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Response Elimination Using Response-Contingent and Response-Contiguous Schedules

Thomas S. Rieg
University of Rhode Island

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RESPONSE ELIMINATION USING RESPONSE-CONTINGENT AND
RESPONSE-CONTIGUOUS SCHEDULES

BY
THOMAS S. RIEG

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

The experiment collected both molar and molecular data to compare the effect Differential Reinforcement of Other Behavior (DRO), Fixed Time (FT), Variable Time (VT), and Extinction (EXT) schedules of reinforcement have on decreasing the frequency of a trained response in rats. The purpose of comparing these schedules was to investigate the relationship between responses and reinforcements in order to determine whether contingency theory or contiguity theory explains the differential effects frequently reported in the literature. Collecting data at both the molar and molecular level allowed a more conclusive theoretical explanation of the suppressive effects seen with these schedules. The experiment consisted of an eight session acquisition phase during which all animals were exposed to a FI 20 sec schedule of reinforcement. During the 15 session treatment phase the subjects were separated into ten groups consisting of a FT 10 sec, FT 20 sec, FT 30 sec, EXT, VT 10 sec, VT 20 sec, VT 30 sec, DRO 10 sec, DRO 20 sec, and DRO 30 sec conditions. Finally, during the reacquisition phase all treatment groups were again exposed to a FI 20 sec schedule for 30 minutes. Molar analyses of the data showed that during the treatment phase the greatest response suppression was seen for the DRO and EXT treatment groups with only limited response elimination effects for the FT and VT treatment groups. A molar analysis of response-reinforcement interval data showed an increase for the FT and VT treatment conditions whereas a molecular interpretation of response-reinforcement intervals showed an increase in contiguity for the DRO animals. During reacquisition recovery of responding to pre-treatment levels was evident for all groups with the slowest resurgence of responding observed in the EXT, then DRO and finally the FT and VT animals. The benefits and implications basic research has for applied settings were discussed.

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At the end of my seemingly unending career as a graduate student, I come to realize that a multitude of others has had a significant effect on shaping my behavior as an experimental psychologist.

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Introduction

In an operant situation, when the experimenter controls the arrangement between responding and reinforcement, three response-reinforcer relationships are possible. A response can produce a reinforcer, a response can delay a reinforcer, or a response can be unrelated to the reinforcer. The first relationship is represented by conventional schedules of reinforcement such as interval and ratio schedules and any combination thereof. The second relationship is illustrated by differential reinforcement of other behavior (DRO) schedules. The last relationship is typified by response independent schedules such as fixed time (FT) and variable time (VT) schedules. The latter two types of relationship are of interest here as these stipulate a relationship between responding and reinforcement that has generally been shown to decrease responding (Lattal, 1981) without the use of aversive stimuli.

The effectiveness of reinforcement has commonly been explained by either of two theoretical positions. Contingency theory focuses on the dependence of reinforcement on the occurrence of a response. Contingency embodies three features; it is generally studied using one instrumental response, involves a short delay between response and reinforcer, and in the absence of responding no reinforcement is delivered. In this view, reinforcement strengthens the behavior on which it is dependent. However, contingency theory is a procedural not a behavioral process. That is, contingencies must act through some mechanism. Contiguity theory of reinforcement focuses on that mechanism by ensuring that behavior is strengthened through the response-reinforcer temporal relationship.

While the terms contiguity and contingency are often used interchangeably they need to be differentiated. A contiguity between response and reinforcer implies only a temporal relationship between the

two. A contingency between response and reinforcer implies a necessary causal relationship between the two. The expressions "response-dependent" and "response-independent" imply that a response is either essential or non-essential for reinforcement to occur. In this way schedules that are used to achieve a high stable state of responding such as FI and FR schedules involve a contingency as well as temporal contiguity between responding and reinforcement. If the animal does not make a response he will not be reinforced, and if a response is made then a reinforcer is delivered immediately although not necessarily for 100% of the responses. A similar type of relationship is true for DRO schedules which necessitate a longer temporal contiguity between responding and reinforcement and imply a dependency between not responding and reinforcement. In DRO schedules then, there is a dependency between not making the targeted response and reinforcement and a delayed contiguity or none at all between responding and reinforcement. Finally, response-independent schedules such as FT and VT allow the contiguity between response and reinforcer to vary and at the same time do not specify a dependency or contingency. The four types of appetitive schedules presented so far may be characterized by Table 1.

Contingency arrangements can be described in terms of a contingency space. Using such a space one can depict all the possible contingency relations between responding and reinforcement. In this way the abscissa (the horizontal axis) in Figure 1 represents the probability of the organism receiving a reinforcer given that no response was made, and the ordinate (the vertical axis) reflects the probability of reinforcement in the situation in which a reinforcer is dependent on a response. The diagonal between the two axes represent a situation in which the two probabilities are equal, that is regardless of whether the organism makes a response or not a reinforcer is delivered, with the same probability. It is therefore true that all possible contingencies fall within

Table 1

Schedules arranged with different response reinforcer relationships

Schedule	Description	Response-Reinforcement:	
		Contingency	Contiguity
"conventional" schedules	response produces reinforcer	dependent	contiguous
EXT schedule	no reinforcer is delivered	independent	non-contiguous
DRO schedules	response delays reinforcer	dependent on not responding	contiguous with other behavior
Time schedules	response-independent reinforcement	independent	non-specified contiguity

Figure Caption

Figure 1. Diagram of the response-reinforcer contingency space.

this space. In terms of the schedules described in Figure 1 the non-contingent schedules of FT and VT fall along the diagonal, no matter whether or not a lever response is emitted, a food pellet is delivered with equal probability. DRO schedules would fall below the diagonal, as the absence of lever responding will increase the probability of pellet delivery. The typical appetitive schedules fall above the non-contingent diagonal as lever pressing will increase the probability of food delivery. The Extinction schedule (EXT) would be represented by the zero point of both axes as by definition in this type of schedule no reinforcers are delivered, so these would be neither contingent nor contiguous.

In the past, one of the ways in which stable responding was decreased or eliminated involved response dependent contingencies and aversives. The use of punishment to decrease responding generally involves the presentation of an aversive stimulus contingent on making a response. In general, results from studies in which the presentation of punishment is contingent and immediately contiguous with responding, show the greatest decrease in responding (Azrin & Holz, 1966; Church, 1963; Church, 1969). Punishment that is delivered independent of responding differs from reinforcement in the direction of its effect. In studies involving response independent punishment, the effect of punishment is generally studied on some ongoing behavior. Azrin (1956) presented electric shock to pigeons on a FT schedule while the animals were responding on a VI schedule of reinforcement. Responding was maintained but at a lower rate while under these conditions (Azrin, 1956). Other studies, directly comparing FT and FI schedules involving independent electric shock presentation, have found patterns similar to those involving independent food presentation. These studies report that the rates of responding were lower for schedules with independent response-punishment relationships than dependent response-punishment relationships (McKearney, 1974; Morse & Kelleher, 1970). Finally, in a Sidman avoidance paradigm in which responding is

maintained by response contingent shock postponement, the juxtaposition of shock delivered according to an FT schedule produced an increase in responding (Sidman, Herrnstein, & Conrad, 1957). The same study showed that when responding no longer delayed shock presentation, and only the FT punishment component was in affect an increase in responding occurred. These findings of shock delivery either contingent or non-contingent with responding are similar to those of food delivery with contingent or non-contingent schedules, with the exception that their effects are in the opposite direction. In situations where contingent reinforcement will increase responding, contingent punishment will decrease responding. And in situations where non-contingent reinforcement decreases responding, non-contingent punishment will increase responding.

Studies that involve varying contingencies between responding and reinforcement (Herrnstein & Hineline, 1966; Sidman, et al., 1957) have frequently been designed to address completely different issues than their differential suppressive effects. An experiment by Herrnstein and Hineline (1966) using aversive conditioning in a Sidman avoidance paradigm was originally conducted in order to counter the argument that avoidance behavior can be adequately explained using the two-factor theory of avoidance learning (Mowrer, 1950). Mowrer's theory postulates two underlying processes, a classically conditioned fear response due to a signaled shock contiguity, and an operant response that is strengthened by contingent fear reduction. Herrnstein and Hineline's study was an attempt to remove the conditions under which a aversive stimuli is predictably paired with any overt stimulus. In their experiment the consequence of the subject's responding was a switch from a high to a low frequency of electrical shock. The results showed that rats were able to learn such a relationship and thereby showed that negative reinforcement can take the form of reduction in shock-frequency. These experimental results are

important as they show that the relationship between response and reinforcement need not necessarily depend on contingency (Herrnstein, 1969). Because the brief shocks are unpredictable and reinforcement takes the form of decreasing the average number of shocks, occasional pairings of shock and responses continue to occur and therefore this experimental procedure may be used to study response-reinforcement contiguity.

