in contrast to the present study, which was more molecular in design and sensitive to transitory effects.

Finally, Woods (1983) recently argued that DRO and DRI (differential reinforcement of incompatible behavior) were equivalent terms, citing evidence from studies of superstition and schedule-induced behavior in support of the notion that DRO reinforces specific incompatible behaviors. However, the question he raises is an empirical one, and the results of this research give evidence of substantial differences in the behavior controlled by these contingencies. The present ALT-R(10) contingency reinforced a specific incompatible response (as in DRI) with the same schedule of reinforcement as in DRO(10); yet significant differences between these groups were found under conditions of response elimination (Phase 2) and reacquisition (Phase 4). While, as Woods (1983) suggests, incompatible responses are probably conditioned under DRO, the response elimination effects of DRO and DRI are not interchangeable.

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