

LABORATORY EVALUATIONS OF NONCONTINGENT REINFORCEMENT (NCR) AND  
VARIATIONS OF DIFFERENTIAL REINFORCEMENT OF OTHER BEHAVIOR (DRO)

By

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To John Richards, an amazing man

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LABORATORY EVALUATIONS OF NONCONTINGENT REINFORCEMENT (NCR) AND  
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By

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The purpose of this study was to evaluate, using rats as subjects, schedules commonly used in treatments for severe behavior disorders: mainly noncontingent reinforcement (NCR) and momentary differential reinforcement of other behavior (mDRO). The latter (mDRO) is a treatment schedule that includes features of both NCR and differential reinforcement of other behavior (DRO). Rats were initially trained to press levers on a variable-interval (VI) 30 s schedule of food reinforcement (i.e., baseline). In Experiment 1, NCR and mDRO were evaluated. When response patterns were stable in baseline, the two treatments were implemented simultaneously in a multiple schedule format and response and reinforcement rates were evaluated. Results from Experiment 1 showed that mDRO resulted in lower response rates than NCR with only slightly lower reinforcement rates. In Experiment 2, NCR and mDRO were evaluated in isolation to reduce the possibility of multiple treatment interference. Results generally showed that mDRO resulted in lower response rates with only slightly lower reinforcement rates than NCR. MDRO might have a practical advantage over non-momentary DRO for two reasons: a) mDRO may be easier to implement than DRO and b) it is known DRO

can yield low rates of reinforcement. The purpose of Experiment 3 was to evaluate the rates of reinforcement in DRO and mDRO. Results showed comparable levels of behavior reduction but substantially higher reinforcer rates in mDRO. One potential limitation of Experiments 1 through 3 was that the mDRO schedule involved a relatively large DRO interval (i.e., 10 s). In Experiment 4, the effects of mDRO 10 s and mDRO 1 s were evaluated on rates of lever pressing. Results generally showed that mDRO 10 s resulted in lower response rates than mDRO 1 s, but mDRO 1 s resulted in higher rates of reinforcement. Results for all experiments are discussed in terms of implications for treatment of severe behavior disorders.

## CHAPTER 1 INTRODUCTION

Behavior analytic approaches to the assessment and treatment of severe behavior disorders typically involve the identification of functional relations between environmental variables and target behavior, and modification of these events to decrease the occurrence of target behavior. Two of the most commonly used reinforcement-based procedures in the treatment of problem behavior are differential reinforcement of other behavior (DRO) and noncontingent reinforcement (NCR). Although there is a large number of research studies supporting the application of these procedures (e.g., Berkson & Mason, 1964; Carr, Dozier, Patel, Adams, & Martin, 2002; Cowdery, Iwata, & Pace, 1990; Favell, McGimsey, & Schell, 1982; Hagopian, Fisher, & Legacy, 1994; Hanley, Piazza, & Fisher, 1997; Mazaleski, Iwata, Vollmer, Zarcone, & Smith, 1993; Repp, Deitz, & Deitz, 1976; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993), several researchers have reported potential disadvantages. For example, some studies have shown that DRO may be difficult to implement because it requires constant monitoring and may have side effects of emotional responding and low rates of reinforcement (e.g. Cowdery et al., 1990; Vollmer et al., 1993). In addition, there is evidence that NCR may result in adventitious response-reinforcer pairings and consequently, maintenance of problem behavior (e.g., Madden & Perone, 2003; Ringdahl, Vollmer, Borrero, & Connell, 2001; Vollmer, Ringdahl, Roane, & Marcus, 1997).

The purpose of this dissertation was to evaluate NCR and DRO, and a third treatment, referred to as momentary DRO (mDRO), and compare the effects in terms of response reduction and reinforcement rates. NCR, DRO, and mDRO were evaluated in a controlled laboratory setting using rats as subjects. The present studies are a part of a series of investigations of NCR, DRO, and mDRO in both laboratory and clinical (treatment) settings. However, this dissertation

will focus solely on the laboratory evaluations. Results from all experiments are discussed in terms of implications for use of mDRO in the treatment of severe behavior disorders.

**Definitions and historical overview:** Differential reinforcement of other behavior (DRO) is a widely used treatment for problem behavior. In DRO, a reinforcer is delivered for the omission of problem behavior in a set interval. The two main variations in implementing DRO include non-resetting and resetting DRO. Both of these variations operate similarly if no responses occur in the interval; yet differ in the effects of responding on reinforcer delivery. In non-resetting DRO, the occurrence of the target behavior at any time during the interval cancels the reinforcer delivery for that interval. The interval times out and the next reinforcer is not available until the end of the subsequent interval. For example, in a non-resetting DRO 1-min schedule, if target behavior occurs at second 25, the reinforcer for that interval would be lost and the next reinforcer would not be available until the end of the second minute. In resetting DRO, the occurrence of the target behavior resets the DRO interval to zero. For example, in a resetting DRO 1-min schedule, if target behavior occurs at second 25, the interval would reset and the next reinforcer would not be available until second 85 (i.e., 1 min from the occurrence of the target response).

The results from early evaluations of DRO indicated that DRO alone was not effective in decreasing problem behavior and the addition of alternative treatments was necessary to adequately treat problem behavior (e.g., Corte, Wolf, & Locke, 1971; Favell et al., 1982). However, the majority of these studies involved the delivery of arbitrary reinforcers rather than the reinforcers maintaining the aberrant behavior. For example, Corte et al., (1971) compared the effects of DRO to punishment and time-out for the treatment of self-injurious behavior (SIB). They found DRO to be only mildly effective in reducing instances of SIB. However, it is unclear

if the reinforcer used in the DRO contingency actually served as a reinforcer for any of the participants. Therefore, it is possible that the event a) was not a reinforcer, b) could not effectively compete with reinforcers maintaining the behavior, or c) was contraindicated for the treatment of the behavior (e.g., delivering attention if the behavior was maintained by escape from demands or social interactions). Thus, the identification of functional reinforcers or arbitrary reinforcers that effectively compete with the functional reinforcer is necessary to evaluate DRO as treatment. Subsequent studies on DRO used functional analyses (Iwata, Dorsey, Slifer, Bauman, & Richman, 1982/1994) to determine variables maintaining problem behavior and showed that DRO is effective at reducing a wide range of problem behavior. For example, Mazaleski, Iwata, Vollmer, Zarcone, and Smith (1993) evaluated the effectiveness of DRO with arbitrary and functional reinforcers, with and without extinction. They found that DRO was effective using arbitrary reinforcers provided that extinction of the functional reinforcers was in place.

Although DRO has been shown to be an effective treatment of problem behavior, several studies have cited potential limitations of this treatment (e.g., Cowdery, Iwata, & Pace, 1990; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993). First, some studies have shown that DRO may result in phenomena similar to extinction bursts such as increases in response rate and intensity, emotional responding, or aggression (e.g., Cowdery et al.). For example, Cowdery and colleagues found that DRO was effective at reducing problem behavior but evoked emotional responding (i.e., crying) in one participant when he did not meet the reinforcement criterion. A second limitation of DRO is that it may result in low rates of reinforcement. For example, Vollmer et al. found that as the DRO schedule was thinned to 3 minutes for one participant, it essentially became an extinction procedure. Specifically, the participant rarely met the criteria to



receive reinforcement in the form of therapist attention. If the DRO procedure was continually implemented with complete integrity, it is possible that the participant would never receive attention. Therefore, this treatment would not be socially acceptable. A third noted limitation of DRO concerns difficulty with implementation. For example, in order to effectively implement DRO, caregivers must constantly monitor clients over extended time periods to ensure correct reinforcer delivery. Several studies have recommended noncontingent reinforcement (NCR) as an alternative treatment method (e.g., Vollmer et al., 1993).

In NCR, also known as fixed-time (FT) or variable-time (VT) schedules, reinforcers are delivered on a time-based, response-independent schedule. The first evaluations of NCR were conducted in basic laboratories using non-human animals as subjects and food pellets as reinforcers (e.g., Rescorla & Skucy, 1969; Zeiler, 1968). The results of these studies generally showed that NCR decreased rates of responding relative to baseline. For example, Rescorla and Skucy (1969) evaluated the effects of extinction (EXT) and VT reinforcer delivery on previously reinforced lever pressing in rats. They found that although EXT resulted in the lowest rates of behavior, the VT schedules also decreased responding to low levels relative to baseline response rates.

Early treatment studies in the applied literature evaluated the effects of time-based delivery of arbitrary reinforcers on problem behavior. For example, a study conducted by Favell, McGimsey, and Schell (1982) showed that response-independent delivery of manipulable objects resulted in decreases in SIB. As with DRO, the efficacy of NCR with arbitrary reinforcers is conditional on the stimuli being able to compete effectively with the maintaining contingencies. Therefore, the advent of functional analysis methodology, and subsequent use of functional reinforcers in NCR procedures greatly improved the efficacy of this treatment.

Mace and Lalli (1991) conducted the first published study evaluating NCR with reinforcers determined via functional analysis. The functional analysis results showed that bizarre vocalizations were maintained by access to attention. Attention was then delivered on a VT schedule resulting in decreased bizarre vocalizations. Vollmer et al. (1993) compared the effectiveness of NCR and DRO when both treatments were based on functional analysis results for three participants who engaged in SIB. The results showed that NCR was as effective as DRO in reducing SIB. Since these initial experiments, numerous studies have shown that NCR is effective in reducing a wide range of problem behavior (e.g., SIB, aggression, and disruption), maintained by a variety of reinforcers (e.g., attention, tangibles, and escape from demands). In addition, several of these studies have noted potential advantages of NCR over alternative procedures such as EXT or DRO (Vollmer et al., 1993). For instance, few studies showed that NCR results in higher rates of reinforcement than DRO (e.g., Vollmer et al., 1993). Additionally, other studies showed NCR may decrease the likelihood of extinction-induced phenomena such as aggression or emotional behavior. For example, Vollmer et al. (1998) compared the effects of NCR and EXT on the treatment of problem behavior for three participants. The results showed that EXT resulted in high, variable response rates while NCR resulted in low response rates for three participants. In addition, EXT resulted in increases in tantrums for one participant, an effect not obtained in the NCR condition. Furthermore, NCR may be easier to implement than other treatments, such as DRO, because it does not require constant monitoring of behavior.

Despite the advantages of NCR, some potential disadvantages have been noted. First, a majority of evaluations of NCR have involved dense or continuous delivery of reinforcers (e.g., Derby, Fisher, & Piazza, 1996; Hanley, Piazza, & Fisher, 1997; Piazza, Contrucci, Hanley, & Fisher, 1997). This type of reinforcer delivery may limit the application of NCR in clinical

settings. For example, it may be difficult or impossible to deliver continuous access to attention or continuous escape from demands. Second, several studies have shown adverse effects when NCR schedules were thinned to more practical levels. There is some evidence that NCR can maintain or increase problematic behavior, possibly as a function of adventitious reinforcement (e.g., Hagopian, Crockett, van Stone, DeLeon, & Bowman, 2000; Lalli, Casey, & Kates, 1997; Vollmer et al., 1997; Vollmer et al., 1998). That is, because reinforcers are delivered response independently in NCR, there is a possibility a reinforcer delivery can coincide with the occurrence of behavior. This accidental pairing may function like an intermittent schedule of reinforcement, and may result in the maintenance of behavior (Iwata & Kahng, 2005). For example, Vollmer, Ringdahl, Roane, and Marcus (1997) evaluated NCR as treatment for aggression for one participant. As the NCR treatment schedule was thinned, increases in aggression were obtained. An analysis of within-session response patterns demonstrated that bursts of aggression ended with reinforcer delivery, showing some evidence for adventitious reinforcement of problem behavior. Recent studies have evaluated the effects of NCR on responding in other contexts. For example, Kahng, Iwata, Thompson, and Hanley (2000) found that NCR was correlated with a post-session increase in behavior for two out of three participants. Similarly, DeLeon, Williams, Gregory, and Hagopian (2005) reviewed several studies on the more remote effects of NCR and concluded that evidence exists for increases in response rates outside of the NCR treatment context (e.g., Ahearn, Clark, Gardenier, Chung, & Dube, 2003).

Given the potential for negative side effects of DRO and NCR, some researchers have proposed an alternative treatment schedule, commonly called "momentary" DRO (mDRO). MDRO schedules of reinforcement involve aspects of both NCR and DRO, and may be

conceptualized as a Tandem FT (or VT) DRO schedule. That is, similar to NCR, responding in the first part of the tandem schedule has no effect on reinforcer delivery. However, the second part of the tandem schedule includes a DRO component. Thus, responses that occur during the second component delay or terminate reinforcer delivery. Therefore, mDRO schedules may provide the benefits of both DRO and NCR schedules while avoiding some of the potential drawbacks. More specifically, mDRO schedules may produce decreases in responding and prevent adventitious response reinforcer pairings associated with NCR. Furthermore, mDRO schedules may also maintain to a degree the ease of implementation and high rates of reinforcement associated with NCR because early responses in the interval have no effect on reinforcer delivery.

The use of the term mDRO has been applied to a range of schedules that employ both a response-independent and DRO component. The parameters of each component have varied greatly in application. The majority of studies have defined the DRO component as "the precise moment" of scheduled reinforcement delivery. That is, a reinforcer is lost if behavior is occurring at the exact moment the interval times out. However, few nominal descriptions of a "moment" have been provided. For example, Repp, Barton, and Brulle (1983) used the above description of mDRO, yet also had an observer signal the teacher and tell her which child met criteria before a reinforcer was delivered. Therefore, the true definition of "moment" is sometimes unclear. Presumably some interval of time must elapse between the "moment" and actual reinforcer delivery (such as during the time the teacher is walking up to the student) and responses occurring in that brief interval would negate or delay reinforcer delivery. Apparently to make the reinforcer delivery rule more precise or practical, other studies have used larger, pre-determined time windows for the DRO component (e.g., 5 s or 10 s). Although schedules

utilizing larger time windows certainly differ from the typical conceptualization of a “moment,” they may accurately reflect the use of mDRO schedules in application. Thus, for the purpose of this paper, all schedules involving both NCR and DRO components will be called mDRO. In addition to the differences in size of the DRO component, there have been differences in the implementation of the DRO component. Some studies have used a non-resetting DRO component (e.g., Lindberg, Iwata, Kahng, & DeLeon, 1999; Vollmer et al., 1997). Thus, responding during the DRO interval terminates the scheduled reinforcer delivery. Other studies have used a resetting component in which responding during the DRO component resets the interval, and only the DRO interval continues to reset until criteria are met and a reinforcer is delivered (e.g., Britton, Carr, Kellum, Dozier, & Weil, 2000; Hagopian et al., 2000).

Early treatment evaluations of mDRO compared its reductive effects to that of other treatments (e.g., Barton, Brulle, & Repp, 1986; Harris & Wolchik, 1979; Repp, Barton, & Brulle, 1983). The results of these experiments generally showed that mDRO was ineffective or less effective than other treatments. For example, Harris and Wolchik compared non-resetting mDRO to two punishment procedures (i.e., overcorrection and timeout) in the treatment of stereotypy. The authors reported that both punishment procedures were effective at reducing stereotypy but mDRO did not adequately reduce behavior for three participants and produced elevated behavior for a fourth participant. Similarly, a study by Repp et al. (1983) compared the effects of non-resetting mDRO to non-resetting whole-interval (WI)DRO in the treatment of disruptive behavior. The results showed that mDRO was ineffective for three participants and the implementation of WIDRO was necessary to decrease responding. For a fourth participant, mDRO was an effective treatment after the participant had been exposed to WIDRO. The authors concluded that mDRO might only be effective after an initial exposure to WIDRO.

Barton, Repp, and Brulle (1986) replicated this finding and showed that non-resetting mDRO maintained the therapeutic effects of non-resetting WIDRO for three participants. In each of these evaluations, it was unclear if the reinforcers delivered were functionally related to the target behavior. As with other reinforcement-based treatments, the delivery of arbitrary reinforcers may not have competed with the functional reinforcer for the target behavior, resulting in less effective treatments. This effect may be especially true if mDRO schedules are used in the treatment of automatically reinforced behavior (such as stereotypy), because the individual could conceivably respond early in the interval, obtain the automatic reinforcers, and still receive the arbitrary reinforcers at the end of the interval. Thus, it is possible that the ineffectiveness of mDRO in these studies was due to the use of arbitrary reinforcers.

Several studies have evaluated the effects of mDRO (referred to in these experiments as Tandem VT DRO) in laboratory settings using both nonhuman and human subjects (e.g., Imam & Lattal, 1988; Madden & Perone, 2003; Rachlin & Baum, 1972; Zeiler, 1976). For example, Rachlin and Baum evaluated the effects of VT and resetting variable mDRO on the rate of key pecking in pigeons using a between subjects design. Pigeons were initially trained to peck keys on a variable interval (VI) schedule of food delivery. Next, pigeons were exposed to VT and resetting variable mDRO schedules of food delivery. Similar reductive effects were obtained across the two schedules. Imam and Lattal conducted a systematic replication of the Rachlin and Baum study. The results showed that resetting variable mDRO produced greater decreases in key pecking than VT schedules. Madden and Perone reported a similar finding. They evaluated the effects of VT and resetting variable mDRO on arbitrary responses (i.e. forward, backward, and side to side movement of a joystick) using human participants. The authors found that resetting variable mDRO was more effective in reducing the target response than VT alone. It should be

noted that in many of these laboratory evaluations, exposure to the resetting variable mDRO schedule followed a previous exposure to the VT schedule. This previous history may have enhanced the effects of resetting variable mDRO. Nonetheless, Madden and Perone concluded that these results might have implications for the use of time-based schedules in the treatment of problem behavior. More specifically, they recommended that mDRO schedules be used as a precaution to prevent the adventitious reinforcement effects sometimes obtained with time-based (NCR) schedules.