One technique for the elimination of responding that uses reinforcement is DRO. The suppressive results of this technique have been well documented in the literature (Leitenberg, Rawson, & Mulick, 1975; Mulick, Leitenberg, & Rawson, 1976; Pacitti & Smith, 1977; Uhl, 1973; Zeiler, 1971). The DRO procedure is best defined by the temporal parameters described by Uhl and Garcia (1969). The contingencies between response and reinforcement are, (a) the response-reinforcement ($R-S^R$) interval, and (b) the reinforcement-reinforcement (S^R-S^R) interval. The response-reinforcement interval is the time that the reinforcement (S^R) is postponed after emission of a target response (R) (the response to be eliminated), and the reinforcement-reinforcement interval is the time between S^R s should no response occur. While the results of studies comparing DRO with EXT (the procedure which is generally regarded as the elimination technique standard, against which all other techniques have been compared and contrasted) have yielded various results even within the same lab (Rieg, Smith, & Collins-Pucino, 1988; Rieg, Smith, Russo, & Vyse, 1987; Uhl, 1973; Uhl & Garcia, 1969). Recent research has shown that the response elimination effect of DRO and EXT is transient at best and should therefore be termed "suppressive" rather than "elimination" techniques (Rieg, et al., 1988; Rieg, et al., 1987). In order to maximize reinforcement in the DRO procedure the subject is required to do anything other than the previously reinforced response, in other words the animal is required not to make the targeted response (Zeiler, 1970). What is important to note is that DRO is a response dependent schedule of

reinforcement which at the same time allows for a change in contiguity, beyond a certain minimum delay. Extinction, on the other hand, by removing the reinforcement altogether, involves both the removal of the contiguity and contingency between responding and reinforcement, and it is therefore theoretically difficult to determine which of these variables contributes to response suppression.

Another type of situation through which response elimination has been studied involves alternate response (Alt-R) schedules. These schedules are arranged so that reinforcement may be available contingent on an alternate response. Generally this takes the form of making reinforcement contingent on responding on another lever, while no longer reinforcing lever presses on the original bar. This situation in which the contingency is removed from the original response and applied to an alternative response has been shown to be more effective than EXT (Leitenberg, et al., 1975; Lowry & Lachter, 1977; Pacitti, et al., 1977) and more effective than DRO (Vyse, Rieg, & Smith, 1985). Comparisons among DRO, Alt-R and EXT show Alt-R to produce the most rapid response elimination effects (Lowry, et al., 1977; Mulick, et al., 1976). All three of these schedules involve the removal of contingencies between responding and reinforcement and in the case of EXT and Alt-R (on the original lever) the removal of reinforcement altogether.

Schedules which deliver reinforcers independent of responding either at some fixed or variable interval of time have been designated Fixed Time (FT) and Variable Time (VT) schedules in order to distinguish them from analogous interval schedules (ie. FI & VI) which employ response-dependent reinforcers. The result of the removal of the contingency between responding and reinforcement in these schedules is that they also reduce responding. In FT schedules, reinforcers are delivered after some period of time (t) independent of whether the subject makes a response or not. The same is true for VT schedules with the difference that a range of

intervals with an average time elapse between reinforcements is employed. The differences between response independent time schedules, response dependent interval schedules and extinction schedules is depicted spatially in Figure 1, according to their location contingency space.

In 1948 Skinner showed that food delivered to experimentally naive animals independent of responding increased the probability of some behaviors. Skinner reported that six of eight pigeons demonstrated an increase in certain behaviors such as head bobbing and circling when presented with reinforcers every 15 seconds. Skinner termed this superstitious or incidental conditioning. Skinner's "adventitious reinforcement" hypothesis is that a response, emitted for some unspecified reason by a subject, which is closely followed by a non-contingent reinforcement is more likely to occur again in the future. This behavior which is now more likely to occur is likely to again be followed closely by reinforcement still further increasing its probability of occurring. This cycle of contiguous but non-contingent reinforcement and increases in the likelihood of occurrence, will continue, and quickly result in stereotypical "superstitious" behavior. At the time of Skinner's writing no attempt was made to quantify his findings. Questions generally raised concerning the theory include: How often do the adventitious pairings need to occur for conditioning to take place, how often are other unreinforced behaviors occurring, how contiguous must the reinforcer be. While these may be empirical questions yet to be answered, the real problem seems to be methodological. A major problem with Skinner's hypothesis concerns a question about response-reinforcer contiguities which are not under the control of the experimenter. That is, the experimenter can control the contiguity aspect by delivering reinforcement immediately upon responding, yet the subject decides whether or not to respond. If the subject is responding in bursts, immediate reinforcement of one response does not imply that the

strengthening of that response occurred due to contiguity. It may be that the increase in responding is due to some other process the subject is sensitive to. Because the subject emits the response the experimenter can not be sure of the effect of the response-reinforcer contiguity. The lack of ability to accurately predict or control the occurrence of a response makes predictions about the role of the response-reinforcer contiguity difficult.

An analysis of the variables affecting contingencies in "superstitious" behavior was conducted in 1966 by Herrnstein. This study presented food contingent on responding during a baseline phase on a FI 11 sec schedule. Once responding was established subjects were exposed to a FT 11 sec schedule. It was predicted that with the removal of a dependency between responding and reinforcement the rates should increase at first and eventually subside. However, results showed that even after extensive training on a response independent schedule, responding was maintained at significant levels. Other researchers have reported similar findings using pigeons (Lachter, 1971; Zeiler, 1968) and rats (Lattal & Mazey, 1971). Herrnstein (1966) explains these results as a corollary to the effects of response-dependent reinforcement. This corollary is that behavior will increase in frequency if it is followed closely by reinforcement. Adventitious conditioning occurs because an animal is making some response when reinforcement occurs then the probability of that response is increased. If the next reinforcer occurs again sufficiently soon after the last reinforcement then the probability that the animal will still be making that response is high and subsequent reinforcement will again strengthen that response's probability. However, if the interval to the next reinforcement is lengthened, and because there is no specified dependency between responding and reinforcement, then the probability that the animal will be reinforced for engaging in some other behavior is increased. This will necessarily result in the reinforcement and strengthening of behaviors other than the one being measured. The

implication of this analysis is that the rate of the target response will decrease and a lower rate of responding is therefore observed with response-independent than with response-dependent schedules. A further implication of this is that contiguity and not contingency is the important factor effecting conditioning, but that contingency works by assuring contiguity.

Two theoretical explanations have been used to explain responding observed under schedules of reinforcement. The molecular view describes responding as controlled by discrete events occurring at any given time (Baum, 1973). This mode of explanation therefore centers on measurements that can be made at the time of reinforcement, such as the quality of a response (measuring the strength of a response) or the time interval between a response and reinforcement. This view holds that temporal contiguity between response and reinforcer is central to the reinforcement effect. The molar interpretation of behavior assumes that the relationship between response rates and reinforcement rates should be computed over long periods of time and not just between individual responses and subsequent reinforcers. This orientation assumes that measures such as average response rates "cannot be assessed at any moment . . . and that order in behavior often only appears at the molar level" (Baum, 1981). The molar view then asserts that animals can discriminate among different schedules based on features other than the one-to-one correlation between responding and reinforcement. Although the two approaches to explaining behavior are not mutually exclusive, and could even be complementary, individual researchers have come to prefer one with an almost total disregard for the other (de Villiers, 1977). One of the purposes of the present experiment was to collect both molecular data and molar data on schedules and then to determine which data better conform to what we know about that schedule.

Several other researchers have investigated response dependent and independent schedules at both a molar and molecular level (Lattal, 1981; Lattal, et al., 1971; Rachlin & Baum, 1972; Zeiler, 1968; Zeiler, 1977). Rachlin and Baum (1972) used a concurrent schedule of reinforcement in which two sources of reinforcement are available simultaneously, to compare DRO and VT schedules of reinforcement which they termed as delayed and undelayed sources of reinforcement. Using pigeons on different combinations of VT 2 sec and DRO 2 sec concurrent schedules they found that both of these schedules resulted in equivalent levels of response suppression. While this is interesting and contrary to the common expectation that necessarily delayed reinforcement would cause more suppression than randomly delayed reinforcement, they further state that in the VT schedule, at least occasionally a response must have occurred immediately preceding a response-independent reinforcer. When this temporal contiguity occurred they argue that the rate of responding would increase just as though there was a response-dependent relationship. They go on to state that when more response-independent reinforcers were delivered, the rate of responding was lower, which is again contrary to what one would expect if response-independent reinforcers were adventitiously reinforcing key pecking through contiguity because more frequent reinforcers would more frequently reinforce the target response. In their conclusions, Rachlin and Baum assume that response-independent (VT) schedules allow for contiguous relationships between responding and reinforcement which lead to the increased rate of responding. Due to the equivalence of the VT and DRO response rates, they suggest that their findings would necessarily suggest a molar explanation of the results as a molecular explanation based on temporal contiguity would lead to the prediction of lower response rates in the DRO than the VT condition. However, Rachlin and Baum did not collect any explicit contiguity data but relied on the logical implication that DRO involves longer contiguities and

therefore the VT schedule's equivalent response rates necessarily implies it's average underlying contiguity. These data are presented as evidence that many variables specified by a contingency need to be analyzed in order to determine the extent to which response dependencies control the rate of responding. The present study attempted to determine if response rates are associated with longer delays between response and reinforcement with DRO schedules, and higher response rates are associated with shorter delay between response and reinforcement with FT and VT schedules.

The process of studying response-independent schedules is facilitated when a particular response is under the control of the experimental situation. The alternative is for the experimenter to wait for some behavior to emerge through chance pairing of response and reinforcer (Herrnstein, 1966; Skinner, 1948). For this reason the field of response dependent research has typically utilized responding dependent on reinforcement and then subsequently studied schedules that do not have a dependency attached to them. For this reason animals in the present experiment were trained to respond on a fixed interval schedule and then various schedules were employed that allowed the differentiation of the effects of dependency and contiguity between responding and reinforcement. A total of four different schedules with multiple parameters that were either response-dependent or response-independent and either contiguous or non-contiguous were compared for their suppressive effects. The response-dependent schedule with a delayed contiguity was a DRO procedure with response-reinforcement intervals of 10, 20 and 30 seconds, and a reinforcement-reinforcement interval of 20 seconds for all three delay intervals. Fixed time and variable time schedules were also run with intervals of 10, 20, and 30 seconds. The final group was exposed to a standard extinction contingency.

Previous studies comparing response-reinforcement intervals using DRO have found varying effects (Rieg, et al., 1988; Rieg, Vyse, & Smith, 1986; Vyse, et al., 1985). Generally, these studies have found that when the response-reinforcement interval is longer than the reinforcement-reinforcement interval it leads to response elimination effects (Rieg, et al., 1986). Specifically when reinforcement is contingent on not responding greater response elimination effects are observed with response-reinforcement intervals twice the reinforcement-reinforcement interval (Rieg, et al., 1987) than response-reinforcement intervals equal to or shorter than the reinforcement-reinforcement interval. These studies further found that, when reinforcement is again made contingent on responding that the longer the response-reinforcement interval used in DRO the slower the recovery. Also, when DRO is compared to EXT for its suppressive effects, only when the response-reinforcement interval is longer than the reinforcement-reinforcement interval was the recovery of the original response retarded (Rieg, et al., 1986). In an effort to replicate these findings in the present study the DRO groups' delay intervals were selected so that they would be shorter, equal, and longer than the interreinforcement interval. The primary reason for the particular delay intervals for the DRO treatment groups and *t* intervals for the FT and VT treatment groups used in the present study was that these values had previously been shown to be effective (Lattal, et al., 1971; Rieg, et al., 1988; Uhl, et al., 1969; Wilkie, 1972). Furthermore, the selection of parameters for the non-contingent schedules was dictated by the desire to equate the interval between reinforcers for these groups to the expected ultimate effect of the DRO condition. That is, if the DRO animals abstained from responding they would earn reinforcers every 20 seconds. For this reason the base schedule for the FT and VT groups should also be 20 seconds. For the DRO 10 group, if just one response was emitted then the maximum delay interval to the next reinforcer would be 30 seconds, and for

the DRO 20 group, just one response would yield a maximum response-reinforcement interval of 40 seconds. In order to equate these intervals, a FT 30 group with reinforcement-reinforcement intervals of 30 seconds was used, and a VT 20 group with reinforcement-reinforcement intervals of up to 38 seconds was also used. Finally, FT and VT treatment groups with very short reinforcement-reinforcement intervals (10 sec) were used in order to double the number of reinforcers delivered from the standard 20 second intervals. The reason for this was to test the idea that lower response rates should be seen in the FT 10 and VT 10 animals as they would have had more occasion for the adventitious pairing of responses other than lever pressing with reinforcement (Skinner, 1948). However, if the data do not show lower response rates for these treatment conditions then the argument of Rachlin and Baum (1972) that more frequent non-contingent reinforcers maintains responding due to increased frequency of pairings would be supported.

The data collected in the proposed study consisted of molar measures such as the mean number of responses and reinforcers for each animal in any one session as well as means of response-response intervals, response-reinforcement intervals, the number of responses per reinforcement-reinforcement interval, and reinforcement-reinforcement intervals. During acquisition it was expected that all animals would increase their responding to an asymptotic level and that the treatment condition would have the effect of decreasing the number of responses emitted by each animal. Differences in the mean response rates for animals during treatment would indicate the effectiveness of each response elimination schedule. Molar data consisting of the individual times between each response and reinforcer, the inter-response times for all the animals, and the inter-reinforcement times for the DRO animals, was also collected. Molecular data consisting of the interval from a response to the next reinforcer was sorted into one second delay intervals (bins).

It was hypothesized that the animals with a specified non-response dependency and a longer delay would show the greatest response decrement. That is, the DRO animals with a $R-S^R$ intervals of 30 sec would show the greatest response suppression as compared to DRO animals with a smaller $R-S^R$ and compared to the animals receiving response-independent reinforcement. It was also hypothesized that the animals that received variable response-independent reinforcement, the VT contingency, would show a different rate of suppression than those with a fixed time contingency. If Rachlin and Baum (1972) are correct that adventitious contiguous reinforcement is what is maintaining the animal's rate of responding during response elimination, then based on Herrnstein's (1966) reinforcement density hypothesis, those animals with longer time intervals would show less suppression than those with a shorter intervals. This is because the animals with longer S^R-S^R would have experienced fewer pairings between some other response and reinforcement during each session. However, if conditioning is purely temporal, then their response maintenance or response decrease may be purely due to short response-reinforcement pairings.

A study replicating Skinner's study on superstitious behavior was conducted by Staddon and Simmelhag (1971). This study used both FI response independent reinforcement (termed FT in the present study) and VI response independent reinforcement (termed VT here). Their findings indicate that animals exposed to FT schedules began emitting the targeted response later into the reinforcement-reinforcement interval than did animals exposed to the VT schedule. The implication is that if the VT animals began responding sooner after reinforcement they would have higher response rates and therefore show less response suppression. It was therefore predicted that when each of the fixed time intervals is compared to the equivalent variable time intervals, that the animals exposed to the fixed time interval schedule would show greater suppression.

Very few of the studies on reinforcement based response elimination have undertaken an analysis of the relative permanence of the treatment effects when reinforcement is again made contingent on the targeted response. The studies that have investigated reacquisition have found the effectiveness of these response elimination techniques transitory at best with complete recovery within 60 minutes (Pacitti, et al., 1977) and 15 minutes (Vyse, et al., 1985) of reexposure to the original schedule. Data from Vyse et al. (1985) shows that within the 15 minutes differential effect of treatment have been found and that these differences were dependent on whether the animals had experienced a shorter or longer DRO delay interval. Pacitti and Smith (1977) found greater resistance to the reacquisition of original lever response (a VI 30 sec schedule) with half of their animals not responding until 36 minutes into the session.

In the present study as a measure of the each condition's response elimination durability, reinforcement was again made contingent on responding during a 30 minute reacquisition phase. It was predicted based on previous studies (Pacitti, et al., 1977; Rieg, et al., 1988; Rieg, et al., 1987; Rieg, et al., 1986; Vyse, et al., 1985), that all animals would recover to levels of the last day of acquisition within the one session. Furthermore, the DRO animals were expected to resume responding faster than the EXT animals because during reacquisition, the absence of the reinforcers delivered during treatment for not responding would serve as a discriminative stimulus for the changed schedule (Rieg, et al., 1988). During the treatment phase the DRO animals received reinforcement for not making lever responses. When during the reacquisition phase reinforcement is no longer delivered according to the DRO schedule, the termination of that schedule is signalled through the absence of reinforcers. For the EXT group, if the subjects do not respond during the reacquisition phase there will be no stimulus provided that a change in contingencies has occurred. Finally, it was predicted that if the animals exposed to the independent

schedules of reinforcement showed response suppression during the treatment phase, they too would recover responding relatively soon into the reacquisition session, and they should recover more quickly than the DRO condition which had a non-response dependency associated with it during treatment.

Method

Subjects

Subjects were 90 experimentally naive Sprague-Dawley male rats obtained from Charles River Breeding Laboratory. The subjects were housed separately and given ad libitum food and water prior to the experiment. During the experiment all subjects were maintained at 80% of their free feeding weight. The weights of the animals prior to experimentation ranged between 250g and 375g with a mean weight of 280g.

Apparatus

The apparatuses consisted of two Coulbourn Instruments model #E10-10 operant chambers, each contained within sound attenuating enclosures. The front and the back walls of the operant chambers were 25 cm wide and made of aluminium. The side walls consisted of clear Plexiglas and are 30 cm wide. The interior of the chamber was 29 cm high. A 3 cm wide food cup was recessed into the middle of the front wall 2 cm above the grid floor. A response lever was located to the right of the food cup and measured 3 by 2 cm. A house light was situated 27 cm from the grid floor in the middle of the front wall. Masking noise was provided by a ventilation fan attached to each chamber. Chamber manipulanda and all experimental relationships were controlled by an Apple II+ computer working with a MED Associates Interface. Software was written by the experimenter specific to this project. Bio Serve 45-mg precision "Dustless" food pellets were used as reinforcers, and standard Purina Rat Chow (Rat, Mouse Hamster 3000) was used to supplement each animal's diet.

Procedure

Four days prior to shaping each subject was weighed and food deprived. Subjects were randomly assigned to one of the two experimental chambers. Two food pellets were placed in the food cup and the animal remained in the chamber for 10 min with the house lights on. After the second day of food deprivation and until the end of the study, each subject was returned to his home cage in the colony and was fed enough to maintain him at 80% of his free feeding weight.

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

Acquisition. During the acquisition phase of the experiment the subjects responded for food on an FI 20 sec schedule. This phase consisted of eight sessions each 30 min in length. A criterion was used such that each subject had to average at least 100 responses per day across the eight days of the acquisition phase in order to be included in the study.