Recent studies have evaluated the effects of mDRO in the treatment of problem behavior using reinforcers identified via functional analysis. The initial studies on mDRO with functional reinforcers evaluated its effects when NCR schedules resulted in increased rates of problem behavior. For example, during schedule thinning of NCR, Vollmer et al., (1997) observed increases in aggression maintained by tangible positive reinforcement (access to magazines) for one participant. To prevent the adventitious response-reinforcer pairings, they implemented a non-resetting mDRO 10-s procedure. The results showed that mDRO decreased response rates, and the effect was maintained as the schedule was thinned to more practical levels. However, the study was limited because mDRO was not evaluated using a proper experimental design.

Hagopian, Crockett, van Stone, DeLeon, and Bowman (2000) observed similar increases in problem behavior when NCR schedules were thinned. They then implemented resetting mDRO 5-s schedules and initially observed increases in responding that eventually decreased to low levels. In addition, the authors concluded that the addition of the DRO component was necessary to successively thin the treatment schedule to therapeutic levels.

Several studies have compared mDRO to WIDRO (Britton et al., 2000; Derwas & Jones, 1993; Lindberg et al., 1999). For example, Lindberg et al., (1999) compared the effects of non-

resetting variable mDRO to non-resetting variable WIDRO using both a multielement and reversal design. They found that the mDRO schedule had reductive effects similar to WIDRO. In addition, they reported that mDRO was easier to implement and resulted in a greater percentage of reinforcers earned. Similarly, Britton, et al. (2000) evaluated the effects of resetting mDRO 10 s for three participants whose problem behavior was maintained by social positive reinforcement. The results showed that mDRO was effective at decreasing problem behavior for all participants. For one of these participants, they compared the mDRO schedule to non-resetting WIDRO. The authors reported that mDRO was easier to implement than DRO and resulted in higher rates of reinforcement but did not present data to support this statement.

Thus, previous research has indicated that mDRO is effective in the treatment of problem behavior and may have some advantages over both DRO and NCR. However, to date, there has been no highly controlled comparison of NCR and mDRO. A more controlled examination of NCR and mDRO would greatly improve the current understanding of these procedures. If differences in effects are subtle, an evaluation might require lengthy conditions and repeated reversals. Because lengthy conditions and repeated reversals with individuals who engage in high rates of self-injurious behavior (or other severe problem behavior) might be dangerous, such a controlled analysis might best be initially conducted in a laboratory experiment. There are several potential advantages to conducting initial evaluations in a nonhuman laboratory setting. First, these settings limit interference from both previous and concurrent environmental contingencies such as those that individuals in clinical settings experience outside of the assessment and treatment sessions (e.g., interactions with teachers and parents). Furthermore, nonhuman laboratory settings may have advantages over other laboratory arrangements such as human operant laboratories, because they avoid interference with verbal behavior (e.g., rules



about the experiment). Finally, nonhuman laboratory settings allow for more control over motivating operations because access to the reinforcer (i.e., food) is limited and controlled by the experimenter. A nonhuman operant laboratory had been recently developed to examine problems encountered in clinical application in a more controlled setting.

The purpose of Experiment 1 was to conduct a laboratory evaluation of NCR and mDRO with rats as subjects. More specifically, NCR and Tandem FT 20 s resetting DRO 10 s (mDRO 10 s) were evaluated. The particular mDRO schedule was selected for several reasons. First, preliminary clinical research was conducted and indicated the 10-s DRO component was more effective than mDRO 1 s. Additionally, results from this preliminary research indicated a resetting mDRO 10 s produced lower response rates and higher reinforcement rates than non-resetting mDRO 10 s. Furthermore, fewer evaluations of this particular schedule have been conducted in the literature (e.g., Britton et al., 2000, Hagopian et al.) and thus less is known about this particular conceptualization of mDRO. Four subjects were used in the evaluation. A two component multiple schedule (MULT) was used in which each component was associated with a specific stimulus (i.e., location of light in operant chambers). Four total components (i.e., two exposures to each component) were presented during each session. Subjects were initially trained to press levers on a MULT VI 30 s VI 30 s schedule of pellet delivery. This condition served as a baseline from which to evaluate the treatment effects. After stability criteria were reached, one component was changed to mDRO and the other was changed to NCR. The effects of each treatment were evaluated using a reversal design. Results were analyzed in terms of initial (i.e., first 10 components of the condition), final (i.e., last 10 components of the condition) and overall response rates. In addition, for each treatment, the overall reinforcement rates were evaluated. One potential limitation of this study was that both treatment conditions were implemented

simultaneously. Therefore, it is possible that the effects of each treatment were due to the combined effects with the other treatment (i.e., multiple treatment interference). Experiment 2 was designed to address this limitation.

The purpose of Experiment 2 was to evaluate the effects of NCR and mDRO when each treatment was administered in isolation. The four subjects from Experiment 1 were included in Experiment 2. Sessions (i.e., two exposures to each two component multiple schedule) and baseline conditions (i.e., MULT VI 30 s VI 30 s) were exactly the same as Experiment 1. In contrast, the treatment evaluation involved the exposure to one treatment condition at a time. For example, when mDRO was introduced in one component, the other component remained at VI 30 s (i.e., MULT mDRO 10 s VI 30 s). The order of treatment conditions was counterbalanced across subjects (e.g., equal subjects experienced mDRO and NCR first). The effects of each treatment were again evaluated using a reversal design and results were analyzed in terms of initial (i.e., first 10 components of the condition), final (i.e., last 10 components of the condition) and overall response and reinforcement rates.

Previous research has compared mDRO and DRO and found that both schedules produced similar decreases in response rates (e.g., Britton et al., 2000, Lindberg et al., 1999). However, one documented disadvantage of DRO is that it can yield relatively low rates of reinforcement (e.g., Lindberg et al.; Vollmer et al., 1993). Only one experiment (Lindberg et al.) has provided data on obtained reinforcement in DRO and mDRO. In that study, the comparison was between non-resetting variable WIDRO and non-resetting variable mDRO 1 s. The authors reported a greater proportion of reinforcers earned in the mDRO than DRO conditions. Thus, the purpose of Experiment 3 was to evaluate the effects of resetting fixed WIDRO and resetting fixed mDRO 10 s, including differences in reinforcement rates, when each treatment was

administered in isolation. Four subjects were included in Experiment 3. The session setup, treatment evaluation, and data analysis was exactly the same as Experiment 2 with DRO substituted for NCR.

Although most mDRO evaluations have described the reinforcement criterion as the "moment" the interval ends, all mDRO schedules must actually involve some lapse of time between the end of the interval and actual reinforcer delivery. However, this interval is usually unspecified. The mDRO evaluations for Experiments 1 through 3 involved relatively long mDRO intervals (i.e., 10 s) that reset upon the occurrence of each response. This type of mDRO schedule is more complicated to implement than NCR or other mDRO (such as mDRO 1 s) schedules. Some studies have shown that mDRO is effective using smaller intervals in the DRO component and a non-resetting feature (e.g., Lindberg et al., 1999). Therefore, the addition of larger intervals and the resetting feature may not be necessary. Thus, the purpose of Experiment 4 was to evaluate the effectiveness of the initial mDRO schedule (i.e., Tandem FT 20 s resetting DRO 10 s) and non-resetting mDRO 1 s. Three naïve subjects were used in the analysis. A fourth subject was removed from the experiment due to failure to respond in the baseline components, which made it impossible to evaluate the treatments or demonstrate experimental control. Sessions (i.e., two exposures to each two component multiple schedule) and baseline conditions (i.e., MULT VI 30 s VI 30 s) were exactly the same as Experiments 1 through 3. Similar to Experiments 2 and 3, each treatment was evaluated individually using a reversal design. Again, the order of exposure to treatments was counterbalanced across subjects and the results were analyzed in terms of initial (i.e., first 10 components of the condition), final (i.e., last 10 components of the condition), overall response and reinforcement rates.

## CHAPTER 2 GENERAL METHOD

### **Subjects**

Subjects were male Wistar rats. Each rat was food deprived approximately 23 hours prior to session, and given 16 grams of standard rat chow post-session. Subjects were individually housed under a 12-hr light dark cycle with constant temperature and humidity conditions. Four experimentally naïve rats (2101, 2102, 2103, and 2106) were included in Experiment 1, and after completing Experiment 1, were included in Experiment 2. Two experimentally naïve rats (2201, and 2201) and two rats that had been previously exposed to a preliminary treatment comparison (2104 and 2105) were included in Experiment 3. Three experimentally naïve rats (2301, 2304, and 2305) were included in Experiment 4.

### **Apparatus**

During the experiment, each rat was placed in one of four identical Coulbourn Instruments operant chambers arranged in sound attenuating ventilated cabinets. An adjacent computer with running software controlled all experimental procedures and data collection. The chambers measured 25 cm high, 30 cm wide and 29 cm deep. The floor of the chamber consisted of a plastic tray lined with bedding under a metal grate. The front wall of the chamber contained an intelligence panel. Figure 2-1 displays a photograph of the intelligence panel from inside the chamber with symbols representing all of the components. A houselight (A) was located 2 cm from the ceiling and a food hopper (B) was located 20 cm below the houselight and measured 4 cm high and 3.5 cm wide. The houselight was illuminated throughout the session except during reinforcer deliveries and the period during the inter-component interval. The chamber contained two response levers (C and D) oneither side of and equidistant from the hopper. The levers extended 2 cm into the chamber. Experimental contingencies were placed on responses to the

operative lever (C) but responding on the inoperative lever (D) was recorded as well. Three stimulus lights (E) were located directly above the lever. Reinforcers in the form of 45 mg food pellets were delivered through the hopper. The feeder made a slight noise similar to the sound of gears turning during pellet delivery followed by a clicking sound when the pellet was dropped into the hopper.

### **Schedules of Reinforcement**

**Baseline:** During baseline, reinforcers were delivered on a variable-interval (VI) 30-s schedule of reinforcement, specifically a MULT VI 30-s VI 30-s schedule. This baseline schedule was in place in all four experiments.

**mDRO 10 s:** The technical term for schedule used during the mDRO 10 s condition was a Tandem FT 20 s resetting DRO 10 s. During this condition, reinforcers were delivered every 30 s as long as no responding occurred in the DRO interval (i.e., final 10 s). If a response occurred during DRO, the interval reset from the point of the response and a reinforcer was delivered when 10 s had elapsed with no response. This mDRO schedule was used in all four experiments

**NCR 30 s:** During the NCR condition, reinforcers were delivered every 30 s, independent of responding, specifically a NCR 30-s schedule. This NCR schedule was used in Experiments 1 and 2.

**DRO 30 s:** During the DRO condition, reinforcers were delivered every 30 s as long as no responding occurred during the entire 30 s. If a response occurred, the interval was reset from the point of the response and a reinforcer was delivered when 30 s had elapsed with no response. This DRO schedule was used in Experiment 3.

**mDRO 1 s:** The technical term for the schedule used during the mDRO 1 s condition was a Tandem FT 29 s non-resetting DRO 1 s. During this condition, reinforcers were delivered every 30 s, as long as responding was absent the last second of the interval. If responding did occur at

the last second (i.e., second 30), the interval timed out and a reinforcer was delivered during the subsequent interval as long as responding was absent at the last second. This mDRO schedule was used in Experiment 4.

### **Procedures**

All naïve subjects were first exposed to a no pellet (NP) condition to measure levels of responding prior to a history of reinforcement. Next, the lever press response was shaped by exposing each subject to two 10-min sessions of a Conjoint FT 1-min FR 1-min schedule of reinforcement. After these sessions, the treatment evaluations were conducted. Conditions were evaluated using a reversal design and a two-component multiple schedule (MULT) in which each treatment was associated with a separate stimulus (i.e., position of the stimulus lights in the chamber). Component 1 (C1) of the multiple was signaled by illuminating the leftmost stimulus light and Component 2 (C2) of the multiple schedule was signaled by illuminating the center stimulus light. Previous research had been conducted using these procedures and showed that subjects were able to respond differentially to the different stimuli. Each component was presented twice during the session in a quasi-random order. That is, the first and third components were randomly selected and followed by the other component. Components were terminated when 20 reinforcers had been delivered or 20-min had elapsed, whichever occurred first. Components were separated by a 60-s blackout period.

Stability and condition changes were determined through visual inspection of the data for all experiments. However, additional stability criteria were used for the baseline condition in Experiment 1 to ensure there was a) a maximum range of the data and b) no downward trend in either of the components.



Figure 2-1. Photograph of interior of Coulbourn Instruments chamber.

CHAPTER 3  
EXPERIMENT 1: LABORATORY EVALUATION OF NCR AND mDRO 1

**Method**

The purpose of Experiment 1 was to evaluate the effects of NCR and mDRO on rates of lever pressing. Four experimentally naïve subjects were included in Experiment 1 (2101, 2102, 2103, and 2106). In this experiment, both treatments were introduced simultaneously but signaled by a distinctive stimulus. The order of conditions for all subjects was ABAB in which A represents the MULT VI 30 s VI 30 s baseline condition and B represents the MULT NCR 30 s mDRO 10 s treatment conditions. Component 1 (C1) of the multiple schedule (VI 30 s, NCR 30 s) was signaled by illuminating the leftmost stimulus light and Component 2 (C2) of the multiple schedule (VI 30 s, mDRO 10 s) was signaled by illuminating the center stimulus light.

**Results and Discussion**

Figures 3-1 and 3-2 show the results for all subjects. In each of the figures, components are plotted on the x-axis and responses per minute (rpm) of lever pressing are plotted on the y-axis. The top panel of Figure 3-1 shows the results from subject 2101. In the NP condition, low rates of responding were obtained averaging .25 rpm. In the MULT VI 30 s VI 30 s condition, lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=31.4$ , C2:  $m=30.5$ ). In the next condition, C1 was changed to NCR 30 s and C2 was changed to mDRO 10 s (i.e., MULT NCR 30 s mDRO 10 s). Lever pressing decreased in both conditions, but was lower overall in the mDRO condition ( $m=7.6$ ) than the NCR condition ( $m=9.9$ ). The MULT VI 30 s VI 30 s condition was implemented and increases in responding were obtained in both components (C1:  $m=28.5$ , C2:  $m=28.1$ ). Both treatment conditions were implemented and similar response rates were obtained in the mDRO ( $m=2.5$ ) and NCR ( $m=3.0$ ) conditions.

The bottom panel of Figure 3-1 shows the results from subject 2102. In the NP condition,



low rates of responding averaging .31 rpm were obtained. In the MULT VI 30 s VI 30 s condition, lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=24.2$ , C2:  $m= 24.2$ ). In the next condition, C1 was changed to NCR 30 s and C2 was changed to mDRO 10 s (i.e., MULT NCR 30 s mDRO 10 s). Lever pressing decreased in both conditions, but was slightly lower overall in the NCR condition ( $m=2.8$ ) than the mDRO condition ( $m=3.5$ ). The MULT VI 30 s VI 30 s condition was implemented and increased responding was obtained in both components (C1:  $m=26.4$ , C2:  $m= 26.4$ ). Both treatment conditions were implemented and slightly lower overall response rates were obtained in the mDRO ( $m=2.3$ ) than NCR ( $m=3.7$ ) condition.

The top panel of Figure 3-2 shows the results from subject 2103. In the NP condition, low rates of responding were obtained averaging 0.23 rpm. In the MULT VI 30 s VI 30 s condition, lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=26.2$ , C2:  $m= 26.2$ ). In the next condition, C1 was changed to NCR 30 s and C2 was changed to mDRO 10 s (i.e., MULT NCR 30 s mDRO 10 s). Lever pressing decreased and was similar in both the mDRO ( $m=2.9$ ) and NCR ( $m=2.6$ ) conditions. The MULT VI 30 s VI 30 s condition was implemented and increases in responding was obtained in both components (C1:  $m=14.7$ , C2:  $m= 14.3$ ). Next, both treatment conditions were implemented and similar overall response rates were obtained in both the mDRO ( $m=0.5$ ) and NCR ( $m=0.5$ ) conditions.

The bottom panel of Figure 3-2 displays the results for subject 2106. In the NP condition, low rates of responding were obtained averaging 0.23 rpm. In the MULT VI 30 s VI 30 s condition, lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=21.8$ , C2:  $m= 21.7$ ). In the next condition, C1 was changed to NCR 30 s and C2 was changed to mDRO 10 s (i.e., MULT NCR 30 s mDRO 10 s). Lever pressing decreased

and was similar in both the mDRO ( $m=3.1$ ) and NCR ( $m=2.5$ ) conditions. The MULT VI 30 s VI 30 s condition was implemented and increases in responding were obtained in both components (C1:  $m=10.6$ , C2:  $m=10.8$ ). Next, both treatment conditions were implemented and similar overall response rates were obtained in both the mDRO ( $m=1.3$ ) and NCR ( $m=1.5$ ) conditions.

Table 3-1 shows the summary statistics for all subjects in Experiment 1. For all subjects, the overall response rates, average response rates for the first and final 10 components of each treatment, and overall reinforcement rates for the first and second treatment evaluations were calculated. For the majority of subjects, mDRO resulted in lower overall response rates, and lower response rates in the first 10 components of the evaluation. Similar response rates were obtained in the final 10 components of the evaluation. In addition, although reinforcement rates were slightly higher in the NCR condition, similar rates of reinforcement were obtained in both treatments.

The results from Experiment 1 showed that NCR and mDRO had comparable effects on the level of responding across subjects. That is, all treatments resulted in decreases in lever pressing. In the NCR and mDRO comparison, lower levels of responding were generally obtained in the mDRO condition. In addition, rates of reinforcement were similar (i.e., 1.8 vs. 1.9 reinforcers per minute) in both conditions.

One potential limitation of the current study was that two treatments were evaluated simultaneously. Although the treatments were evaluated using a multiple schedule signaled by separate stimuli, there is no evidence that the subjects responded differentially to the signals. That is, it is possible that the decreases in responding in both treatments were due to the combined effects of the treatments rather than separate effects of each individual treatment.