Treatment. This phase of the experiment consisted of 15 sessions each 30 min in length, during which each subject was exposed to one of the following ten treatment conditions: (a) DRO 10, (b) DRO 20, (c) DRO 30, (d) FT 10, (e) FT 20, (f) FT 30, (g) VT 10, (h) VT 20, (i) VT 30, and (j) EXT. With the DRO contingencies the reinforcement-reinforcement (S^R - S^R) interval was always 20 seconds. Thus reinforcement occurred every 20 sec if the subject did not make the previously reinforced response, in this case lever pressing. However, if the subject emitted a response the response-reinforcement (R - S^R) interval was in effect. This caused an additional

delay besides the 20 sec reinforcement-reinforcement interval until the next reinforcement occurred. This delay was 10 sec for the DRO 10 group, 20 sec for the DRO 20 group and 30 sec for the DRO 30 group. The Fixed Time treatment condition had no contingency associated with it. In this way the animals were reinforced every 10, 20, or 30 sec dependent on which group they were in, regardless of whether they made a response or not. The same was true for the Variable Time schedule with the exception that these animal were reinforced on the average every 10, 20, or 30 sec. The extinction group received a regular extinction procedure where reinforcement was no longer presented whether a response had occurred or not.

Reacquisition. The reacquisition phase of the experiment was run on the day following the 15th treatment session. This phase consisted of one 30 min session during which an FI 20 sec schedule of reinforcement was in effect for all subjects.

Results

Subject Attrition

Over the course of the experiment two subjects were eliminated due to equipment failure and four subjects were rejected for not meeting the shaping criterion within 75 min. All of these subjects were replaced with other animals so that the data from 90 subjects were used for data analysis.

General Considerations

Over the course of the experiment a total of 989,428 responses were recorded and analyzed, and a total of 239,093 reinforcers were delivered. A detailed breakdown of responding and reinforcements delivered by group and phase is given in Tables 2 and 3. These are presented to provide a global overview of response frequencies and a preliminary interpretation of the effects the experimental manipulation had. The data indicate very stable rates of responding during the acquisition phase, with differences in response rates during the treatment and reacquisition phases. The

Table 2

Number of Responses Recorded by Phase and Group for Entire Experiment

		Phase			
Group		Acquisition [*]	Treatment ^{**}	Reacquisition ^{***}	Study
FT 10	<u>M</u>	4812.220	6431.556	833.556	12077.333
	<u>SD</u>	1669.631	9738.297	594.447	11759.543
FT 20	<u>M</u>	4935.222	8237.000	654.111	13826.333
	<u>SD</u>	1505.544	8930.742	656.504	10594.457
FT 30	<u>M</u>	4804.889	8916.222	637.556	14358.667
	<u>SD</u>	2014.232	7047.233	543.975	9549.682
EXT	<u>M</u>	5282.556	657.556	396.333	6336.444
	<u>SD</u>	2164.427	207.193	266.548	2455.718
VT 10	<u>M</u>	5204.778	6164.889	918.111	12287.778
	<u>SD</u>	1563.587	4861.561	323.823	6046.847
VT 20	<u>M</u>	5404.778	9402.333	766.556	15573.667
	<u>SD</u>	3318.016	8899.429	604.004	12580.538
VT 30	<u>M</u>	5686.222	9523.889	742.556	15952.667
	<u>SD</u>	1243.768	5566.640	384.235	6728.933
DRO 10	<u>M</u>	5987.000	733.444	667.889	7388.333
	<u>SD</u>	800.865	288.063	252.162	1081.729
DRO 20	<u>M</u>	5125.111	434.333	367.333	5926.778
	<u>SD</u>	843.336	266.787	299.510	1244.070
DRO 30	<u>M</u>	4775.222	823.556	609.667	6208.444
	<u>SD</u>	1182.073	162.353	236.394	1477.127
Total	<u>M</u>	5201.800	5132.478	659.367	3664.548
	<u>SD</u>	1727.443	6840.539	453.222	4590.217

* Eight 30 min Sessions

** Fifteen 30 min Sessions

*** One 30 min Session

Table 3

Number of Reinforcers Delivered by Phase and Group for the Entire Experiment

Group	Phase				Study
		Acquisition*	Treatment**	Reacquisition***	
FT 10	<u>M</u>	653.000	2679.111	833.556	3413.000
	<u>SD</u>	40.147	4.622	594.447	38.445
FT 20	<u>M</u>	645.556	1328.556	654.111	2045.000
	<u>SD</u>	52.901	4.613	656.504	53.603
FT 30	<u>M</u>	651.778	878.000	637.556	1606.889
	<u>SD</u>	39.874	4.183	543.975	43.956
EXT	<u>M</u>	650.667	0.000	396.333	752.333
	<u>SD</u>	82.278	0.000	266.548	202.442
VT 10	<u>M</u>	661.000	2685.444	918.111	3428.333
	<u>SD</u>	41.464	0.527	323.837	43.304
VT 20	<u>M</u>	657.778	1350.000	766.556	2086.556
	<u>SD</u>	60.508	0.000	604.004	62.656
VT 30	<u>M</u>	666.667	900.000	742.556	1644.556
	<u>SD</u>	36.139	0.000	384.235	36.243
DRO 10	<u>M</u>	683.667	1220.444	667.889	1971.889
	<u>SD</u>	32.5000	28.601	252.162	36.995
DRO 20	<u>M</u>	664.222	1229.556	367.333	1948.333
	<u>SD</u>	29.541	65.391	299.510	65.924
DRO 30	<u>M</u>	641.889	1124.889	609.667	1839.111
	<u>SD</u>	24.927	53.220	236.394	55.992
Total	<u>M</u>	657.622	1339.600	659.367	885.530
	<u>SD</u>	45.944	771.512	453.222	607.510

* Eight 30 min Sessions

** Fifteen 30 min Sessions

*** One 30 min Session

following statistical analyses were undertaken to separate out what differences were significant and where those differences laid. Associated with each response and each reinforcer is the exact time into the session that each response and reinforcer occurred and from these the various interval data were computed and analyzed.

Statistical Analyses

Acquisition. For the eight session acquisition phase the dependent variables collected were the number of responses, the number of reinforcements, and the time between responses (response-response (R-R) intervals) for each animal.

Table 4 shows the means and standard deviations for lever responses during the eight days of the acquisition phase. Figure 2 displays the means for each group during this phase. A Hartley's test for homogeneity was computed for this data and found to violate homogeneity of variance [$F_{\max}(10,8) = 87.456, p > .01$]. A common log transformation was conducted in order to equalize variances (Winer, 1971). After transformation to a common log scale violations in homogeneity persisted [$F_{\max}(10,8) = 94.204, p > .01$]. However, studies by Box (1953) indicate that ANOVA is robust for violations in its underlying assumptions. Furthermore, Table 5 shows that the greatest deviations in variances occurred during the early sessions of this phase. Because the purpose of the acquisition phase was to establish the equivalence of responding just prior to treatment, which was found to be the case, all further data was analyzed using this common log transformed data. The log transformed data are graphically represented in Figure 3. A 10 x 7 (group x sessions) Analysis of Variance was performed on these acquisition data (see Appendix A for ANOVA summary Table). The analysis indicated no significant interaction effect [$F(54,480) = 1.064, p > .05$], a significant main effect for sessions [$F(6,480) = 93.335, p < .05$], and no significant main effect for treatment group [$F(9,80) = .683, p > .05$]. As can be seen in Figure 3 there is a marked increase in mean lever responding

Table 4

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

		Sessions			
Group		1	2	3	4
FT 10	<u>M</u>	292.333	464.667	574.778	563.333
	<u>SD</u>	165.276	171.146	248.802	222.492
FT 20	<u>M</u>	226.889	448.000	513.000	607.778
	<u>SD</u>	114.379	96.875	103.036	224.061
FT 30	<u>M</u>	251.000	409.778	511.333	599.444
	<u>SD</u>	116.614	147.832	228.823	253.181
EXT	<u>M</u>	314.222	425.778	556.000	629.889
	<u>SD</u>	176.124	183.447	242.516	288.113
VT 10	<u>M</u>	295.111	535.667	498.222	647.778
	<u>SD</u>	150.430	108.334	168.236	195.093
VT 20	<u>M</u>	335.111	496.333	635.556	651.333
	<u>SD</u>	186.524	301.979	428.693	363.070
VT 30	<u>M</u>	311.667	560.556	669.333	697.000
	<u>SD</u>	125.706	93.015	146.602	174.975
DRO 10	<u>M</u>	342.889	572.111	635.111	760.556
	<u>SD</u>	160.316	125.250	126.813	208.193
DRO 20	<u>M</u>	339.333	509.111	517.778	532.444
	<u>SD</u>	119.370	140.023	95.849	89.825
DRO 30	<u>M</u>	259.222	453.889	579.444	587.222
	<u>SD</u>	80.704	97.025	163.830	211.461

		Sessions			
Group		5	6	7	8
FT 10	<u>M</u>	568.000	674.333	768.889	905.889
	<u>SD</u>	202.943	191.731	315.344	365.026
FT 20	<u>M</u>	675.556	783.556	793.556	886.889
	<u>SD</u>	225.848	284.130	309.017	311.722
FT 30	<u>M</u>	598.444	776.889	787.778	870.222
	<u>SD</u>	262.366	318.048	394.008	455.997
EXT	<u>M</u>	688.333	884.111	896.444	887.778
	<u>SD</u>	285.702	344.334	425.550	468.411
VT 10	<u>M</u>	665.889	847.000	818.444	896.667
	<u>SD</u>	276.780	314.228	342.088	372.950
VT 20	<u>M</u>	720.444	784.000	884.111	901.889
	<u>SD</u>	490.652	574.725	569.980	511.136
VT 30	<u>M</u>	739.444	959.111	836.000	913.111
	<u>SD</u>	191.621	311.893	276.467	250.832
DRO 10	<u>M</u>	792.667	994.667	972.889	916.111
	<u>SD</u>	183.602	194.865	222.172	251.869
DRO 20	<u>M</u>	620.111	857.667	843.000	905.667
	<u>SD</u>	126.815	259.469	253.125	328.051
DRO 30	<u>M</u>	576.444	727.333	737.778	853.889
	<u>SD</u>	263.992	190.070	206.007	224.921

Figure Caption

Figure 2. Means for lever responding for each group across the eight sessions during the acquisition phase.