Therefore, it is possible that different outcomes would be obtained if each treatment were evaluated in isolation. Thus, the purpose of Experiment 2 was to conduct a laboratory evaluation of the effects NCR and mDRO in isolation.

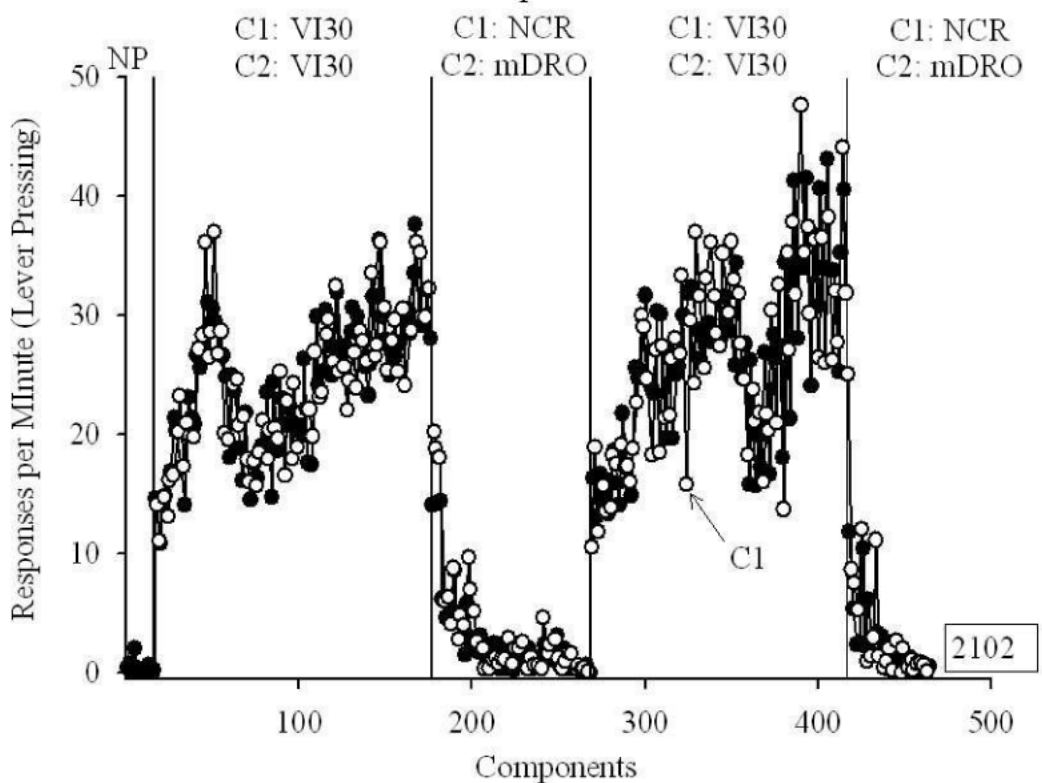
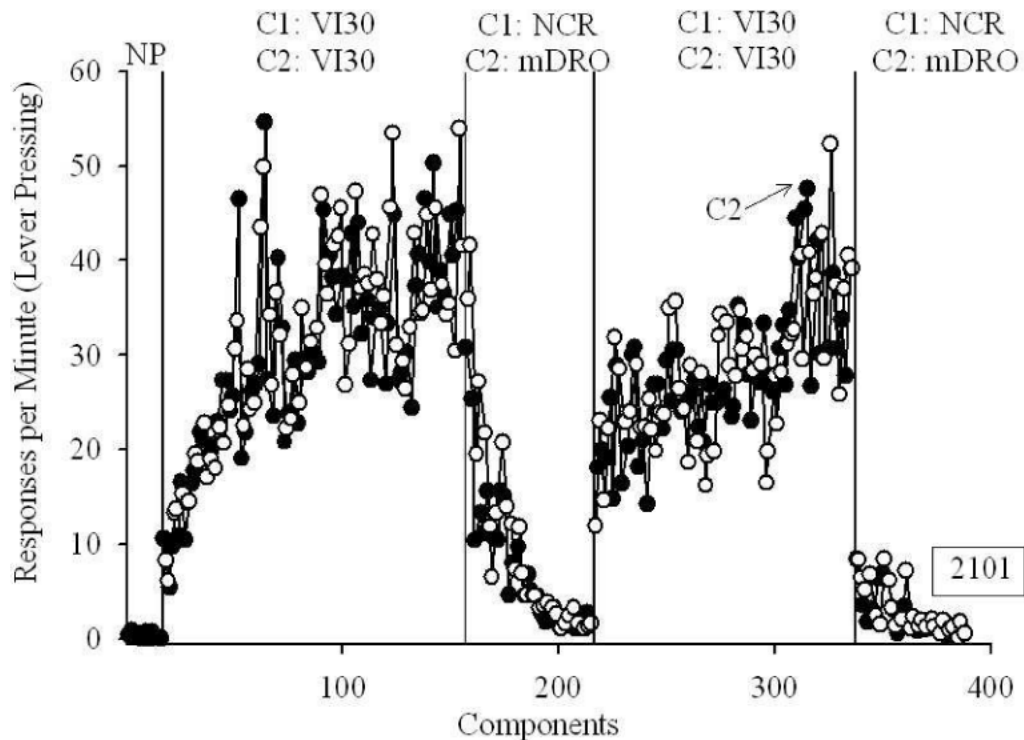


Figure 3-1. Subjects 2101 and 2102: overall response rates

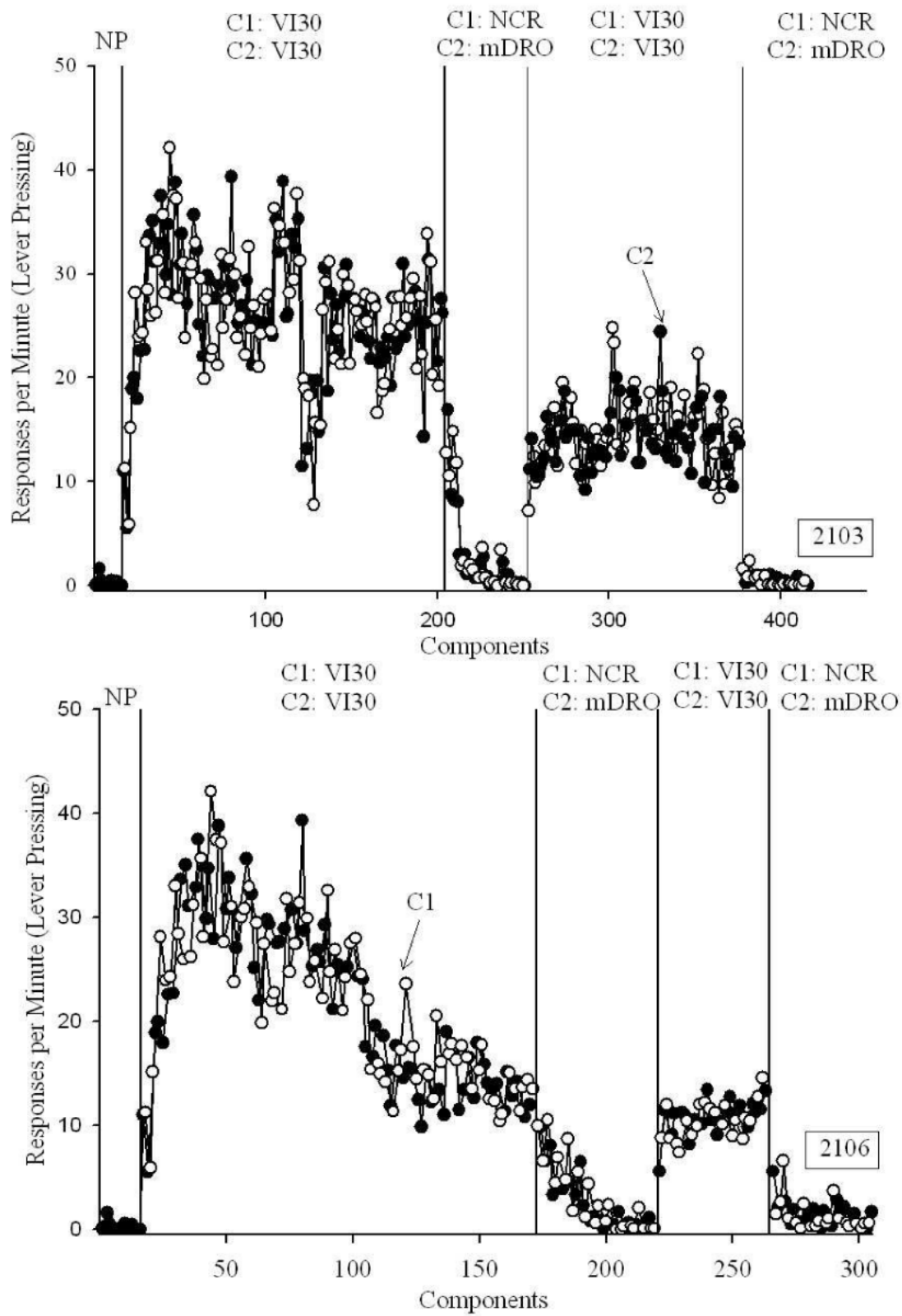


Figure 3-2. Subjects 2103 and 2106: overall response rates

Table3-1. Summary statistics for each presentation (pres.) of NCR and mDRO for all subjects (subj.) in experiment 1.

Subj.- Pres.	RPM (overall)		RPM (1 <sup>st</sup> 10)		RPM (last 10)		R of Sr (overall)	
	NCR	mDRO	NCR	mDRO	NCR	mDRO	NCR	mDRO
2101-1	9.9	7.6	21.3	15.9	2.1	1.8	1.9	1.8
2101-2	3.0	2.5	5.0	4.3	1.2	1.1	1.9	1.9
2102-1	3.5	2.8	9.4	7.9	0.9	0.8	1.9	1.9
2102-2	3.7	2.3	7.6	4.7	0.9	0.5	1.9	1.9
2103-1	2.9	2.6	6.0	5.2	0.5	0.4	1.9	1.9
2103-2	0.4	0.5	0.8	0.7	0.1	0.3	1.9	1.9
2106-1	3.1	2.5	6.1	5.3	0.6	0.5	1.9	1.8
2106-2	1.3	1.5	1.7	1.8	0.9	1.3	1.9	1.9

CHAPTER4  
EXPERIMENT 2: LABORATORY EVALUATION OF NCR AND MDRO 2

**Method**

The purpose of Experiment 2 was to evaluate the effects of NCR and mDRO, in isolation, on rates of lever pressing. The four subjects that had previously completed Experiment 1 were included in Experiment 2 (2101, 2102, 2103, and 2106). In this experiment, only one treatment was introduced at a time for each subject. That is, when one component was changed to a treatment condition (e.g., NCR 30 s), the other component remained as VI 30 s. In order to partially control for order of presentation, two subjects were exposed to the NCR treatment condition first, and two subjects were exposed to the mDRO treatment condition first. In addition, the number of component exposures of each treatment evaluation was kept constant across the subjects. For example, if a subject received 100 components of the initial NCR evaluation, it received 100 components to the initial evaluation of mDRO. Each treatment was evaluated twice for all subjects except 2101, which was exposed to the NCR treatment 3 times due to an experimental error. The order of conditions for subjects who received the NCR treatment first was ABABACACAB for one subject and ABACACAB for the other subject. The order of conditions for subjects who received the mDRO treatment first was ACABABAC for both subjects. A represents the MULT VI 30 s VI 30 s baseline condition, B represents the MULT NCR 30 s VI 30 s treatment conditions, and C represents the MULT VI 30 s mDRO 10 s treatment condition. Component 1 (C1) of the multiple schedule (VI 30 s, NCR 30 s) was signaled by illuminating the leftmost stimulus light and Component 2 (C2) of the multiple schedule (VI 30 s, mDRO 10 s) was signaled by illuminating the center stimulus light.

**Results and Discussion**

Figures 4-1 through 4-4 show the results from all subjects. In each of the graphs,

components are plotted on the x-axis and responses per minute (rpm) of lever pressing are plotted on the y-axis. The top and bottom panel of each figure display the results for one subject in the experiment. Due to the larger number of component presentations, the graphs have been separated into the initial and subsequent presentation for each treatment. The top panel of Figure 4-1 shows the results from initial presentation of each treatment for subject 2101. In the MULT VI 30 s VI 30 s baseline condition, lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=30.4$ , C2:  $m=29.2$ ). In the next condition, C1 was changed to NCR 30 s and C2 remained at VI 30 s (i.e., MULT NCR 30 s VI 30 s). Lever pressing was lower in the NCR condition ( $m=10.2$ ) relative to the VI 30 s condition ( $m=25.4$ ). A reversal to the MULT VI 30 s VI 30 s condition was conducted and increases in responding were obtained (C1:  $m=29.8$ , C2:  $m=29.4$ ). Next, the MULT NCR 30 s VI 30 s condition was implemented again and lower rates of lever pressing in the NCR condition ( $m=8.9$ ) relative to the VI 30 s condition ( $m=22.7$ ) were obtained. After a reversal to the baseline condition (C1:  $m=28.3$ , C2:  $m=29.5$ ), mDRO was evaluated in the MULT VI 30 s mDRO 10 s condition and lower rates of lever pressing ( $m=6.6$ ) were obtained relative to the baseline condition ( $m=27.2$ ). The bottom panel of Figure 4-1 shows the results for the second presentation of each treatment condition. The baseline condition was implemented and increases in responding were obtained in both components (C1:  $m=24.1$ , C2:  $m=26.2$ ). During the second evaluation of mDRO, further decreases in responding ( $m=3.5$ ) were obtained relative to the baseline condition ( $m=20.0$ ). A reversal to baseline was implemented and increases in responding again were obtained in both (C1:  $m=28.4$ , C2:  $m=31.0$ ). Finally, another evaluation of NCR was conducted and the lowest overall response rates obtained in the NCR condition ( $m=4.7$ ) were obtained relative to the VI 30 s condition ( $m=19.5$ ).



The top panel of Figure 4-2 displays the results from the initial presentation of each treatment for subject 2102. In the MULT VI 30 s VI 30 s baseline condition, lever pressing increased and similar rates of responding were obtained across both components (C1:  $m=27.2$ , C2:  $m=26.6$ ). In the next condition, C1 was changed to NCR 30 s and C2 remained at VI 30 s (i.e., MULT NCR 30 s VI 30 s). Lever pressing was lower in the NCR condition ( $m=5.1$ ) relative to the VI 30 s condition ( $m=13.7$ ). Next, the MULT VI 30 s VI 30 s condition was implemented and increases in responding were obtained in both components (C1:  $m=17.3$ , C2:  $m=16.9$ ). Next, the mDRO treatment was evaluated in the MULT VI 30 s mDRO 10 s condition and lower rates of lever pressing ( $m=2.2$ ) were obtained relative to the VI 30 s condition ( $m=11.6$ ). The bottom panel of Figure 4-2 displays the results for the second presentation of each treatment for subject 2102. A reversal to baseline was implemented and increases in responding in both components were obtained (C1:  $m=24.1$ , C2:  $m=26.2$ ). During the second presentation of mDRO, further decreases in responding ( $m=1.5$ ) were obtained relative to the VI 30 s condition ( $m=9.0$ ). Another reversal to baseline was implemented and again increases in responding (C1:  $m=9.3$ , C2:  $m=9.7$ ) were obtained in both components. Finally, a second presentation of NCR was conducted and low overall response rates were obtained ( $m=2.3$ ) relative to the VI 30 s condition ( $m=8.9$ ).

The top panel of Figure 4-3 displays the results from the initial presentation of each treatment for subject 2103. In the MULT VI 30 s VI 30 s baseline condition, lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=10.1$ , C2:  $m=10.3$ ). In the next condition, C2 was changed to mDRO 10 s and C1 remained at VI 30 s (i.e., MULT VI 30 s mDRO 10 s). Lever pressing was lower in the mDRO condition ( $m=2.4$ ) relative to the VI 30 s condition ( $m=9.0$ ). Next, the MULT VI 30 s VI 30 s condition was implemented

and increases in responding were obtained in both components (C1:  $m=9.7$ , C2:  $m=9.5$ ). Next, the NCR treatment was evaluated in the MULT NCR 30 s VI 30 s condition and lower rates of lever pressing ( $m=1.8$ ) were obtained relative to the VI 30 s condition ( $m=9.3$ ). The bottom panel of Figure 4-3 displays the results for the second presentation of each treatment for subject 2103. A reversal to baseline was implemented and increases in responding in both components was obtained (C1:  $m=11.2$ , C2:  $m=10.6$ ). During the second presentation of NCR, further decreases in responding ( $m=1.5$ ) were obtained relative to the VI 30 s condition ( $m=8.3$ ). Another reversal to baseline was implemented and again increases in responding (C1:  $m=9.7$ , C2:  $m=9.4$ ) were obtained in both components. Finally, a second evaluation of mDRO was conducted and low overall response rates were obtained ( $m=1.2$ ) relative to the VI 30 s condition ( $m=7.8$ ).

The top panel of Figure 4-4 displays the results from the initial presentation of each treatment for subject 2106. In the MULT VI 30 s VI 30 s baseline condition, lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=5.9$ , C2:  $m=5.9$ ). In the next condition, C2 was changed to mDRO 10 s and C1 remained at VI 30 s (i.e., MULT VI 30 s mDRO 10 s). Lever pressing was lower in the mDRO condition ( $m=1.5$ ) relative to the VI 30 s condition ( $m=6.8$ ). Next, the MULT VI 30 s VI 30 s condition was implemented and increases in responding were obtained in both components (C1:  $m=9.2$ , C2:  $m=8.8$ ). Next, the NCR treatment was evaluated in the MULT NCR 30 s VI 30 s condition and lower rates of lever pressing ( $m=2.2$ ) were obtained relative to the VI 30 s condition ( $m=9.6$ ). The bottom panel of Figure 4-4 displays the results for the second presentation of each treatment for subject 2106. A reversal to baseline was implemented and increases in responding in both components were obtained (C1:  $m=7.3$ , C2:  $m=7.6$ ). During the second presentation of NCR, further decreases in responding ( $m=1.7$ ) were obtained relative to the VI 30 s condition ( $m=8.9$ ). Another reversal to

baseline was implemented and again increases in responding (C1:  $m=10.1$ , C2:  $m= 9.5$ ) were obtained in both components. Finally, a second evaluation of mDRO was conducted and low overall response rates were obtained ( $m=1.6$ ) relative to the VI 30 s condition ( $m=10.2$ ).

Table 4-1 shows the summary statistics for all subjects in Experiment 2. For all subjects, the overall response rates, average response rates for the first and final 10 components of each treatment, and overall reinforcement rates for the first and second treatment evaluations were calculated. For all subjects, mDRO generally resulted in lower overall response rates, and lower response rates in the first and final 10 components of the evaluation. In addition, for all subjects, slightly higher reinforcement rates were obtained in the NCR condition.

In Experiment 2, the effects of NCR and mDRO were evaluated in isolation on rates of lever pressing in rats. Exposure to each treatment was counterbalanced across subjects and the number of exposures of the treatments was equated within subjects to ensure a fair comparison of the treatment conditions. The results generally showed that each treatment resulted in decreases in lever pressing from the baseline condition. Yet, slightly greater decreases in responding were obtained during the mDRO condition than NCR condition. This finding was consistent in subjects regardless of the order of presentation (e.g., if mDRO was the first treatment evaluated). That is, higher overall rates were generally obtained in the NCR condition when it was the second treatment presented. Thus, a previous history with mDRO did not seem to positively affect (i.e., result in lower response rates) the subsequent NCR treatment condition. However, lower overall response rates were obtained during the second implementation of each treatment. Therefore, it is possible that the previous history with both treatments resulted in decreases in overall response rates throughout the analysis.

Although each treatment showed similar reductions in responding when evaluated

individually as when evaluated in combination (Experiment 1), more exposures to each component were necessary to obtain low levels of responding. It is possible that exposing the subjects to the VI 30 s condition (or another response-dependent reinforcement schedule) during the treatment evaluation delayed treatment effects. In addition, it is possible that all treatments would be more effective when combined with another treatment (Experiment 1) or evaluated in the absence of a response dependent schedule. However, the method used in Experiment 2 facilitated comparison of the treatments and prevented interaction effects during the evaluation.

The results from Experiment 2 indicate that mDRO generally produced greater reductions in response rates than NCR, but these differences were modest across all subjects. That being said, even if similar reductions were obtained in both NCR and mDRO, the advantages of mDRO potentially outweigh NCR in the treatment of problem behavior because it eliminates the risk of accidental reinforcement. One limitation of the current experiment is that response reinforcer pairings during NCR were not evaluated. Although increased rates of responding were obtained during NCR for one subject (i.e., 2101), a within session analysis of response rates is necessary to determine the possibility of accidental reinforcement. However, that analysis was beyond the scope of the current investigation.

Given that mDRO is effective, it is intuitive that WI DRO would be effective. However, a comparison of reinforcement rates is warranted. If mDRO yields higher reinforcement rates, it might protect against intolerably low levels of reinforcement during behavior treatment. The purpose of Experiment 3 was to evaluate mDRO and DRO.

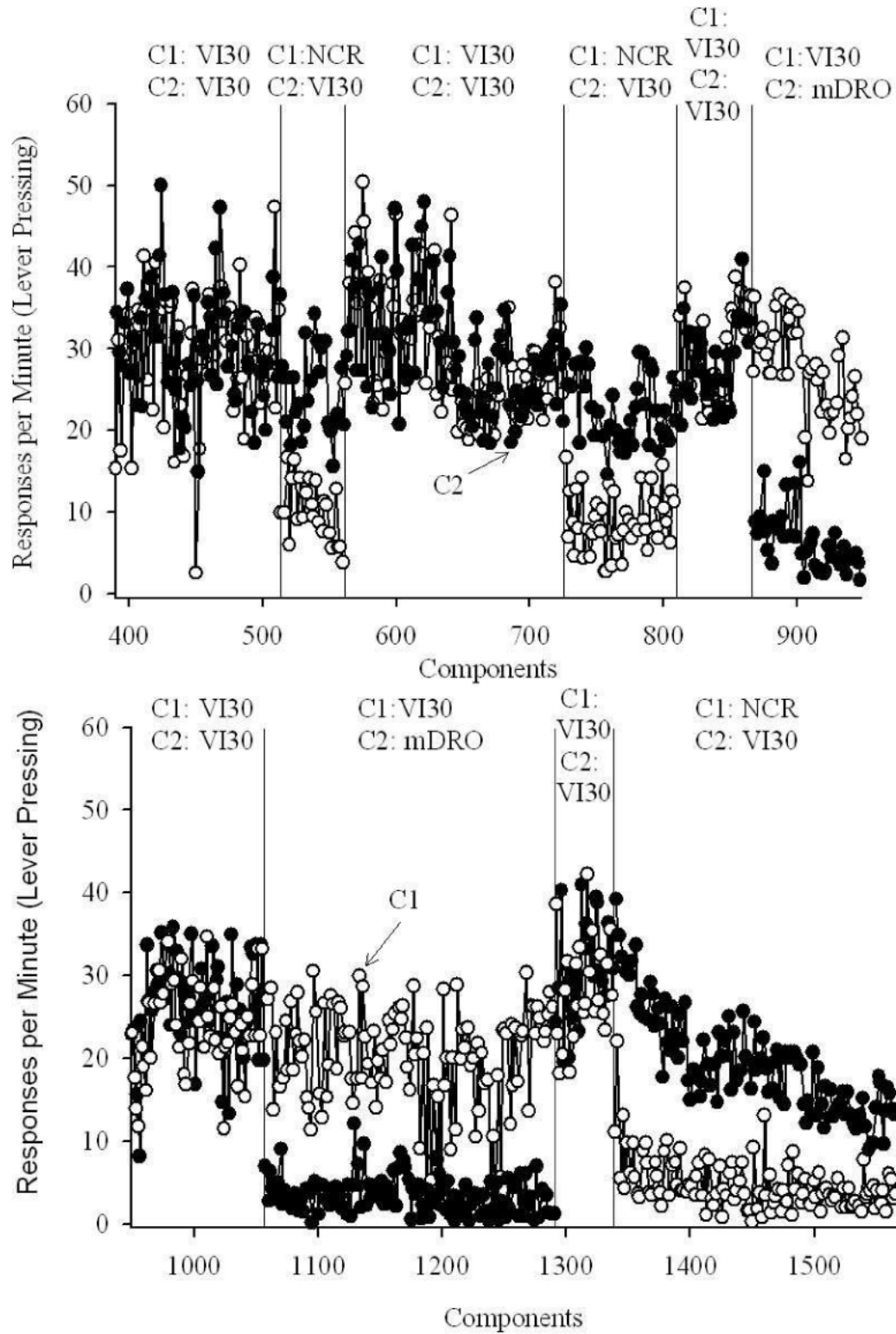


Figure 4-1. Subject 2101: overall response rates in the first and second presentation of each treatment

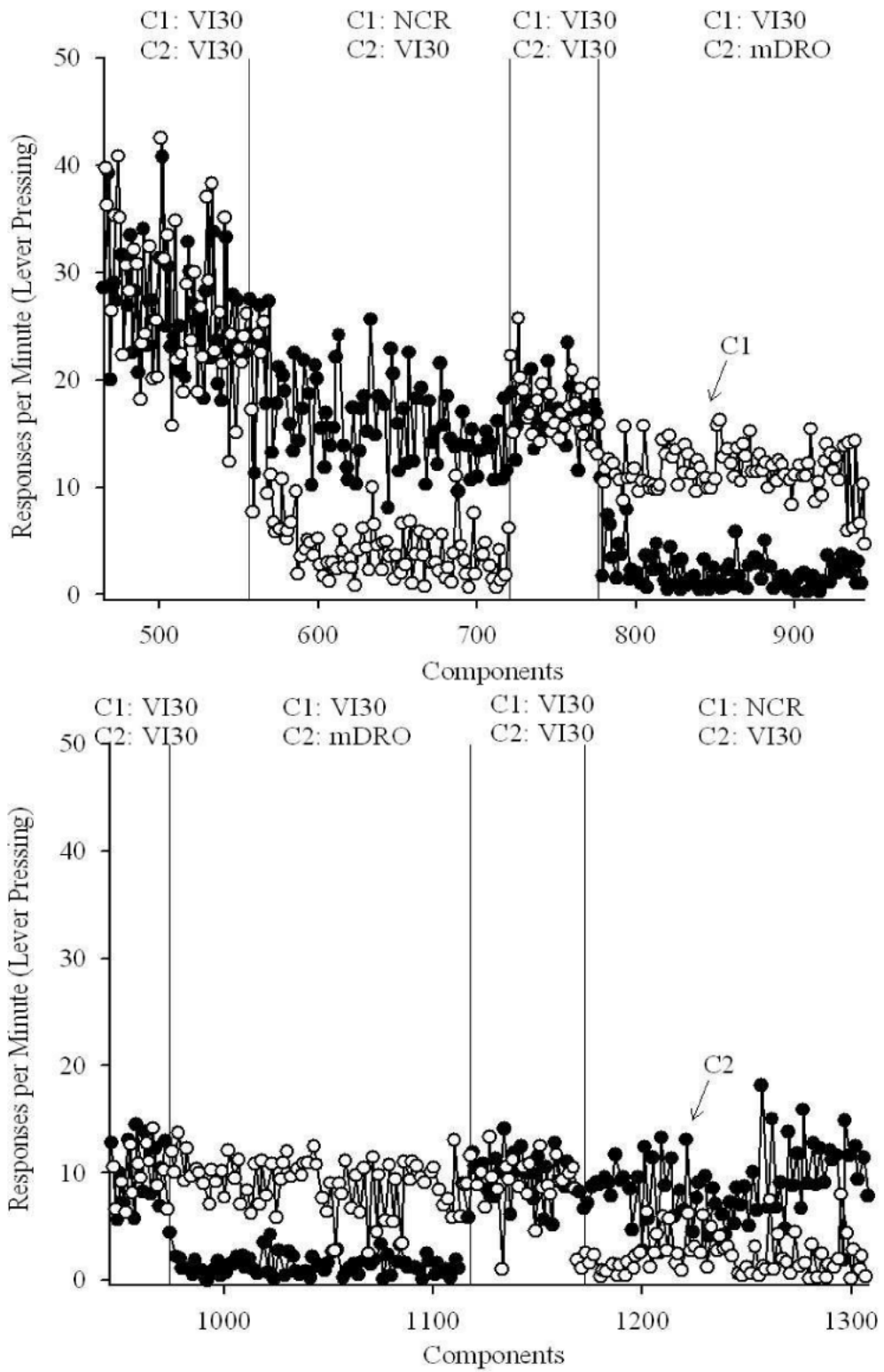


Figure4-2. Subject 2102: overall response rates in the first and second presentation of each treatment

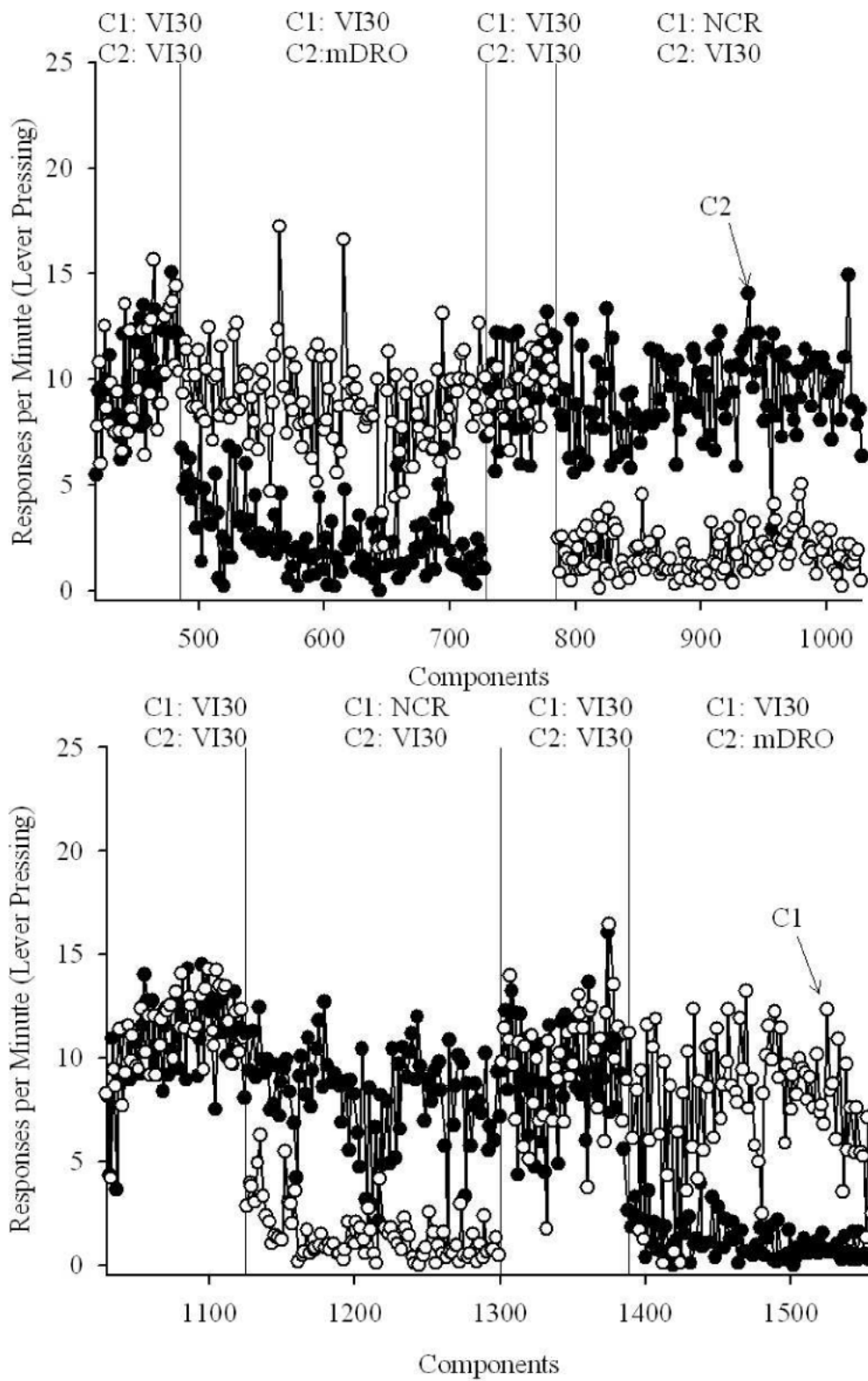


Figure 4-3. Subject 2103: overall response rates in the first and second presentation of each treatment

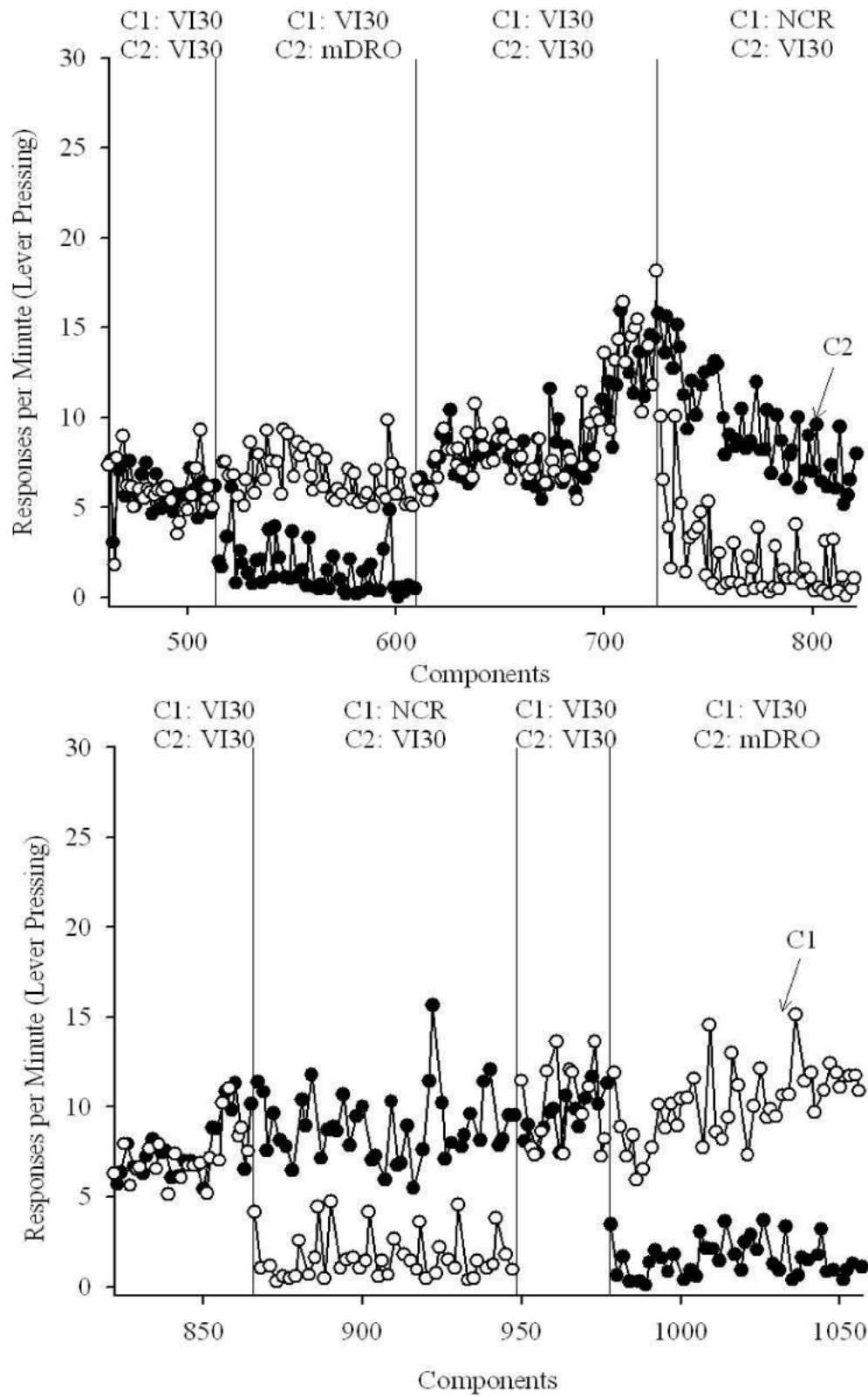


Figure 4-4. Subject 2106: overall response rates in the first and second presentation of each treatment



Table 4-1. Summary statistics for each presentation (pres.) of NCR and mDRO for all subjects (subj.) in experiment 2.