Table 5

Means and Standard Deviations of Common Log Transformed Lever Responses for Each Group During the Acquisition Phase

Group		Sessions			
		1	2	3	4
FT 10	<u>M</u>	2.401	2.639	2.719	2.721
	<u>SD</u>	.257	.171	.204	.168
FT 20	<u>M</u>	2.279	2.643	2.703	2.754
	<u>SD</u>	.306	.088	.086	.179
FT 30	<u>M</u>	2.358	2.589	2.671	2.745
	<u>SD</u>	.204	.147	.190	.178
EXT	<u>M</u>	2.303	2.558	2.701	2.770
	<u>SD</u>	.660	.320	.224	.156
VT 10	<u>M</u>	2.395	2.72	2.662	2.793
	<u>SD</u>	.308	.094	.213	.138
VT 20	<u>M</u>	2.455	2.633	2.734	2.755
	<u>SD</u>	.288	.230	.246	.239
VT 30	<u>M</u>	2.465	2.744	2.816	2.830
	<u>SD</u>	.166	.068	.101	.115
DRO 10	<u>M</u>	2.487	2.746	2.795	2.870
	<u>SD</u>	.227	.112	.086	.100
DRO 20	<u>M</u>	2.506	2.692	2.708	2.721
	<u>SD</u>	.159	.123	.081	.070
DRO 30	<u>M</u>	2.394	2.649	2.749	2.748
	<u>SD</u>	.139	.085	.116	.138

		Sessions			
Group		5	6	7	8
FT 10	<u>M</u>	2.731	2.812	2.852	2.924
	<u>SD</u>	.148	.133	.188	.183
FT 20	<u>M</u>	2.807	2.870	2.872	2.923
	<u>SD</u>	.150	.154	.161	.157
FT 30	<u>M</u>	2.743	2.858	2.853	2.893
	<u>SD</u>	.180	.177	.204	.210
EXT	<u>M</u>	2.813	2.923	2.914	2.900
	<u>SD</u>	.148	.146	.189	.214
VT 10	<u>M</u>	2.783	2.893	2.875	2.912
	<u>SD</u>	.214	.199	.202	.215
VT 20	<u>M</u>	2.774	2.797	2.868	2.890
	<u>SD</u>	.280	.305	.275	.257
VT 30	<u>M</u>	2.855	2.960	2.899	2.946
	<u>SD</u>	.120	.149	.156	.117
DRO 10	<u>M</u>	2.890	2.991	2.978	2.948
	<u>SD</u>	.092	.077	.100	.118
DRO 20	<u>M</u>	2.784	2.916	2.909	2.933
	<u>SD</u>	.091	.128	.127	.148
DRO 30	<u>M</u>	2.712	2.849	2.852	2.916
	<u>SD</u>	.234	.107	.128	.127

Figure Caption

Figure 3. Common Log transformed means for lever responding for each group across the eight sessions during the acquisition phase.

for all ten groups over the eight sessions. The lack of significant differences for the treatment group effect establishes the equivalence of the groups' responding during this phase. Omega squared values were computed for this design in order to determine effect sizes. For the responses made during acquisition the values for the group x session interaction was .001, .019 for treatment groups, and .216 for sessions. This indicated that while the majority of the variance was due to the interaction effect, most of the variance accounted for was due to increased response rate over the eight sessions.

The data for the mean number of reinforcements delivered by group during the acquisition phase are shown in Table 6 and Figure 4. An F_{max} test on these data showed violations of homogeneity, [$F_{max}(10,8) = 2636.599$, $p > .01$] and were therefore transformed using a common log scale (Winer, 1971). These transformed data are reported in Table 7 and Figure 5. A 10×7 (group x sessions) ANOVA was computed on the transformed data (the summary Table can be found in Appendix B). The interaction effect between treatment group and session was non-significant [$F(54,480) = .916$, $p > .05$], nor was the main effect for treatment group [$F(9,80) = .763$, $p > .05$]. However, there was a significant main effect for session [$F(6,480) = 42.805$, $p < .05$]. The higher rate of reinforcement seen in Figure 5 for the first session reflects the fact that the animals were working on a Fixed Interval 10 sec schedule for this session while they were on a FI 20 sec schedule for the remainder of this phase. It is clear that by the end of the eight sessions all animals were receiving equivalent numbers of reinforcers. Omega squared computations for this analysis were .004 for the treatment group x session interaction effect, .006 for the treatment groups main effect, and .233 for the sessions main effect. This indicates that the increase in the number of reinforcers delivered accounted for the majority of the variance and is consistent with the underlying assumption that a

Table 6

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

		Sessions			
		1	2	3	4
FT 10	<u>M</u>	92.111	72.444	79.333	78.778
	<u>SD</u>	26.695	7.535	5.385	3.383
FT 20	<u>M</u>	84.222	73.444	77.111	78.333
	<u>SD</u>	30.622	5.812	5.883	8.559
FT 30	<u>M</u>	91.556	72.444	76.222	80.556
	<u>SD</u>	23.938	5.525	6.140	4.391
EXT	<u>M</u>	97.111	69.556	75.000	78.333
	<u>SD</u>	40.154	15.993	15.859	7.053
VT 10	<u>M</u>	99.000	76.889	73.667	80.556
	<u>SD</u>	29.854	2.522	16.560	4.157
VT 20	<u>M</u>	102.444	72.556	77.667	79.778
	<u>SD</u>	29.833	9.645	5.979	4.206
VT 30	<u>M</u>	98.333	76.556	79.778	81.556
	<u>SD</u>	19.641	3.972	2.863	2.506
DRO 10	<u>M</u>	104.111	75.222	80.000	83.556
	<u>SD</u>	26.260	4.206	2.693	1.509
DRO 20	<u>M</u>	98.667	72.111	78.333	80.889
	<u>SD</u>	22.793	6.092	3.317	2.088
DRO 30	<u>M</u>	84.667	70.333	78.000	78.667
	<u>SD</u>	21.628	6.946	4.301	4.472

		Sessions			
Group		5	6	7	8
FT 10	<u>M</u>	80.333	82.222	83.444	84.333
	<u>SD</u>	2.062	1.865	1.878	1.118
FT 20	<u>M</u>	82.111	83.000	83.556	83.778
	<u>SD</u>	3.060	1.500	2.297	2.333
FT 30	<u>M</u>	80.444	83.222	83.556	83.778
	<u>SD</u>	3.745	2.224	2.242	1.202
EXT	<u>M</u>	81.222	83.556	83.000	82.889
	<u>SD</u>	2.587	2.603	3.640	2.892
VT 10	<u>M</u>	80.778	83.000	82.889	84.222
	<u>SD</u>	8.715	3.240	3.296	3.153
VT 20	<u>M</u>	80.444	79.222	81.889	83.778
	<u>SD</u>	6.085	5.954	2.759	2.333
VT 30	<u>M</u>	82.778	84.111	79.556	84.000
	<u>SD</u>	3.193	2.088	13.059	3.500
DRO 10	<u>M</u>	83.444	85.111	85.667	86.556
	<u>SD</u>	1.130	0.782	1.000	1.333
DRO 20	<u>M</u>	82.222	84.222	83.889	83.889
	<u>SD</u>	2.224	0.972	1.167	2.147
DRO 30	<u>M</u>	78.333	83.667	84.111	84.111
	<u>SD</u>	7.365	1.323	1.167	2.522

Figure Caption

Figure 4. Means for reinforcers received for each group across the eight sessions during the acquisition phase.