Subj.- Pres.	RPM (all)		RPM (1 <sup>st</sup> 10)		RPM (last 10)		R of Sr (all)	
	NCR (VI)	mDRO (VI)	NCR (VI)	mDRO (VI)	NCR (VI)	mDRO (VI)	NCR	mDRO
2101-1	8.9 (22.7)	6.6 (27.2)	9.7 (26.3)	9.3 (30.7)	10.5 (22.3)	3.9 (23.9)	1.9	1.6
2101-2	4.7 (19.5)	3.5 (20.0)	9.1 (32.5)	4.6 (21.4)	3.6 (14.6)	2.7 (25.1)	1.9	1.8
2102-1	5.1 (13.7)	2.2 (11.6)	13.6 (16.5)	4.9 (12.0)	3.0 (21.1)	2.5 (9.7)	1.9	1.7
2102-2	2.3 (8.9)	1.5 (9.1)	1.5 (8.7)	1.4 (10.7)	2.4 (10.5)	1.2 (8.7)	1.9	1.8
2103-1	1.8 (9.3)	2.4 (9.0)	1.7 (8.7)	4.7 (9.9)	1.4 (9.6)	1.3 (9.9)	1.9	1.8
2103-2	1.5 (8.3)	1.2 (7.8)	3.2 (9.8)	2.5(7.6)	1.0 (7.7)	0.9 (5.8)	1.9	1.8
2106-1	2.2 (9.6)	1.5 (6.8)	5.0 (13.0)	2.3 (7.1)	1.0 (7.1)	1.1 (6.3)	1.9	1.8
2106-2	1.7 (8.9)	1.6 (10.2)	1.3 (9.3)	1.2 (8.6)	1.7 (9.3)	1.4 (11.4)	1.9	1.8

CHAPTER 5  
EXPERIMENT 3: LABORATORY EVALUATION OF DRO AND MDRO

**Method**

The purpose of Experiment 3 was to evaluate the effects of DRO and mDRO in terms of rates of lever pressing and rates of reinforcement. Four subjects were included in Experiment 3. Two of the subjects had previously been exposed to a preliminary treatment comparison (2104 and 2105). In addition, two naïve subjects were included.

As in Experiment 2, only one treatment was introduced at a time for each subject. That is, when one component was changed to a treatment condition (e.g., DRO 30 s), the other component remained as VI 30 s. In order to partially control for order of presentation, two subjects were exposed to the DRO treatment condition first, and two subjects were exposed to the mDRO treatment condition first. Each subject was exposed to two presentations of each treatment. The exception was subject 2105, for which each treatment was evaluated once. The number of component exposures of each treatment evaluation was kept constant within each subject. For example, if a subject received 100 components of the initial DRO presentation, it received 100 components of the initial presentation of mDRO. The order of conditions for subjects who received the DRO treatment first was ABACACAB. The order of conditions for subjects who received the mDRO treatment first was ACABABAC for one subject and ACAB for the other subject. A represents the MULT VI 30 s VI 30 s baseline condition, B represents the MULT DRO 30 s VI 30 s treatment conditions, and C represents the MULT VI 30 s mDRO 10 s treatment condition. Component 1 (C1) of the multiple schedule (VI 30 s, DRO 30 s) was signaled by illuminating the leftmost stimulus light and Component 2 (C2) of the multiple schedule (VI 30 s, mDRO 10 s) was signaled by illuminating the center stimulus light.

## Results and Discussion

Figures 5-1 through 5-4 show the results for all subjects. In each of the graphs, components are plotted on the x-axis and responses per minute (rpm) of lever pressing are plotted on the y-axis. The top and bottom panel of each figure display the results for one subject in the experiment. Due to the larger number of component presentations, the graphs have been separated into the initial and subsequent presentation for each treatment. The top panel of Figure 5-1 displays the results from the initial presentation of each treatment for subject 2104. In the MULT VI 30 s VI 30 s baseline condition, lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=46.9$ , C2:  $m=45.7$ ). In the next condition, C1 was changed to resetting DRO 30 s and C2 remained at VI 30 s (i.e., MULT DRO 30 s VI 30 s). Lever pressing was lower in the DRO condition ( $m=3.3$ ) relative to the VI 30 s condition ( $m=19.6$ ). Next, the MULT VI 30 s VI 30 s condition was implemented and increases in responding were obtained in both components (C1:  $m=34.8$ , C2:  $m=33.9$ ). Next, the mDRO treatment was evaluated in the MULT VI 30 s mDRO 10 s condition and lower rates of lever pressing ( $m=2.3$ ) were obtained relative to the VI 30 s condition ( $m=24.5$ ). The bottom panel of Figure 5-1 displays the results for the second presentation of each treatment for subject 2104. A reversal to baseline was implemented and increases in responding in both components was obtained (C1:  $m=30.9$ , C2:  $m=33.4$ ). During the second presentation of mDRO, slightly higher rates of responding ( $m=3.4$ ) than the initial mDRO presentation were obtained; however, rates were lower relative to the VI 30 s condition ( $m=30.1$ ). Another reversal to baseline was implemented and again increases in responding (C1:  $m=36.2$ , C2:  $m=34.2$ ) were obtained in both components. Finally, a second evaluation of DRO was conducted. Overall response rates were higher compared to the initial DRO evaluation ( $m=6.0$ ), however, were lower relative to the VI 30 s condition ( $m=28.4$ ).

The top panel of Figure 5-2 displays the results from the initial presentation of each treatment for subject 2201. In the no pellet (NP) condition, very low levels of responding were obtained ( $m=0.02$ ). After lever pressing training, the MULT VI 30 s VI 30 s baseline condition was implemented and lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=18.3$ , C2:  $m= 19.6$ ). In the next condition, C2 was changed to mDRO 10 s and C1 remained at VI 30 s (i.e., MULT VI 30 s mDRO 10 s). Lever pressing was lower in the mDRO condition ( $m=2.7$ ) relative to the VI 30 s condition ( $m=8.7$ ). After component 215 of this condition, a marked decrease in both components was noted, which was associated with a veterinary mandated change to medicated post-session food to prevent pinworms. The change in food was documented and the evaluation was continued. Next, the MULT VI 30 s VI 30 s condition was implemented and increases in responding were obtained in both components (C1:  $m=7.6$ , C2:  $m= 8.1$ ). Next, the DRO treatment was evaluated in the MULT DRO 30 s VI 30 s condition and lower rates of lever pressing ( $m=1.8$ ) were obtained relative to the VI 30 s condition ( $m=8.0$ ). The bottom panel of Figure 5-2 displays the results for the second presentation of each treatment for subject 2201. A reversal to baseline was implemented and increases in responding in both components were obtained (C1:  $m=17.0$ , C2:  $m= 17.0$ ). After component 812, the post-session medicated food was changed back to the regular post-session feed and responding increased. During the second presentation of DRO, lower response rates ( $m=3.0$ ) were obtained relative to the VI 30 s condition ( $m=15.8$ ). Another reversal to baseline was implemented and again increases in responding (C1:  $m=19.5$ , C2:  $m= 19.2$ ) were obtained in both components. Finally, a second evaluation of mDRO was conducted and low overall response rates were obtained ( $m=2.3$ ) relative to the VI 30 s condition ( $m=18.7$ ).

The top panel of Figure 5-3 displays the results from the initial presentation of each

treatment for subject 2202. In the NP condition, very low levels of responding were obtained ( $m=0.1$ ). In the MULT VI 30 s VI 30 s baseline condition, lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=20.9$ , C2:  $m=21.5$ ). In the next condition, C1 was changed to resetting DRO 30 s and C2 remained at VI 30 s (i.e., MULT DRO 30 s VI 30 s). Lever pressing was lower in the DRO condition ( $m=2.9$ ) relative to the VI 30 s condition ( $m=13.3$ ). During this condition (component 213), there was a veterinary mandated change to medicated food. After a brief decrease in responding associated with the food change, response rates returned to high steady levels in the VI 30 s condition. Next, the MULT VI 30 s VI 30 s condition was implemented and increases in responding were obtained in both components (C1:  $m=25.1$ , C2:  $m=24.1$ ). Next, the mDRO treatment was evaluated in the MULT VI 30 s mDRO 10 s condition and lower rates of lever pressing ( $m=3.9$ ) were obtained relative to the VI 30 s condition ( $m=24.6$ ). The bottom panel of Figure 5-3 displays the results for the second exposure of each treatment for subject 2202. A reversal to baseline was implemented and increases in responding in both components was obtained (C1:  $m=27.0$ , C2:  $m=27.8$ ). During this condition (after component 816), the medicated food was changed back to the normal post-session feed and response rates increased in both components. During the second presentation of mDRO, further decreases in response rates ( $m=1.8$ ) were obtained relative to the VI 30 s condition ( $m=19.6$ ). Another reversal to baseline was implemented and again increases in responding (C1:  $m=21.1$ , C2:  $m=21.9$ ) were obtained in both components. Finally, a second evaluation of DRO was conducted and low overall response rates were obtained ( $m=3.2$ ) relative to the VI 30 s condition ( $m=18.0$ ).

Figure 5-4 displays the results for subject 2105. In the MULT VI 30 s VI 30 s baseline condition, lever pressing increased and similar rates of responding were obtained in both

components (C1:  $m=14.7$ , C2:  $m= 15.8$ ). In the next condition, C2 was changed to mDRO 10 s and C1 remained at VI 30 s (i.e., MULT VI 30 s mDRO 10 s). Lever pressing was lower in the mDRO condition ( $m=1.7$ ) relative to the VI 30 s condition ( $m=11.5$ ). Next, the MULT VI 30 s VI 30 s condition was implemented and increases in responding were obtained in both components (C1:  $m=14.7$ , C2:  $m= 14.7$ ). Next, the DRO treatment was evaluated in the MULT DRO 30 s VI 30 s condition and lower rates of lever pressing ( $m=2.4$ ) were obtained relative to the VI 30 s condition ( $m=11.1$ ).

Table 5-1 shows the summary statistics for all subjects in Experiment 3. The top portion of the table shows the results from the response rate analysis for both treatments which were conducted in a similar manner to Experiments 1 and 2. However, additional analyses of reinforcement rates throughout the condition were also conducted for Experiment 3 and are shown on the bottom portion of the table. For all subjects, the overall response rates and average response rates of the first and final 10 components of each treatment were calculated. For three of the subjects, mDRO resulted in lower overall response rates, and lower response rates in the first and final 10 components of the evaluation.

Slightly overall higher response rates were obtained in the second presentation of DRO for all subjects, and mixed effects (i.e., one subject exhibited higher response rates, two lower response rates) were obtained during the second mDRO treatment presentation. For example, for subject 2104, DRO was the first and fourth treatment presented in the evaluation and mDRO was the second and third treatment presented. For this subject, the highest response rates in the entire evaluation were obtained in the second presentation of DRO (fourth treatment presented overall). Thus, it appears for some subjects that a previous history with the treatment schedules did not affect response rates. The fact that DRO resulted in higher overall response rates than mDRO for

some subjects was surprising. However, this effect may be due to difference in rates of reinforcement in the treatment conditions.

The results from the analysis of overall reinforcement rates are presented in the bottom portion of the table and higher reinforcement rates are indicated in bold. The results showed that higher reinforcement rates were obtained in the mDRO condition across the entire condition (i.e., overall), first 10 components and final 10 components of each treatment. Higher reinforcement rates are likely due to both the NCR component and the shorter resetting feature of the DRO schedule. That is, only responses at the end of the interval affected reinforcer deliveries, and responding only needed to be absent in the last 10 s for a reinforcer to be delivered. In contrast, lower reinforcement rates were obtained in the DRO condition. Even though this condition also had a resetting feature, responding needed to be absent for the entire interval (i.e., 30 s) for a reinforcer to be delivered and this could have contributed to the lower reinforcement rates. Lower rates of reinforcement may have made the DRO condition more akin to an extinction schedule, which may have contributed to the overall higher response rates for some subjects.

In addition to reinforcement rates, the percent increase in reinforcement rate from the DRO to mDRO condition was calculated by subtracting the rate of reinforcement in the DRO condition from the rate of reinforcement in the mDRO condition and dividing by the rate of reinforcement in the DRO condition (bottom portion of Table 4-1). Although increases were obtained across each of the analyses (e.g., first 10 components, overall), the lowest increases were obtained in the final 10 components of the treatment and the greatest increases were obtained in the first 10 presentations of the treatments. The average increase for the analysis was 52.3% and ranged from a 12% increase for one subject (in the final 10 components comparison) to a 143% increase for another subject (in the first 10 components comparison).

Although mDRO produced increases in reinforcement rate relative to DRO, DRO generally averaged at least one reinforcer per minute across each component. However, on some occasions, DRO resulted in fewer and sometimes zero reinforcer deliveries in a component. In contrast, for all subjects, mDRO always produced greater than one reinforcer per minute in each component. For subject 2104, in 156 components of DRO, 17 components produced less than one reinforcer per minute. Of those 17 components, four produced a reinforcement rate of less than one reinforcer per two minutes and two produced zero reinforcer deliveries. For subject 2105, in 36 components of DRO, five components produced less than one reinforcer per minute. Of those five components, one produced a reinforcement rate of less than one reinforcer every two minutes. For subject 2201, in 159 components of DRO, 43 components produced less than one reinforcer per minute. Of those 43 components, 15 produced a reinforcement rate of less than one reinforcer per two minutes and one produced zero reinforcer deliveries. For subject 2202, in 130 components of DRO, 32 components produced less than one reinforcer per minute. Of those 32 components, one produced a reinforcement rate of less than one reinforcer per two minutes.

Thus, the results from Experiment 3 indicate that in most cases, mDRO produced lower levels of responding than DRO and in all cases produced higher rates of reinforcement. Given the potential disadvantages of DRO cited in the literature (i.e., low rates of reinforcement, difficulty with implementation), mDRO may be a more effective and practical treatment.

One potential limitation of Experiments 1 through 3 was that the mDRO schedule involved a relatively large DRO component (i.e., 10 s) which resets upon the occurrence of behavior. Although previous studies have used similar schedules (e.g., Britton et al., 2000, Hagopian et al., 1998), other studies have effectively used 1-s DRO intervals (similar to Lindberg et al., 2000) or



intervals which do not reset (e.g., Vollmer et al. 1997). Therefore, larger DRO intervals may not be necessary to reduce responding, but may be more akin to how these schedules are implemented in clinical settings. That is, there is typically some delay between the “moment” the interval ends and the reinforcer delivery such as the time it takes to approach or deliver items to individuals. To date, no study has compared the effectiveness of variations of mDRO. Thus, the purpose of Experiment 4 was to evaluate the effectiveness of the initial mDRO schedule (i.e., resetting mDRO 10 s) and non-resetting mDRO 1 s in a laboratory setting.