Table 7

Means and Standard Deviations of Common Log Transformed
Reinforcements Received for Each Group During the Acquisition Phase

		Sessions			
		1	2	3	4
FT 10	<u>M</u>	1.943	1.858	1.899	1.896
	<u>SD</u>	.155	.048	.031	.019
FT 20	<u>M</u>	1.892	1.865	1.886	1.891
	<u>SD</u>	.191	.036	.034	.053
FT 30	<u>M</u>	1.947	1.859	1.881	1.905
	<u>SD</u>	.124	.034	.035	.025
EXT	<u>M</u>	1.857	1.828	1.862	1.892
	<u>SD</u>	.524	.130	.123	.042
VT 10	<u>M</u>	1.972	1.886	1.851	1.906
	<u>SD</u>	.167	.014	.141	.023
VT 20	<u>M</u>	1.985	1.857	1.889	1.901
	<u>SD</u>	.179	.064	.035	.024
VT 30	<u>M</u>	1.985	1.883	1.902	1.911
	<u>SD</u>	.087	.023	.015	.014
DRO 10	<u>M</u>	2.003	1.876	1.903	1.922
	<u>SD</u>	.122	.025	.015	.007
DRO 20	<u>M</u>	1.983	1.857	1.894	1.908
	<u>SD</u>	.105	.037	.019	.011
DRO 30	<u>M</u>	1.915	1.845	1.891	1.895
	<u>SD</u>	.111	.048	.025	.025

		Sessions			
Group		5	6	7	8
FT 10	<u>M</u>	1.905	1.915	1.921	1.926
	<u>SD</u>	.011	.010	.010	.005
FT 20	<u>M</u>	1.914	1.919	1.922	1.923
	<u>SD</u>	.016	.007	.012	.012
FT 30	<u>M</u>	1.905	1.920	1.922	1.923
	<u>SD</u>	.021	.012	.012	.006
EXT	<u>M</u>	1.909	1.922	1.919	1.918
	<u>SD</u>	.014	.014	.020	.015
VT 10	<u>M</u>	1.905	1.919	1.918	1.925
	<u>SD</u>	.054	.018	.018	.017
VT 20	<u>M</u>	1.904	1.898	1.913	1.923
	<u>SD</u>	.034	.034	.015	.012
VT 30	<u>M</u>	1.918	1.925	1.894	1.924
	<u>SD</u>	.017	.011	.091	.019
DRO 10	<u>M</u>	1.921	1.930	1.933	1.937
	<u>SD</u>	.005	.003	.005	.006
DRO 20	<u>M</u>	1.915	1.925	1.924	1.924
	<u>SD</u>	.012	.005	.006	.011
DRO 30	<u>M</u>	1.892	1.923	1.925	1.925
	<u>SD</u>	.046	.006	.006	.013

Figure Caption

Figure 5. Common Log transformed means for reinforcers received for each group across the eight sessions during the acquisition phase.

contingent and closely contiguous schedule such as FI will deliver more reinforcers with an increase in responding.

Response-response interval data for the acquisition phase are reported in Table 8 and illustrated in Figure 6. An $F_{\max}$ test of homogeneity of variance was found to be significant for these data, [$F_{\max}(10,8) = 19,356.827, p > .01$]. A common log transformation was conducted on the data in order to equalize variances which reduced the extent of violations of homogeneity, [$F_{\max}(10,8) = 58.618, p > .01$] (Winer, 1971). The means and standard deviations for the transformed data are represented in Table 9. All further data were analyzed using this common log transformed data, as seen in Table 9. A 10×7 (groups $\times$ sessions) ANOVA was computed on the transformed data (the summary table can be found in Appendix C). The treatment group by session interaction effect was not significant [$F(54,480) = 1.025, p > .05$]. The main effect for treatment group was also non-significant [$F(9,80) = .687, p > .05$], however, the main effect for sessions was found to be significant [$F(6,480) = 89.919, p < .05$]. Figure 7 shows a decrease in the response-response intervals for all 10 groups over the course of this phase, with all animals responding at equivalent rates by the end of this stage. Again omega squared values were computed and indicated that the significant sessions effect accounted for the greatest amount of variance ($w^2 = .211$), while the computed treatment group $\times$ session interaction effect values was .001, and .019 for the treatment group main effect.

In summary, all three dependent measures collected during the acquisition phase showed no differences between groups. There were significant differences between sessions indicating that animals in all groups acquired the lever press response during this phase and it seems that by the end of this phase all animals were responding at or approaching asymptotic rates. These results are important in that they

Table 8

Means and Standard Deviations of Response-Response Intervals for Each Group During the Acquisition Phase

		Sessions			
		1	2	3	4
FT 10	<u>M</u>	7.966	4.361	4.040	3.650
	<u>SD</u>	4.721	1.842	2.115	1.347
FT 20	<u>M</u>	11.515	4.129	3.604	3.411
	<u>SD</u>	9.706	0.754	0.691	1.526
FT 30	<u>M</u>	8.085	4.770	4.103	3.480
	<u>SD</u>	3.395	1.468	1.716	1.346
EXT	<u>M</u>	19.481	6.584	4.085	3.138
	<u>SD</u>	41.043	7.549	2.736	0.841
VT 10	<u>M</u>	8.854	3.451	4.469	2.995
	<u>SD</u>	9.103	0.840	3.179	0.970
VT 20	<u>M</u>	7.549	4.565	3.729	3.565
	<u>SD</u>	6.844	2.106	1.732	1.805
VT 30	<u>M</u>	6.103	3.219	2.819	2.739
	<u>SD</u>	1.982	0.448	0.697	0.747
DRO 10	<u>M</u>	6.228	3.329	2.915	2.478
	<u>SD</u>	3.441	1.049	0.584	0.497
DRO 20	<u>M</u>	5.619	3.714	3.557	3.446
	<u>SD</u>	2.005	1.091	0.663	0.528
DRO 30	<u>M</u>	6.609	4.011	3.272	3.324
	<u>SD</u>	1.712	0.695	0.819	0.908

		Sessions			
Group		5	6	7	8
FT 10	<u>M</u>	3.515	2.894	2.761	2.332
	<u>SD</u>	1.117	0.953	1.304	1.035
FT 20	<u>M</u>	2.955	2.574	2.540	2.261
	<u>SD</u>	1.036	0.878	0.868	0.828
FT 30	<u>M</u>	3.471	2.679	2.769	2.542
	<u>SD</u>	1.275	1.052	1.234	1.197
EXT	<u>M</u>	2.885	2.240	2.367	2.506
	<u>SD</u>	0.845	0.667	0.990	1.230
VT 10	<u>M</u>	3.329	2.543	2.647	2.498
	<u>SD</u>	1.998	1.433	1.507	1.582
VT 20	<u>M</u>	3.535	3.463	2.849	2.692
	<u>SD</u>	1.915	2.026	1.620	1.588
VT 30	<u>M</u>	2.599	2.072	2.373	2.093
	<u>SD</u>	0.760	0.724	0.854	0.545
DRO 10	<u>M</u>	2.345	1.858	1.927	2.095
	<u>SD</u>	0.461	0.295	0.439	0.558
DRO 20	<u>M</u>	3.007	2.251	2.291	2.199
	<u>SD</u>	0.663	0.621	0.642	0.677
DRO 30	<u>M</u>	3.990	2.604	2.615	2.248
	<u>SD</u>	2.614	0.600	0.825	0.695

Figure Caption

Figure 6. Means of response-response intervals in seconds for each group across the eight sessions during the acquisition phase.

Table 9

Means and Standard Deviations of Common Log Transformed Response-Response Intervals for Each Group During the Acquisition Phase

		Sessions			
		1	2	3	4
FT 10	<u>M</u>	.833	.606	.554	.534
	<u>SD</u>	.264	.179	.226	.170
FT 20	<u>M</u>	.955	.609	.549	.499
	<u>SD</u>	.301	.085	.085	.177
FT 30	<u>M</u>	.873	.658	.577	.510
	<u>SD</u>	.185	.145	.191	.180
EXT	<u>M</u>	.884	.685	.552	.478
	<u>SD</u>	.490	.304	.223	.149
VT 10	<u>M</u>	.828	.527	.591	.457
	<u>SD</u>	.299	.100	.212	.137
VT 20	<u>M</u>	.780	.612	.517	.497
	<u>SD</u>	.281	.227	.248	.238
VT 30	<u>M</u>	.764	.504	.439	.424
	<u>SD</u>	.149	.064	.102	.116
DRO 10	<u>M</u>	.742	.507	.457	.385
	<u>SD</u>	.222	.114	.087	.100
DRO 20	<u>M</u>	.727	.554	.544	.532
	<u>SD</u>	.149	.122	.080	.070
DRO 30	<u>M</u>	.807	.597	.502	.504
	<u>SD</u>	.113	.084	.115	.137

		Sessions			
Group		5	6	7	8
FT 10	<u>M</u>	.524	.442	.403	.333
	<u>SD</u>	.150	.133	.189	.184
FT 20	<u>M</u>	.447	.387	.380	.330
	<u>SD</u>	.151	.154	.161	.154
FT 30	<u>M</u>	.510	.397	.402	.362
	<u>SD</u>	.179	.178	.204	.211
EXT	<u>M</u>	.441	.330	.339	.352
	<u>SD</u>	.146	.145	.191	.219
VT 10	<u>M</u>	.470	.360	.376	.343
	<u>SD</u>	.212	.197	.202	.215
VT 20	<u>M</u>	.478	.456	.383	.364
	<u>SD</u>	.279	.305	.275	.257
VT 30	<u>M</u>	.400	.294	.351	.307
	<u>SD</u>	.121	.148	.151	.117
DRO 10	<u>M</u>	.362	.263	.275	.307
	<u>SD</u>	.094	.077	.100	.118
DRO 20	<u>M</u>	.469	.336	.344	.321
	<u>SD</u>	.093	.127	.126	.149
DRO 30	<u>M</u>	.539	.404	.400	.336
	<u>SD</u>	.232	.108	.129	.122

Figure Caption

Figure 7. Means of Common Log transformed response-response intervals in seconds for each group across the eight sessions during the acquisition phase.

indicate the equivalence of responding by the individual treatment groups prior to exposure to the treatment condition.