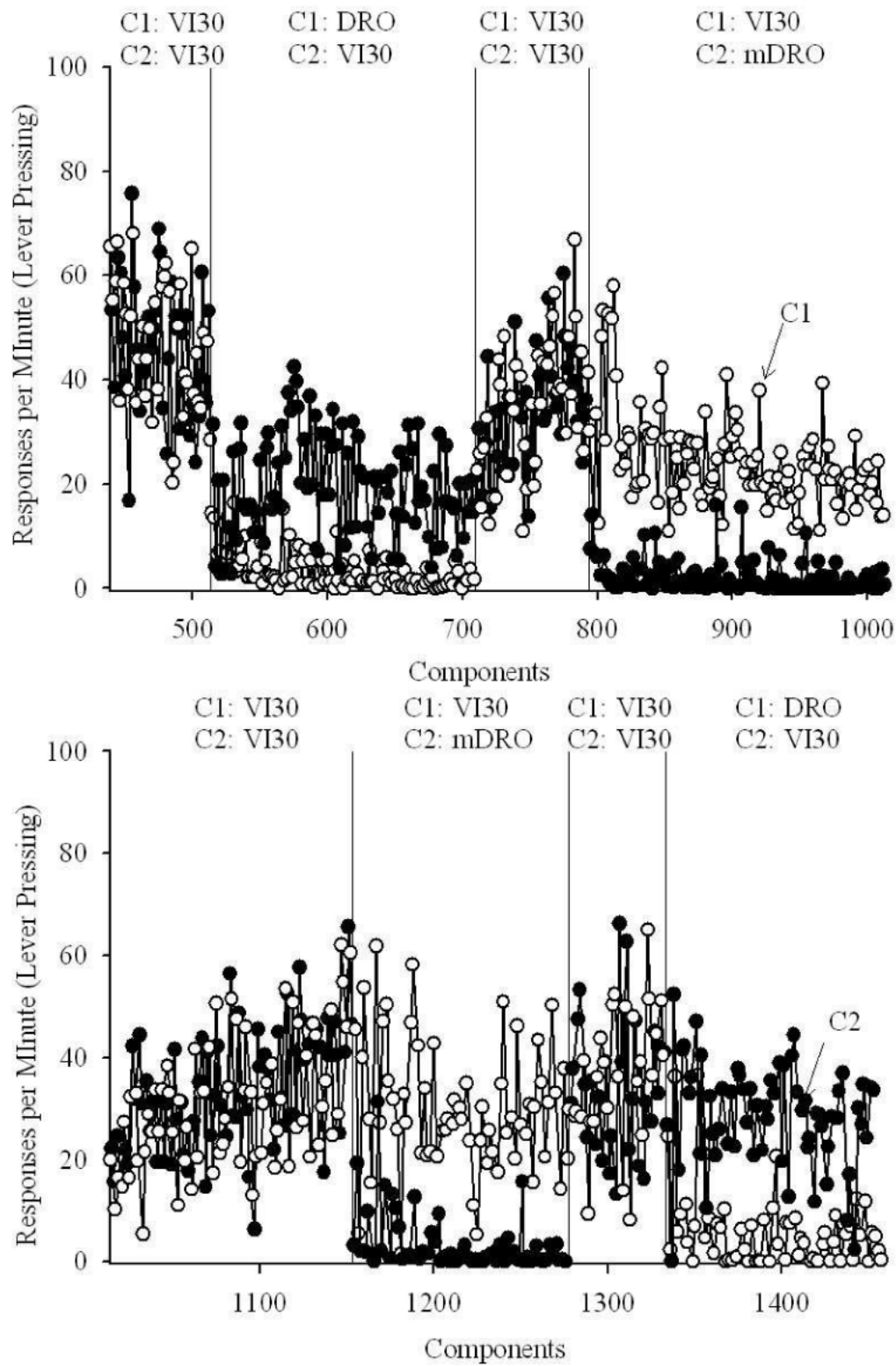


Figure 5-1. Subject 2104: overall response rates in the first and second presentation of each treatment

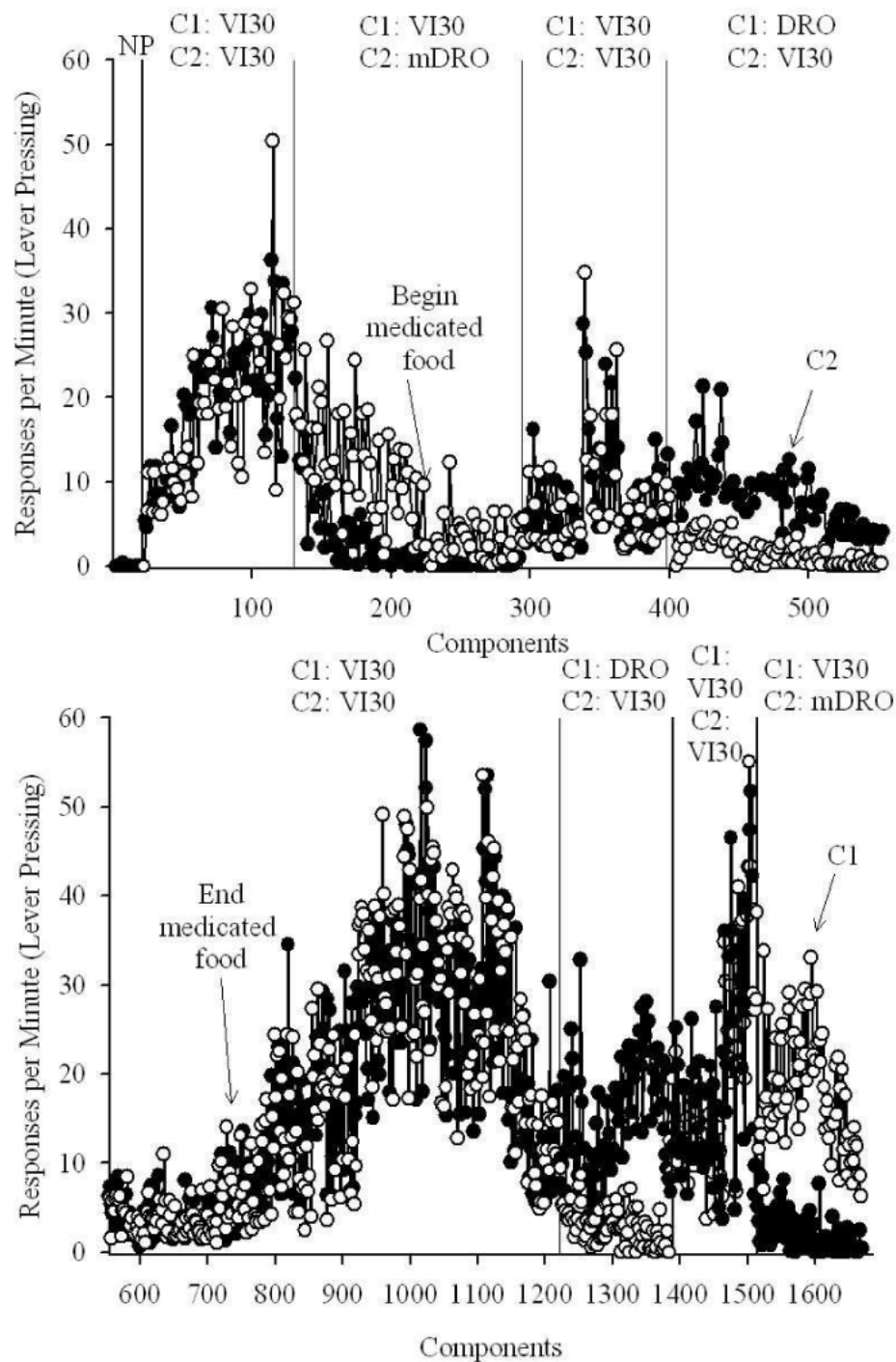


Figure 5-2. Subject 2201: overall response rates in the first and second presentation of each treatment

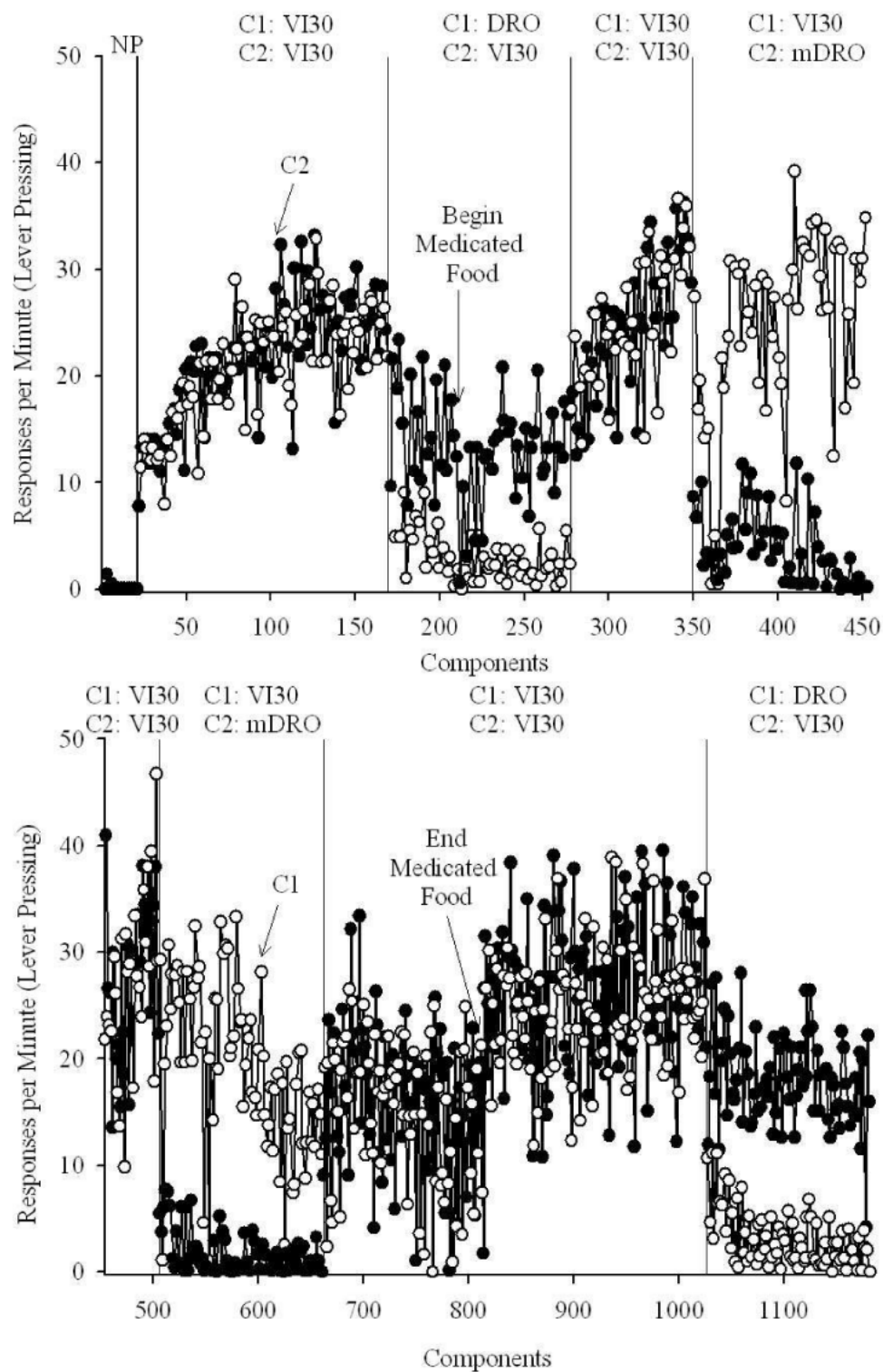


Figure 5-3. Subject 2202: overall response rates in the first and second presentation of each treatment

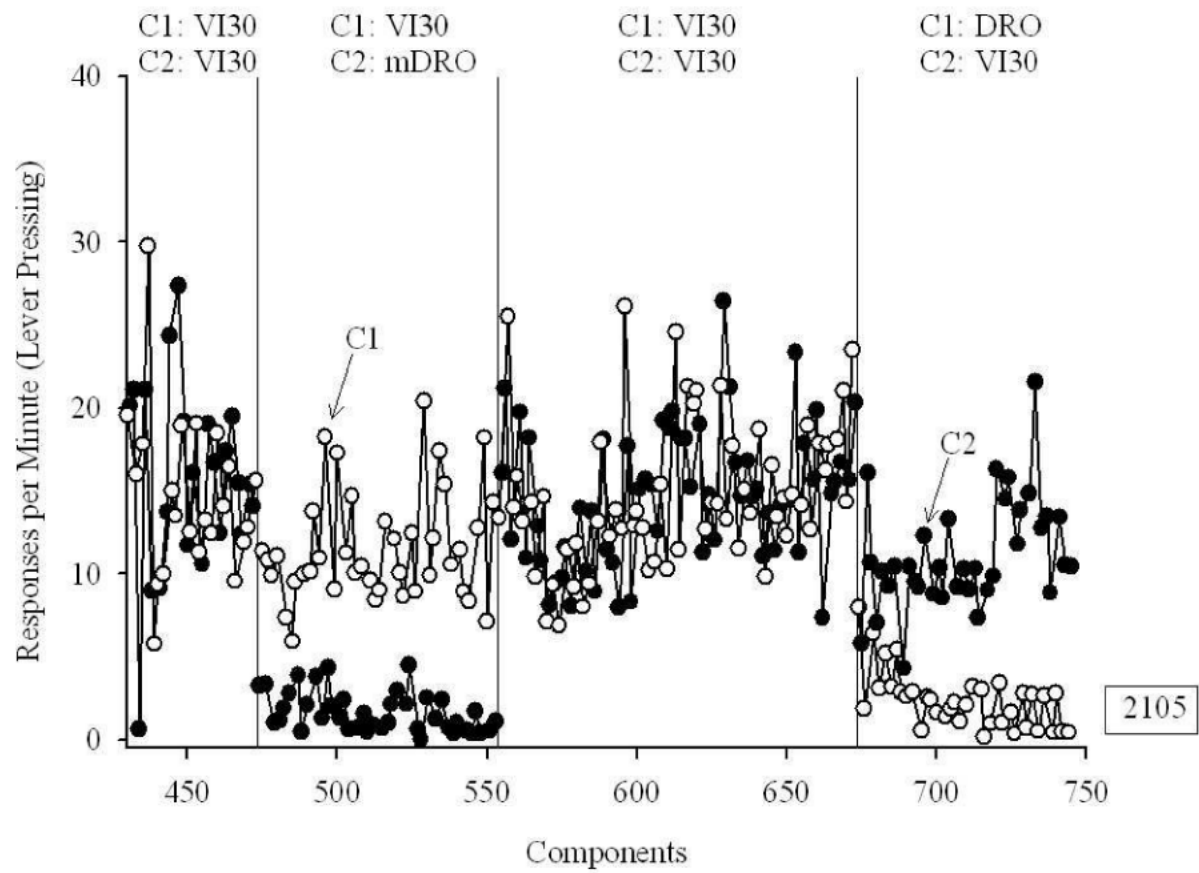


Figure 5-4. Subject 2105: overall response rates in the presentation of each treatment

Table 5-1. Summary statistics for each presentation (pres.) of DRO and mDRO for all subjects (subj.) in experiment 3.

Response Rate Analysis									
Subj.-Pres.	RPM (overall)			RPM (1 <sup>st</sup> 10)			RPM (last 10)		
	DRO (VI)	mDRO (VI)		DRO (VI)	mDRO (VI)		DRO (VI)	mDRO (VI)	
2104-1	3.3 (19.6)	2.3 (24.5)		8.0 (13.8)	4.8 (38.2)		1.9 (15.2)	1.2 (19.2)	
2104-2	6.3 (28.4)	3.4 (30.1)		13.7 (1.8)	8.6 (37.5)		6.0 (24.8)	1.4(31.6)	
2201-1	1.8 (8.0)	2.7 (8.7)		4.0 (9.4)	11.5 (17.9)		0.3 (3.5)	0.4 (2.8)	
2201-2	3.0 (15.8)	2.3 (18.7)		5.2 (15.0)	5.6 (22.0)		1.4 (17.0)	0.9 (10.2)	
2202-1	2.9 (13.3)	3.9 (25.0)		5.4 (15.8)	4.3 (14.0)		2.5 (14.1)	0.7 (28.4)	
2202-2	3.2 (18.0)	1.8 (19.6)		7.3 (19.4)	4.3 (23.8)		1.7 (15.6)	0.1 (13.3)	
2105-1	2.4(11.5)	1.7(11.1)		4.2 (9.5)	2.4 (9.9)		1.4 (12.7)	0.9 (11.6)	

Rate of Reinforcement Analysis									
Subj.-Pres.	Sr Rate (overall)			Sr Rate (1 <sup>st</sup> 10)			Sr Rate (last 10)		
	DRO	mDRO	% incr. in Sr rate	DRO	mDRO	% incr. in Sr rate	DRO	mDRO	% incr. in Sr rate
2104-1	1.3	1.8	39	1.0	1.7	70	1.5	1.9	27
2104-2	1.4	1.7	21	1.0	1.7	70	1.2	1.9	58
2201-1	1.4	1.8	29	0.8	1.5	88	1.7	1.9	12
2201-2	1.2	1.8	50	0.7	1.7	143	1.5	1.8	20
2202-1	1.2	1.8	50	1.0	1.7	70	1.3	1.9	46
2202-2	1.2	1.8	50	0.8	1.6	100	1.5	1.8	20
2105-1	1.3	1.8	39	1.0	1.7	70	1.5	1.9	27

CHAPTER 6  
EXPERIMENT 4: LABORATORY EVALUATION OF mDRO 10 S AND mDRO 1 S

**Method**

The purpose of Experiment 4 was to evaluate the effects of mDRO 10 s and mDRO 1 s on rates of lever pressing. Three experimentally naïve male Wistar rats served as subjects in Experiment 4 (2301, 2304, and 2305). A fourth subject was excluded from the study due to failure to respond in the baseline condition.

As in Experiments 2 and 3, only one treatment was introduced at a time for each subject. That is, when one component was changed to a treatment condition (e.g., mDRO 1 s), the other component remained as VI 30 s. In order to partially control for order of presentation, two subjects were exposed to the mDRO 1 s treatment condition first, and one subject was exposed to the mDRO 10 s treatment condition first. In addition, the number of component exposures of each treatment evaluation was kept constant within each subject. For example, if a subject received 100 components of the initial presentation of mDRO 10 s, it received 100 components of the initial presentation of mDRO 1 s. The order of conditions for subjects who received the mDRO 1 s treatment first was DABACACAB for both subjects. The order of conditions for the subject who received the mDRO 10 s treatment first was DACABABAC. D represents the no pellet (NP) condition, A represents the MULT VI 30 s VI 30 s baseline condition, B represents the MULT mDRO 1 s VI 30 s treatment conditions, and C represents the MULT VI 30 s mDRO 10 s treatment condition. Component 1 (C1) of the multiple schedule (VI 30 s, mDRO 1 s) was signaled by illuminating the leftmost stimulus light and Component 2 (C2) of the multiple schedule (VI 30 s, mDRO 10 s) was signaled by illuminating the center stimulus light.

**Results and Discussion**

Figures 6-1 through 6-3 show the results from all subjects in Experiment 3. In each of the

graphs, components are plotted on the x-axis and responses per minute (rpm) of lever pressing are plotted on the y-axis. The top and bottom panel of each figure display the results for one subject in the experiment. Due to the larger number of component presentations, the graphs have been separated into the initial and subsequent presentation for each treatment. The top panel of Figure 6-1 shows the results from initial presentation of each treatment for subject 2301. In the NP condition, low rates of responding were obtained ( $m=0.7$ ). In the MULT VI 30 s VI 30 s baseline condition, lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=22.1$ , C2:  $m= 21.7$ ). In the next condition, C1 was changed to mDRO 1 s and C2 remained at VI 30 s (i.e., MULT mDRO 1 s VI 30 s). Lever pressing was lower in the mDRO 1 s condition ( $m=7.7$ ) relative to the VI 30 s condition ( $m=29.4$ ). The MULT VI 30 s VI 30 s condition was implemented and increases in responding in both components were obtained (C1:  $m=42.5$ , C2:  $m= 47.8$ ). Next, the MULT VI 30 s mDRO 10 s condition was implemented and lower rates of lever pressing in the mDRO 10 s condition ( $m=3.3$ ) relative to the VI 30 s condition ( $m=27.4$ ) were obtained. Due to the large number of components necessary to decrease responding in the mDRO 1 s condition (i.e., 118 component exposures) and relatively rapid decrease in responding in the mDRO 10 s condition (i.e., < 50 component exposures), the number of component exposures was reduced in the initial mDRO 10 s condition and therefore not matched to the initial mDRO 1 s condition. The bottom panel of Figure 6-1 shows the results for the second presentation of each treatment condition. The MULT VI 30 s VI 30 s condition was implemented and increases in responding were obtained in both components (C1:  $m=23.3$ , C2:  $m= 21.6$ ). During the second presentation of mDRO 10 s, further decreases in responding ( $m=1.8$ ) were obtained relative to the baseline condition ( $m=19.6$ ). A reversal to baseline was implemented and increases in responding again were obtained in both components (C1:  $m=28.1$ ,



C2:  $m=25.9$ ). Finally, a second evaluation of mDRO 1 s was conducted and low overall response rates ( $m=4.1$ ) were obtained relative to the VI 30 s condition ( $m=20.1$ ).

The top panel of Figure 6-2 displays the results from the initial presentation of each treatment for subject 2304. In the NP condition, moderate levels of responding were obtained ( $m=1.4$ ). In the MULT VI 30 s VI 30 s baseline condition, lever pressing increased and similar rates of responding were obtained in both components (C1:  $m=30.0$ , C2:  $m=28.5$ ). In the next condition, C1 was changed to mDRO 1 s and C2 remained at VI 30 s (i.e., MULT mDRO 1 s VI 30 s). Lever pressing was only slightly lower in the mDRO 1 s condition ( $m=21.6$ ) relative to the VI 30 s condition ( $m=39.4$ ). Next, the MULT VI 30 s VI 30 s condition was implemented and increases in responding were obtained in both components (C1:  $m=60.8$ , C2:  $m=58.5$ ). The mDRO 10 s treatment was then evaluated in the MULT VI 30 s mDRO 10 s condition and lower rates of lever pressing ( $m=7.9$ ) were obtained relative to the VI 30 s condition ( $m=29.7$ ). The bottom panel of Figure 5-2 displays the results for the second presentation of each treatment for subject 2304. A reversal to baseline was implemented and increases in responding in both components were obtained (C1:  $m=31.4$ , C2:  $m=30.4$ ). During the second presentation of mDRO 10 s, further decreases in responding ( $m=4.7$ ) were obtained relative to the VI 30 s condition ( $m=28.5$ ). Another reversal to baseline was implemented and again increases in responding (C1:  $m=33.5$ , C2:  $m=27.6$ ) were obtained in both components. Finally, a second evaluation of mDRO 1 s was conducted and lower rates of lever pressing ( $m=3.3$ ) were obtained relative to the VI 30-s condition ( $m=23.7$ ).

The top panel of Figure 6-3 displays the results from the initial presentation of each treatment for subject 2305. In the NP condition, low rates of responding were obtained ( $m=0.5$ ). In the MULT VI 30 s VI 30 s baseline condition, lever pressing increased and similar rates of

responding were obtained in both components (C1:  $m=23.4$ , C2:  $m= 23.9$ ). In the next condition, C2 was changed to mDRO 10 s and C1 remained at VI 30 s (i.e., MULT VI 30 s mDRO 10 s). Lever pressing was lower in the mDRO 10 s condition ( $m=8.8$ ) relative to the VI 30 s condition ( $m=28.5$ ). Next, the MULT VI 30 s VI 30 s condition was implemented and increases in responding were obtained in both components (C1:  $m=42.0$ , C2:  $m= 44.4$ ). Next, the mDRO 1 s treatment was evaluated in the MULT mDRO 1 s VI 30 s condition and lower rates of lever pressing ( $m=8.7$ ) were obtained relative to the VI 30-s condition ( $m=39.0$ ). The bottom panel of Figure 6-3 displays the results for the second presentation of each treatment for subject 2305. A reversal to baseline was implemented and increases in responding in both components was obtained (C1:  $m=34.4$ , C2:  $m= 37.3$ ). During the second presentation of mDRO 1 s, decreases in responding ( $m=5.7$ ) were obtained relative to the VI 30 s condition ( $m=42.0$ ). Another reversal to baseline was implemented and again increases in responding (C1:  $m=30.2$ , C2:  $m= 33.8$ ) were obtained in both components. Finally, a second evaluation of mDRO 10 s was conducted and lower rates of lever pressing ( $m=3.2$ ) were obtained relative to the VI 30-s condition ( $m=30.0$ ).

Table 6-1 shows the summary statistics for the three subjects in Experiment 4. For all subjects, the overall response rates, average response rates of the first and final 10 components of each treatment, and overall reinforcement rates for the first and second presentations of each treatment condition were calculated. MDRO 10 s generally produced lower overall response rates, and lower response rates in the first and final 10 components of the treatment presentation. mDRO 1 s resulted in higher rates of reinforcement than mDRO 10 s.

For one subject, 2301, mDRO 10 s resulted in lower response rates in both the first and second presentation. A slightly different pattern of responding was observed for subject 2304. For this subject, the initial presentation of mDRO 1 s produced moderately high response rates

( $m= 21.6$ ) and the initial presentation of mDRO 10 s produced greater decreases in responding ( $m= 7.9$ ). However, the overall pattern across both the initial and second presentations of each treatment was a general decrease in responding with the introduction of each subsequent treatment presentation. That is, that highest response rates were obtained in the initial mDRO 1 s condition (first treatment presented) and the lowest response rates were obtained in the second mDRO 1 s condition (fourth treatment presented). Therefore, it is possible that previous exposure to the treatments produced lower overall response rates as the evaluation progressed.

In Experiment 4, the reductive effects of two variations of mDRO were evaluated. Results generally showed that both schedules produced decreases in responding relative to baseline. Although mDRO 10 s produced slightly greater overall reductions in responding than mDRO 1 s, mDRO 1 s produced higher reinforcement rates. Thus, mDRO 1 s may have practical advantages in clinical application. That being said an initial presentation of mDRO 1 s did not produce substantial decreases in responding for one subject, 2304. This finding is similar to previous studies which have shown that in some cases, previous exposure to larger DRO intervals (such as WI DRO) are necessary to produce decreases in responding (e.g., Repp, Barton, & Brulle, 1983).

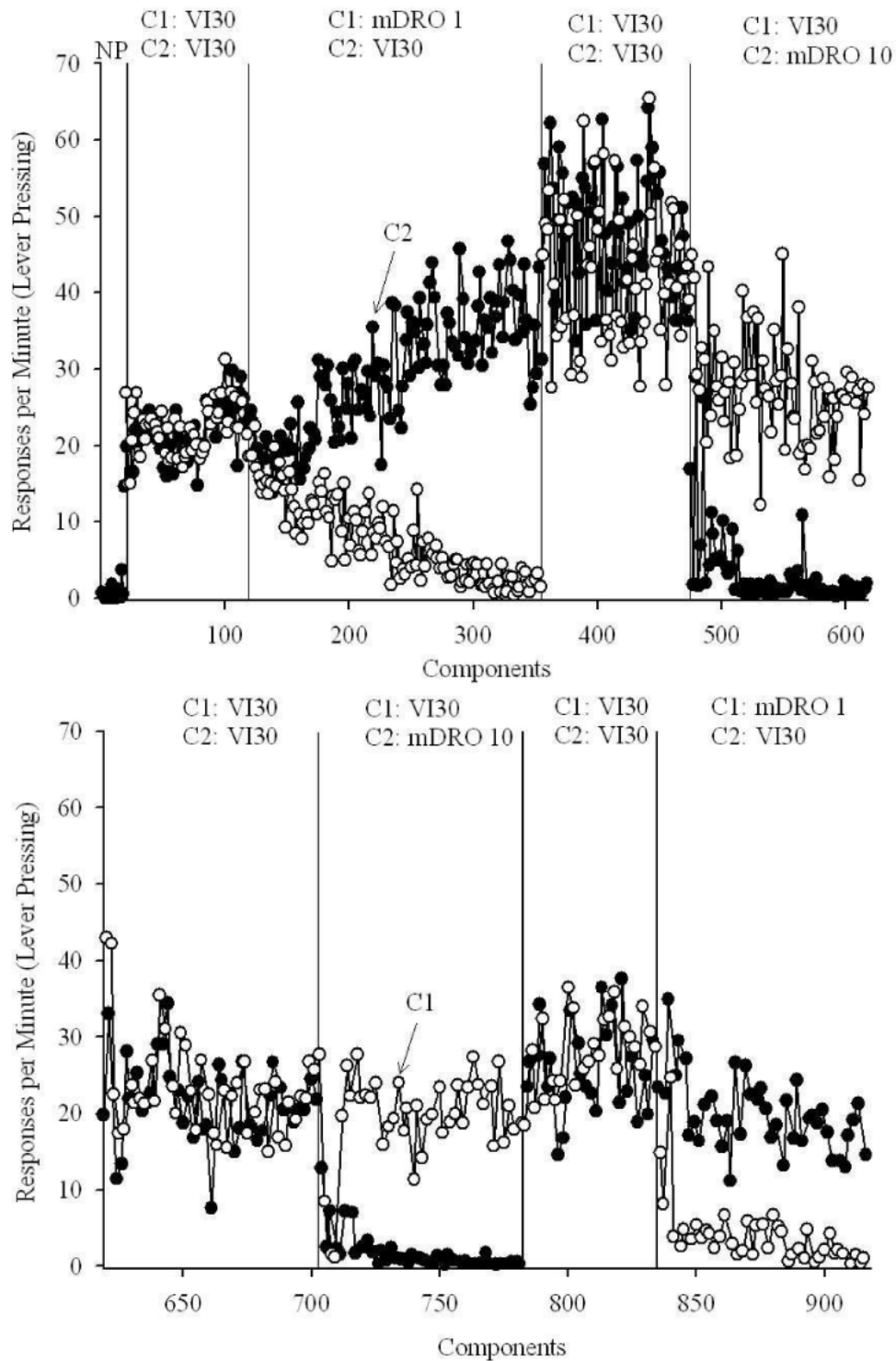


Figure 6-1. Subject 2301: overall response rates in the first and second presentation of each treatment

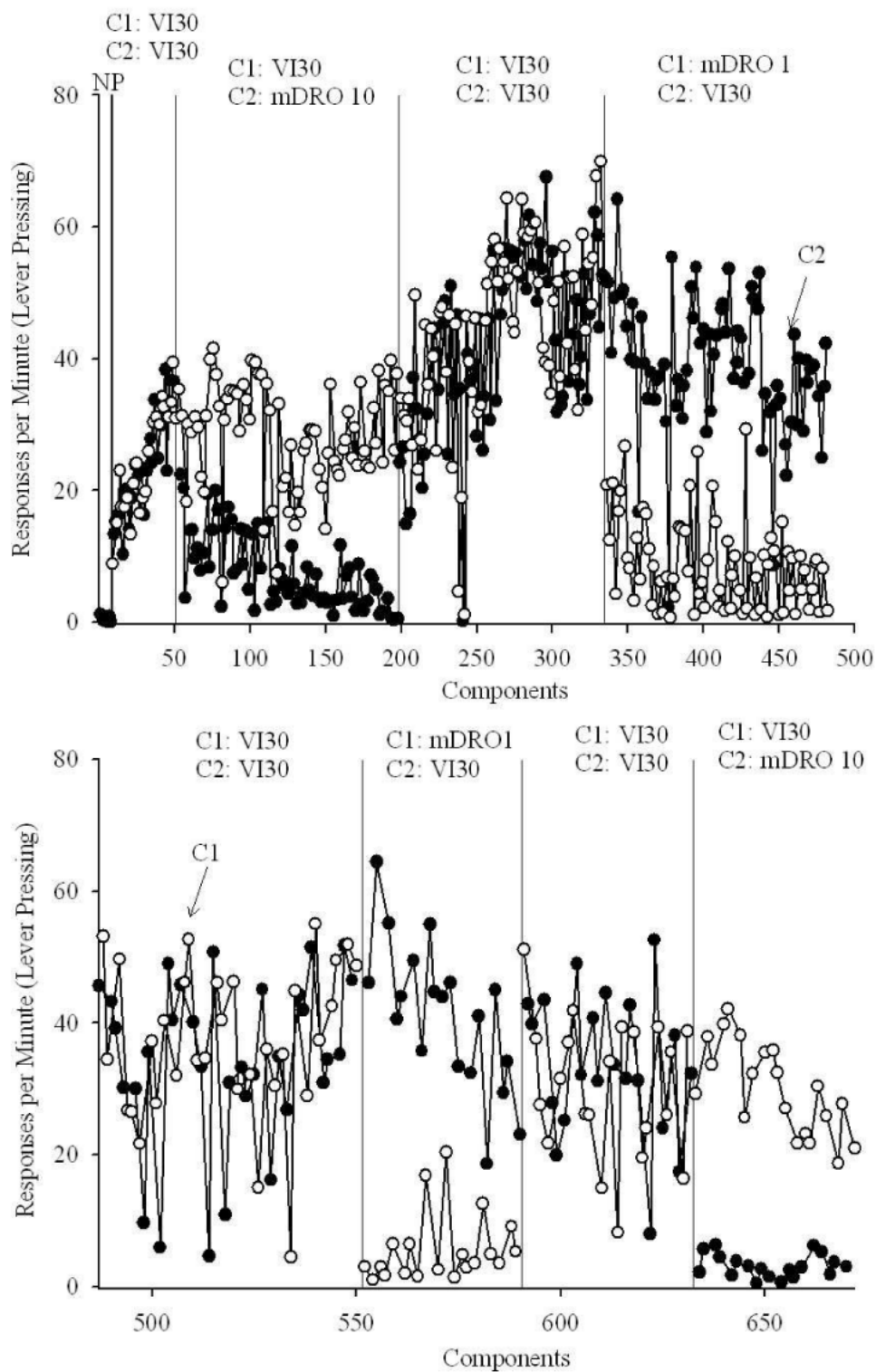


Figure 6-2. Subject 2304: overall response rates in the first and second presentation of each treatment

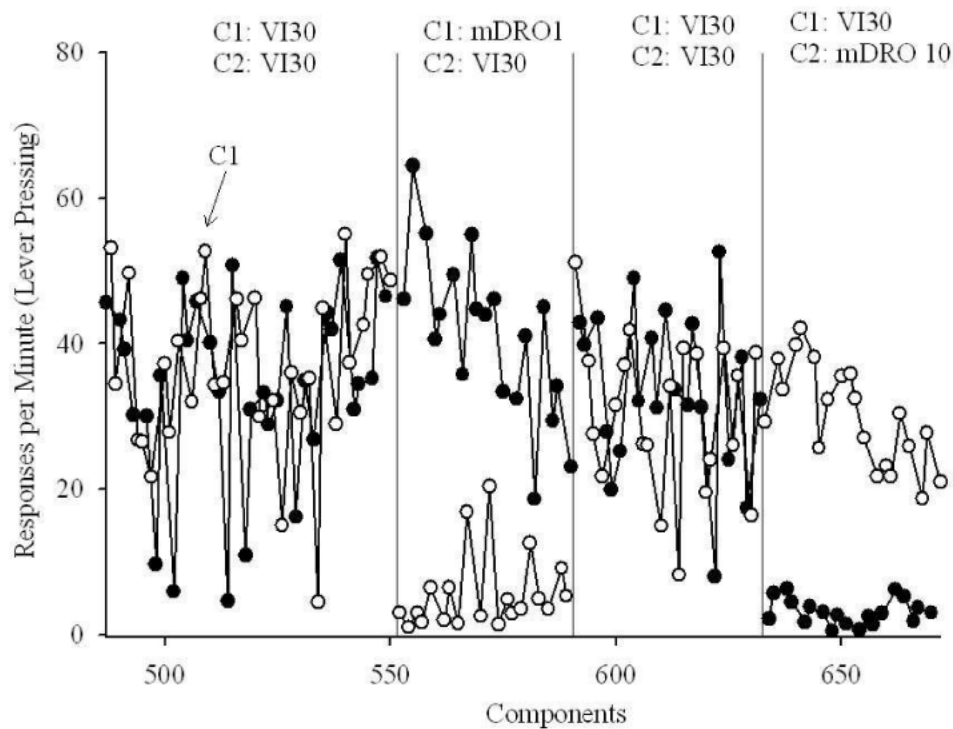
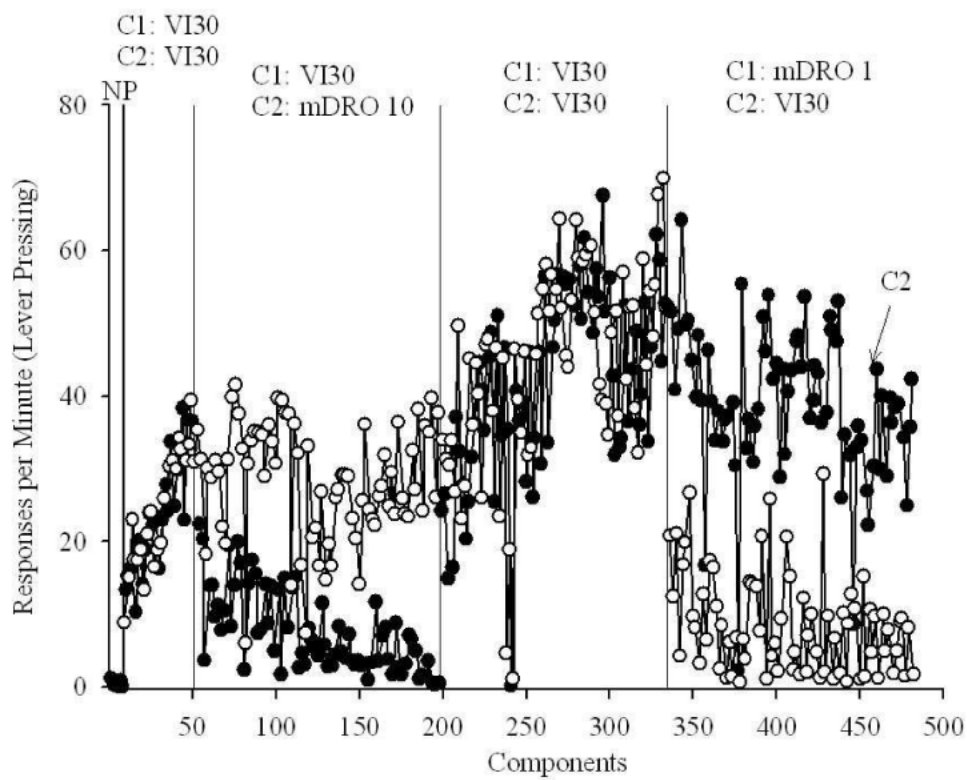


Figure 6-3. Subject 2305: overall response rates in the first and second presentation of each treatment

Table 6-1. Summary statistics for each presentation (pres.) of mDRO 1s (1) and mDRO 10 s (10) for all subjects (subj.) in experiment 4.