Treatment. During the 15 session treatment phase the data collected and analyzed consisted of the number of responses made, the number of reinforcements received, the response-reinforcement interval (R-S^R), the response-response interval (R-R), the reinforcement-reinforcement interval (S^R-S^R), and the number of responses per reinforcement interval (R / S^R-S^R).

The means and standard deviations for the lever responses of each group during the treatment phase are presented in Table 10 and Figure 8. An $E_{\max}$ test on these data showed violations of homogeneity, [$E_{\max}(10,8) = 128,881.320$, $p > .01$]. A common log transformation was conducted on the data in order to reduce variances [$E_{\max}(10,8) = 72.570$, $p > .01$]. These transformed data are reported in Table 11. A 10 x 15 (treatment group x sessions) ANOVA was computed on the transformed data whose summary table can be found in Appendix D.1. The interaction effect (treatment group x session) was found to be significant [$F(126,1120) = 5.345$, $p < .05$], as was the treatment group main effect [$F(9,80) = 25.257$, $p < .05$], and main effect for sessions [$F(14,1120) = 97.192$, $p < .05$]. Omega squared values for the interaction, treatment group, and session effect were found to be .042, .103, and .537 respectively.

Simple effects tests were performed for each session during this phase. The Satterthwaite method (Winer, 1971) was used to compute the degrees of freedom for the denominator for each of the simple effects tests. The simple effects test on session one was found to be nonsignificant with the remaining 14 simple effects tests, sessions two through 15, all found to be significant (see Appendix D.2 for computed simple effects tests). Tukey Honestly Significant Difference (hsd) follow-up tests for each significant simple effects test found the following differences: All three FT and all three VT groups responded more than the EXT and DRO 10 groups who

Table 10

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

		Sessions				
Group		1	2	3	4	5
FT 10	<u>M</u>	499.556	393.111	397.444	359.111	362.778
	<u>SD</u>	395.693	499.568	496.691	476.673	497.335
FT 20	<u>M</u>	780.444	650.778	761.889	624.444	653.333
	<u>SD</u>	385.338	454.530	461.247	503.074	597.405
FT 30	<u>M</u>	872.889	800.222	819.667	727.889	631.556
	<u>SD</u>	488.349	472.258	579.572	600.735	526.764
EXT	<u>M</u>	297.556	98.000	59.222	28.444	19.222
	<u>SD</u>	156.446	35.990	75.144	24.347	14.704
VT 10	<u>M</u>	557.889	515.778	569.778	484.667	370.222
	<u>SD</u>	334.427	347.457	349.856	349.914	363.951
VT 20	<u>M</u>	720.667	663.333	743.444	663.222	464.778
	<u>SD</u>	534.616	580.021	568.010	640.709	370.675
VT 30	<u>M</u>	864.778	760.333	720.000	663.556	601.444
	<u>SD</u>	237.466	298.647	325.072	347.557	359.866
DRO 10	<u>M</u>	497.667	70.222	55.556	21.444	11.111
	<u>SD</u>	198.972	41.719	61.681	29.168	3.100
DRO 20	<u>M</u>	324.222	32.444	27.000	15.778	7.000
	<u>SD</u>	187.938	36.246	20.298	19.466	14.841
DRO 30	<u>M</u>	563.111	130.778	54.444	11.889	10.444
	<u>SD</u>	159.579	58.418	35.833	14.031	13.812

		Sessions				
Group		6	7	8	9	10
FT 10	<u>M</u>	393.667	307.556	451.333	455.556	445.111
	<u>SD</u>	554.963	471.576	660.673	708.048	804.879
FT 20	<u>M</u>	604.889	479.333	458.556	509.778	459.111
	<u>SD</u>	632.067	638.182	638.615	681.623	701.172
FT 30	<u>M</u>	599.222	522.000	553.556	521.000	492.667
	<u>SD</u>	484.820	400.941	445.466	517.884	471.903
EXT	<u>M</u>	13.556	15.556	19.333	28.667	13.556
	<u>SD</u>	7.350	19.040	15.788	42.702	9.748
VT 10	<u>M</u>	431.222	405.222	405.444	396.556	376.667
	<u>SD</u>	394.635	394.654	340.650	319.857	334.497
VT 20	<u>M</u>	598.889	544.444	642.333	655.111	649.667
	<u>SD</u>	588.175	598.645	611.311	626.185	687.708
VT 30	<u>M</u>	557.889	522.556	688.000	584.000	638.444
	<u>SD</u>	374.108	329.055	373.355	401.091	454.525
DRO 10	<u>M</u>	10.889	7.000	17.111	6.222	7.444
	<u>SD</u>	7.524	6.205	15.799	3.930	7.213
DRO 20	<u>M</u>	5.556	3.444	2.556	2.444	2.556
	<u>SD</u>	6.966	3.844	3.468	2.506	2.242
DRO 30	<u>M</u>	10.222	5.111	7.111	6.889	4.222
	<u>SD</u>	16.947	5.645	6.972	5.904	3.193

		Sessions				
Group		11	12	13	14	15
FT 10	<u>M</u>	436.333	494.333	502.222	481.889	451.556
	<u>SD</u>	999.177	1012.977	786.396	865.706	850.947
FT 20	<u>M</u>	469.556	451.889	453.444	445.778	433.778
	<u>SD</u>	698.730	713.233	666.189	686.211	703.084
FT 30	<u>M</u>	463.444	471.222	511.778	462.000	467.111
	<u>SD</u>	424.378	476.502	466.715	433.487	465.625
EXT	<u>M</u>	15.333	8.778	22.667	8.444	9.222
	<u>SD</u>	7.018	12.775	19.183	6.207	8.303
VT 10	<u>M</u>	367.556	340.778	310.444	307.889	324.778
	<u>SD</u>	310.440	379.434	311.642	297.212	265.386
VT 20	<u>M</u>	641.556	598.222	638.111	596.222	582.333
	<u>SD</u>	664.843	630.633	699.087	666.787	661.196
VT 30	<u>M</u>	597.556	504.222	641.667	601.444	598.000
	<u>SD</u>	500.455	446.722	588.012	491.911	536.723
DRO 10	<u>M</u>	4.000	2.889	7.222	9.333	5.333
	<u>SD</u>	2.784	2.472	9.563	17.103	5.523
DRO 20	<u>M</u>	1.778	2.333	2.889	2.000	2.333
	<u>SD</u>	2.991	2.872	3.296	2.500	2.646
DRO 30	<u>M</u>	4.000	3.667	4.222	2.222	5.222
	<u>SD</u>	4.213	3.969	6.457	.972	6.648

Figure Caption

Figure 8. Means for lever responding for each group across the fifteen sessions during the treatment phase.

Table 11

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

		Sessions				
Group		1	2	3	4	5
FT 10	<u>M</u>	2.593	2.354	2.367	2.281	2.188
	<u>SD</u>	.312	.451	.433	.479	.630
FT 20	<u>M</u>	2.836	2.696	2.794	2.670	2.646
	<u>SD</u>	.251	.370	.320	.362	.423
FT 30	<u>M</u>	2.872	2.818	2.794	2.645	2.555
	<u>SD</u>	.279	.321	.394	.618	.650
EXT	<u>M</u>	2.389	1.962	1.609	1.339	1.182
	<u>SD</u>	.343	.196	.358	.360	.384
VT 10	<u>M</u>	2.660	2.561	2.666	2.553	2.351
	<u>SD</u>	.312	.465	.322	.389	.482
VT 20	<u>M</u>	2.755	2.650	2.728	2.631	2.482
	<u>SD</u>	.319	.442	.420	.463	.494
VT 30	<u>M</u>	2.921	2.854	2.810	2.747	2.688
	<u>SD</u>	.133	.164	.227	.300	.331
DRO 10	<u>M</u>	2.669	1.769	1.592	1.132	1.068
	<u>SD</u>	.167	.313	.379	.432	.130
DRO 20	<u>M</u>	2.421	1.250	1.253	.983	.512
	<u>SD</u>	.341	.570	.556	.493	.547
DRO 30	<u>M</u>	2.734	2.075	1.664	.914	.841
	<u>SD</u>	.137	.218	.282	.419	.423

		Sessions				
Group		6	7	8	9	10
FT 10	<u>M</u>	2.135	1.882	2.167	2.067	1.628
	<u>SD</u>	.745	.827	.784	.859	1.264
FT 20	<u>M</u>	2.538	2.292	2.267	2.342	2.029
	<u>SD</u>	.532	.660	.652	.613	.872
FT 30	<u>M</u>	2.518	2.375	2.412	2.297	2.40
	<u>SD</u>	.701	.944	.867	.872	.673
EXT	<u>M</u>	1.097	1.045	1.158	1.050	1.064
	<u>SD</u>	.279	.405	.401	.667	.319
VT 10	<u>M</u>	2.412	2.351	2.427	2.420	2.378
	<u>SD</u>	.510	.547	.459	.466	.475
VT 20	<u>M</u>	2.553	2.498	2.623	2.593	2.565
	<u>SD</u>	.527	.507	.446	.520	.533
VT 30	<u>M</u>	2.644	2.611	2.767	2.633	2.669
	<u>SD</u>	.335	.357	.241	.404	.406
DRO 10	<u>M</u>	.951	.729	1.035	.759	.743
	<u>SD</u>	.418	.473	.545	.368	.478
DRO 20	<u>M</u>	.618	.469	.404	.434	.474
	<u>SD</u>	.451	.435	.370	.323	.279
DRO 30	<u>M</u>	.829	.572	.777	.755	.624
	<u>SD</u>	.387	.490	.355	.415	.329