Subj.- Pres.	RPM (all)		RPM (1 <sup>st</sup> 10)		RPM (last 10)		R of Sr (all)	
	1 (VI)	10 (VI)	1 (VI)	10 (VI)	1 (VI)	10 (VI)	1	10
2301-1	7.7 (29.4)	3.3 (27.4)	16.6 (19.8)	10.8 (33.0)	2.2 (35.0)	1.2 (26.0)	1.9	1.8
2301-2	4.1 (20.1)	1.8 (19.6)	7.6 (23.6)	4.8 (17.9)	1.6 (17.4)	0.5 (21.2)	1.9	1.9
2304-1	21.6 (39.4)	7.9 (29.7)	21.7 (32.0)	12.2 (29.7)	19.4 (48.2)	4.6 (24.7)	1.9	1.6
2304-2	3.3 (23.7)	4.7 (28.5)	5.2 (24.2)	5.8 (29.1)	2.4 (24.5)	6.1 (27.2)	1.9	1.7
2305-1	8.7 (39.0)	8.8 (28.5)	14.3 (49.1)	13.5 (27.7)	6.0 (36.0)	2.8 (32.0)	1.9	1.7
2305-2	5.7 (42.0)	3.2 (30.0)	4.7 (49.2)	3.2 (35.0)	6.9 (33.7)	3.1 (25.0)	1.9	1.8

## CHAPTER 7 GENERAL DISCUSSION

In Experiment 1, NCR and a variation of mDRO (Tandem FT DRO 10 s; mDRO 10 s) were evaluated in a combined multiple (MULT) schedule and reversal design in which each subject was exposed to two treatments simultaneously. The results showed that both treatments resulted in decreases in responding. Summary statistics of the overall rates of responding, responding during the first and final 10 components of the condition, and overall rates of reinforcement were calculated to identify subtle differences between the treatments. In general, although each treatment resulted in decreases in responding from the baseline condition, mDRO produced lower rates of responding than NCR. Furthermore, although NCR by definition yields high reinforcement rates, the reinforcer rates were similar between the mDRO and NCR conditions.

Because the two treatments were introduced simultaneously in Experiment 1, it is possible that the similar reductive effects of the two treatments were due to multiple treatment interference. Although signals were used to facilitate discrimination of each treatment, there was no clear evidence that the rats responded differentially to the treatments. Thus, the purpose of Experiment 2 was to reevaluate NCR and mDRO individually.

In Experiment 2, a similar MULT schedule format was used but when one component was changed to a treatment condition (e.g. NCR); the other component remained in baseline (e.g., VI 30 s). In general, larger and more consistent differences between the two treatment conditions were obtained in Experiment 2 than Experiment 1. Four subjects were exposed to two presentations each of NCR and mDRO. Summary statistics, identical to Experiment 1, were calculated. In seven out of eight presentations, mDRO produced lower overall response rates and lower response rates in the first and final 10 component exposures of the condition.



The purpose of Experiment 3 was to evaluate mDRO and DRO in terms of efficacy but also in terms of reinforcement rates. Three subjects were exposed to two presentations each of DRO and mDRO and one subject was exposed to one presentation of each treatment. In five out of the seven presentations, mDRO produced lower overall response rates and lower response rates in the first 10 components of the condition. In addition, in six out of seven presentations, mDRO resulted in lower response rates in the final 10 components of the condition. This finding is somewhat similar to previous research which has shown that DRO and mDRO produce similar reductions in responding (e.g., Britton et al., 2000; Lindberg et al., 1999).

The results from the rate of reinforcement analysis showed mDRO produced higher rates of reinforcement than DRO for all seven presentations. In addition, mDRO produced an approximately 50% increase in reinforcement rate from DRO. This increase in reinforcement rate was more marked in the first 10 components of each treatment. A low rate of reinforcement at the onset of treatment may be particularly problematic because DRO is more akin to extinction and may result in extinction induced side effects (e.g., bursts, increase in variability and intensity of response), and if used clinically may yield unacceptably low reinforcement rates.

The MULT schedule was used to facilitate individual evaluations of each treatment in which a response-dependent schedule (i.e., VI 30 s) was alternated with the treatment schedule. However, higher overall levels of responding were obtained and greater number of component exposures was necessary to reduce responding in Experiment 2. This finding may have important implications for treatment implementation in clinical settings. That is, if treatments are implemented in one setting but baseline contingencies remain in place in other settings, reductions in behavior may be delayed or compromised. Thus, not surprisingly, it is likely that implementing treatments simultaneously across settings improve treatment effects.

Two general patterns of responding in the VI 30-s condition in Experiments 2 through 4 should be noted. First, an overall decrease in rates of responding in the baseline sessions over the course of the analysis was obtained for several of the subjects. Thus, it is possible that repeated exposure to the baseline conditions produced more efficient responding (i.e., fewer responses while maintaining equal reinforcer rates) in some subjects. A second general pattern was observed in the VI 30-s condition during the treatment analysis. That is, for several of the subjects, the introduction of a treatment (e.g., mDRO) was correlated with a slight decrease in responding in the alternating VI 30-s condition. This finding may be due to a lack of discrimination between the two alternating components. However, this explanation is unlikely because large differences between the components were generally obtained. Another possible explanation is the availability of response-independent reinforcers (NCR) or reinforcers for the absence of responses (mDRO and DRO) in the treatment conditions served as an abolishing operation for responding in the VI 30-s condition. It is possible that similar reductions may be obtained in clinical settings when treatments are introduced sequentially across settings (i.e., generalization of treatment effects). More specifically, it may be that case that the introduction of an effective treatment in one setting decreases responding in another setting, even when a response-dependent schedule remains in place. However, in the current experiments, decreases in response rates in the VI 30-s condition were slight compared to the decreases obtained in the treatment condition. Moreover, as discussed previously, simultaneous introduction of treatments across settings may yield greater and more rapid decreases in responding.

Experiments 1 through 3 showed that DRO, NCR, and mDRO resulted in decreases in response rates from baseline. These findings support previous research on the effectiveness of DRO, NCR, and mDRO in the treatment of problem behavior (e.g., Cowdery et al., 1990; Britton

et al., 2000, Vollmer et al., 1993). Despite the widespread use of DRO and NCR, some negative side effects have been reported in the literature. For example, some authors have noted that DRO may result in unethically low rates of reinforcement (e.g., Vollmer et al., 1993). Relatively lower overall rates of reinforcement in the DRO condition were obtained for all subjects in Experiment 3, yet, most subjects averaged at least 1 reinforcer per minute. However, on some occasions, subjects failed to earn reinforcers in the DRO condition which highlights a potential drawback to this schedule.

Some studies have reported response maintenance during NCR (e.g., Hagopian et al., 1998; Vollmer et al., 1997). Although some low levels of responding were present in both treatment components, there was no evidence of response maintenance for three of the four subjects in Experiment 2. For one subject, 2101, moderate, increasing levels of responding (i.e., 9 rpm) were obtained during the second evaluation of NCR. However, within session patterns of responding were not assessed in order to evaluate whether adventitious response-reinforcer pairings occurred during this condition.

The results from the first three experiments generally showed that mDRO resulted in low rates of behavior and high rates of reinforcement for all subjects and support the use of this type of treatment over NCR and DRO. In Experiments 1 through 3, the variation of mDRO involved a large DRO interval (10 s) with a resetting feature (e.g., Britton et al., 2000). However, it is possible that mDRO schedules employing smaller DRO intervals (e.g., 1 s) with no resetting feature would also be effective at reducing behavior (e.g., Lindberg et al., 1999). This type of schedule would also improve the ease of implementation of treatment. Thus, the purpose of Experiment 4 was to evaluate two variations of mDRO: mDRO 1 s and mDRO 10 s.

In Experiment 4, three subjects were exposed to two presentations each of mDRO 1 s and

mDRO 10 s. The results from Experiment 4 indicated that both mDRO 1 s and mDRO 10 s generally produced reductions in responding from baseline conditions. In four out of six presentations, mDRO 10 s resulted in lower overall response rates than mDRO 1 s. In addition, in five out of the six presentations, mDRO 10 s produced lower response rates in the first and final 10 components of the condition. However, mDRO 1 s produced higher rates of reinforcement than mDRO 10 s for five of the six presentations. It is possible that mDRO 10 s is a closer approximation to how mDRO is applied in clinical settings. That is, there is typically some delay between the moment the interval ends and the delivery of a reinforcer (such as the time it takes to deliver tangible items to an individual). Thus, it is encouraging that the 10 s variety was at least as effective as the 1 s variation.

The current series of experiments are a part of a line of research evaluating DRO, NCR, and mDRO in clinical and laboratory settings. Laboratory investigations allow for evaluations of treatments under highly controlled conditions and may provide an initial starting point when conducting treatment comparisons. Treatment comparisons generally necessitate numerous exposures to baseline and treatment conditions and may be especially difficult in clinical settings with individuals who engage in severe problem behavior. The results from the laboratory evaluations support the further investigation of mDRO in the treatment of problem behavior.

## LIST OF REFERENCES

- Ahearn, W.H., Clark, K.M., Gardenier, N.C., Chung, B., & Dube, W.V. (2003). Persistence of stereotypic behavior: Examining the effects of external reinforcers. *Journal of Applied Behavior Analysis*, 36, 439-448.
- Barton, L. E., Brulle, A. R., & Repp, A. C. (1986). Maintenance of therapeutic change by momentary DRO. *Journal of Applied Behavior Analysis*, 19, 277-282.
- Berkson, G. & Mason, W.A. (1964). Stereotyped movements of mental defectives: IV. The effects of toys and the character of the acts. *American Journal of Mental Deficiency*, 68, 511- 524.
- Britton, L. N., Carr, J. E., Kellum, K. K., Dozier, C. L., & Weil, T. M. (2000). A variation of noncontingent reinforcement in the treatment of aberrant behavior. *Research in Developmental Disabilities*, 21, 425-435.
- Carr, J. E., Dozier, C. L., Patel, M. R., Adams, A., N., & Martin, N. (2002). Treatment of automatically reinforced object mouthing with noncontingent reinforcement and response blocking: experimental analysis and social validation, *Research in Developmental Disabilities*, 23, 37-44.
- Corte, H. E., Wolf, M. M., & Locke, B. J. (1971). A comparison of procedures for eliminating self-injurious behavior of retarded adolescents. *Journal of Applied Behavior Analysis*, 4, 201-213.
- Cowdery, G. E., Iwata, B. A., & Pace, G. M. (1990). Effects and side effects of DRO as treatment for self-injurious behavior. *Journal of Applied Behavior Analysis*, 23, 497-506.
- DeLeon, I. G., Williams, D. C., Gregory, M. K., & Hagopian, L. P. (2005). Unexamined potential effects of the noncontingent delivery of reinforcers. *European Journal of Behavior Analysis*, 5, 57-69.
- Derby, K. M., Fisher, W. W., & Piazza, C. C. (1996). The effects of contingent and noncontingent attention on self-injury and self-restraint. *Journal of Applied Behavior Analysis*, 29, 107-110.
- Derwas, H., & Jones, R. S. (1993). Reducing stereotyped behavior using momentary DRO: An experimental analysis. *Behavioral Residential Treatment*, 8, 45-53.
- Favell, J.E., McGimsey, J.F., & Schell, R.M. (1982). Treatment of self-injury by providing alternate sensory activities. *Analysis and Intervention in Developmental Disabilities*, 2, 83-104.

- Hagopian, L. P., Crockett, J. L., van Stone, M., DeLeon, I. G., & Bowman, L. G. (2000). Effects of noncontingent reinforcement on problem behavior and stimulus engagement: The role of satiation, extinction, and alternative reinforcement. *Journal of Applied Behavior Analysis*, 33, 433-449.
- Hagopian, L. P., Fisher, W. W., & Legacy, S. M. (1994). Schedule effects of noncontingent reinforcement on attention-maintained destructive behavior in identical quadruplets. *Journal of Applied Behavior Analysis*, 27, 317-325.
- Hanley, G. P., Piazza, C. C., & Fisher, W. W. (1997). Noncontingent presentation of attention and alternative stimuli in the treatment of attention-maintained destructive behavior. *Journal of Applied Behavior Analysis*, 30, 229-237.
- Harris, S. L., & Wolchik, S. A. (1979). Suppression of self-stimulation: Three alternative strategies. *Journal of Applied Behavior Analysis*, 12, 185-198.
- Imam, A. A., & Lattal, K. A. (1988). Effects of alternative reinforcement sources: A reevaluation. *Journal of the Experimental Analysis of Behavior*, 50, 261-271.
- Iwata, B. A., Dorsey, M., Slifer, K., Bauman, K., & Richman, G. (1994). Toward a functional analysis of self-injury. *Journal of Applied Behavior Analysis*, 27, 197-209. (Reprinted from *Analysis and Intervention in Developmental Disabilities*, 2, 3-20, 1982).
- Iwata, B. A., & Kahng, S. (2005). Some undesirable effects of noncontingent reinforcement. *European Journal of Behavior Analysis*, 6, 47-50.
- Kahng, S., Iwata, B. A., Thompson, R. H., & Hanley, G. P. (2000). A method for identifying satiation versus extinction effects under noncontingent reinforcement schedules. *Journal of Applied Behavior Analysis*, 33, 419-432.
- Lindberg, J. S., Iwata, B. A., Kahng, S., & DeLeon, I. G. (1999). DRO contingencies: An analysis of variable-momentary schedules. *Journal of Applied Behavior Analysis*, 32, 123-136.
- Lalli, J. S., Casey, S. D., & Kates, K. (1997). Noncontingent reinforcement as treatment for severe problem behavior: Some procedural variations. *Journal of Applied Behavior Analysis*, 30, 127-137.
- Mace, F. C., & Lalli, J. S. (1991). Linking descriptive and experimental analysis in the treatment of bizarre speech. *Journal of Applied Behavior Analysis*, 24, 553-562.
- Madden, G. J., & Perone, M. (2003). Effects of alternative reinforcement on human behavior: The source does matter. *Journal of the Experimental Analysis of Behavior*, 79, 193-206.

- Mazaleski, J. L., Iwata, B. A., Vollmer, T. R., Zarcone, J. R., & Smith, R. G. (1993). Analysis of the reinforcement and extinction components in DRO contingencies with self-injury. *Journal of Applied Behavior Analysis*, 26, 143-156.
- Piazza, C. C., Contrucci, S. A., Hanley, G. P., & Fisher, W. W. (1997). Nondirective prompting and noncontingent reinforcement in the treatment of destructive behavior during hygiene routines. *Journal of Applied Behavior Analysis*, 30, 705-708.
- Rachlin, H., & Baum, W. M. (1972). Effects of alternative reinforcement: Does the source matter? *Journal of the Experimental Analysis of Behavior*, 18, 231-241.
- Repp, A. C., Barton, L. E., & Brulle, A. R. (1983). A comparison of two procedures for programming the differential reinforcement of other behaviors. *Journal of Applied Behavior Analysis*, 16, 435-445.
- Repp A.C, Deitz, S.M, & Deitz, D.E.D. (1976). Reducing inappropriate behaviors in classrooms and individual sessions through DRO schedules of reinforcement, *Mental Retardation*, 14, 11-15.
- Rescorla, R. A., & Skucy, J. C. (1969). Effect of response-independent reinforcers during extinction. *Journal of Comparative and Physiological Psychology*, 67, 381-389.
- Ringdahl, J. E., Vollmer, T. R., Borrero, J. C., & Connell, J. E. (2001). Fixed-time schedule effects as a function of baseline reinforcement rate. *Journal of Applied Behavior Analysis*, 34, 1-15.
- Vollmer, T. R., Iwata, B. A., Zarcone, J. R., Smith, R. G., & Mazaleski, J. L. (1993). The role of attention in the treatment of attention-maintained self-injurious behavior: Noncontingent reinforcement and differential reinforcement of other behavior. *Journal of Applied Behavior Analysis*, 26, 9-21.
- Vollmer, T. R., Progar, P. R., Lalli, J. S., Van Camp, C. M., Sierp, B. J., Wright, C. S., Nastasi, J., & Eisenschink, K. J. (1998). Fixed-time schedules attenuate extinction-induced phenomena in the treatment of severe aberrant behavior. *Journal of Applied Behavior Analysis*, 31, 529-542.
- Vollmer, T. R., Ringdahl, J. E., Roane, H. S., & Marcus, B. A. (1997). Negative side effects of noncontingent reinforcement. *Journal of Applied Behavior Analysis*, 30, 161-164.
- Zeiler, M. D. (1968). Fixed and variable schedules of response-independent reinforcement. *Journal of the Experimental Analysis of Behavior*, 11, 405-414.

## BIOGRAPHICAL SKETCH

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