		Sessions				
Group		11	12	13	14	15
FT 10	<u>M</u>	1.480	1.729	1.951	1.855	1.706
	<u>SD</u>	1.076	1.130	1.034	1.043	1.133
FT 20	<u>M</u>	1.979	1.921	2.118	2.063	1.821
	<u>SD</u>	1.016	1.068	.827	.929	1.068
FT 30	<u>M</u>	2.319	2.376	2.537	2.342	2.257
	<u>SD</u>	.846	.694	.429	.765	.951
EXT	<u>M</u>	1.172	.699	1.270	.888	.860
	<u>SD</u>	.210	.518	.315	.306	.424
VT 10	<u>M</u>	2.365	2.157	2.260	2.215	2.292
	<u>SD</u>	.498	.686	.516	.622	.575
VT 20	<u>M</u>	2.533	2.440	2.546	2.463	2.470
	<u>SD</u>	.591	.688	.540	.612	.587
VT 30	<u>M</u>	2.622	2.534	2.606	2.620	2.562
	<u>SD</u>	.413	.417	.474	.428	.517
DRO 10	<u>M</u>	.618	.507	.681	.718	.625
	<u>SD</u>	.311	.294	.499	.462	.447
DRO 20	<u>M</u>	.289	.387	.444	.342	.401
	<u>SD</u>	.355	.362	.389	.364	.351
DRO 30	<u>M</u>	.553	.495	.484	.480	.596
	<u>SD</u>	.396	.435	.464	.190	.429

Figure Caption

Figure 9. Common Log transformed means for lever responding for each group across the fifteen sessions during the treatment phase.

responded more than the DRO 20 and DRO 30 groups for session two. For sessions three through the end of this phase the FT and VT groups responded more than the EXT and DRO groups. During session five, eight and eleven the EXT group responded more than the DRO 10 and DRO 20 group. During sessions nine, ten, and 14 the EXT group responded more than the DRO 20 group. The data in Figure 9 show an early gradual decrease in responding over sessions, and a leveling out of the rate of responding in most groups is evident by the end of this phase. Furthermore, the FT and VT groups showed a decrease in responding which was not as great as that of the DRO animals, with the EXT group responding at times above those of the DRO animals.

The means and standard deviations for the reinforcers delivered during the treatment phase are presented in Table 12 and Figure 10. Because the EXT group, by definition did not receive any reinforcers during this phase they were excluded from this analysis. In this case, the $F_{\max}$ test of homogeneity of variance was found to be significant [$F_{\max}(9,8) = 3453.768, p > .01$], and as in the previous analysis, a common log transformation was performed with the resulting means and standard deviation reported in Table 13. A mixed design ANOVA summary table for the common log transformed data is presented in Appendix E.1. The interaction effect (treatment group x sessions) was significant [$F(112,1008) = 25.234, p < .05$], as were the main effects for treatment groups [$F(8,72) = 1053.673, p < .05$], and sessions [$F(14,1008) = 78.45, p < .05$]. An assessment of the practical significance of the effects for these data using omega squared values showed that the treatment group effect accounted for .757 of the variance, the session main effect had an omega squared value of .052, and the treatment group x session interaction effect had a calculated Omega squared of .130.

Simple effects tests (presented in Appendix E.2) for this analysis were found to be significant for all 15 sessions. These tests were expected to be

Table 12

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

		Sessions				
Group		1	2	3	4	5
FT 10	<u>M</u>	178.333	178.111	178.444	178.667	178.444
	<u>SD</u>	.500	.333	.527	.500	.527
FT 20	<u>M</u>	88.444	88.333	88.444	88.556	88.667
	<u>SD</u>	.527	.500	.527	.527	.500
FT 30	<u>M</u>	58.222	58.111	58.222	58.333	58.778
	<u>SD</u>	.441	.333	.441	.500	.441
VT 10	<u>M</u>	179.444	179.000	179.000	179.000	179.000
	<u>SD</u>	.527	0.000	0.000	0.000	0.000
VT 20	<u>M</u>	90.000	90.000	90.000	90.000	90.000
	<u>SD</u>	0.000	0.000	0.000	0.000	0.000
VT 30	<u>M</u>	60.000	60.000	60.000	60.000	60.000
	<u>SD</u>	0.000	0.000	0.000	0.000	0.000
DRO 10	<u>M</u>	38.222	71.889	76.000	83.556	84.778
	<u>SD</u>	13.581	7.219	8.930	4.531	1.716
DRO 20	<u>M</u>	41.000	74.889	75.111	81.667	85.000
	<u>SD</u>	19.570	12.888	10.006	8.803	7.681
DRO 30	<u>M</u>	16.444	40.556	64.222	77.000	79.667
	<u>SD</u>	10.702	17.465	9.667	13.407	10.247

		Sessions				
Group		6	7	8	9	10
FT 10	<u>M</u>	178.556	178.667	178.667	178.556	178.667
	<u>SD</u>	.527	.500	.500	.527	.500
FT 20	<u>M</u>	88.556	88.667	88.556	88.000	88.778
	<u>SD</u>	.527	.500	.527	0.000	.441
FT 30	<u>M</u>	58.556	58.667	58.444	58.667	58.444
	<u>SD</u>	.527	.500	.527	.500	.527
VT 10	<u>M</u>	179.000	179.000	179.000	179.000	179.000
	<u>SD</u>	0.000	0.000	0.000	0.000	0.000
VT 20	<u>M</u>	90.000	90.000	90.000	90.000	90.000
	<u>SD</u>	0.000	0.000	0.000	0.000	0.000
VT 30	<u>M</u>	60.000	60.000	60.000	60.000	60.000
	<u>SD</u>	0.000	0.000	0.000	0.000	0.000
DRO 10	<u>M</u>	85.444	86.667	84.556	87.000	86.222
	<u>SD</u>	2.603	2.500	3.712	1.414	2.991
DRO 20	<u>M</u>	84.889	86.222	88.000	87.778	87.222
	<u>SD</u>	5.711	3.598	1.936	1.787	1.716
DRO 30	<u>M</u>	80.333	83.889	83.222	83.444	84.444
	<u>SD</u>	10.654	5.947	4.790	4.003	3.504

		Sessions				
Group		11	12	13	14	15
FT 10	<u>M</u>	178.889	178.667	178.778	178.778	178.889
	<u>SD</u>	.333	.500	.441	.441	.333
FT 20	<u>M</u>	88.778	88.667	88.556	88.778	88.778
	<u>SD</u>	.441	.500	.527	.441	.441
FT 30	<u>M</u>	58.667	58.889	58.667	58.444	58.889
	<u>SD</u>	.500	.333	.500	.527	.333
VT 10	<u>M</u>	179.000	179.000	179.000	179.000	179.000
	<u>SD</u>	0.000	0.000	0.000	0.000	0.000
VT 20	<u>M</u>	90.000	90.000	90.000	90.000	90.000
	<u>SD</u>	0.000	0.000	0.000	0.000	0.000
VT 30	<u>M</u>	60.000	60.000	60.000	60.000	60.000
	<u>SD</u>	0.000	0.000	0.000	0.000	0.000
DRO 10	<u>M</u>	88.000	87.889	86.222	86.889	87.111
	<u>SD</u>	1.225	1.537	3.193	3.371	2.472
DRO 20	<u>M</u>	87.778	87.333	87.444	87.889	87.333
	<u>SD</u>	2.774	2.500	1.944	1.537	1.936
DRO 30	<u>M</u>	86.444	86.667	87.111	86.333	85.111
	<u>SD</u>	2.698	3.041	2.667	1.581	4.167

Figure Caption

Figure 10. Means for reinforcers received for each group across the fifteen sessions during the treatment phase.

Table 13

Means and Standard Deviations of Common Log Transformed
Reinforcements for Each Group During the Treatment Phase

		Sessions				
Group		1	2	3	4	5
FT 10	<u>M</u>	2.251	2.251	2.252	2.252	2.252
	<u>SD</u>	.001	.000	.001	.001	.001
FT 20	<u>M</u>	1.947	1.946	1.947	1.947	1.948
	<u>SD</u>	.002	.002	.002	.002	.002
FT 30	<u>M</u>	1.765	1.764	1.765	1.766	1.769
	<u>SD</u>	.003	.002	.003	.003	.003
VT 10	<u>M</u>	2.254	2.253	2.253	2.253	2.253
	<u>SD</u>	.001	.000	.000	.000	.000
VT 20	<u>M</u>	1.954	1.954	1.954	1.954	1.954
	<u>SD</u>	.000	.000	.000	.000	.000
VT 30	<u>M</u>	1.778	1.778	1.778	1.778	1.778
	<u>SD</u>	.000	.000	.000	.000	.000
DRO 10	<u>M</u>	1.554	1.855	1.878	1.921	1.928
	<u>SD</u>	.173	.043	.054	.025	.008
DRO 20	<u>M</u>	1.566	1.868	1.872	1.909	1.928
	<u>SD</u>	.220	.079	.062	.052	.044
DRO 30	<u>M</u>	1.094	1.570	1.803	1.879	1.898
	<u>SD</u>	.395	.195	.074	.088	.061

		Sessions				
Group		6	7	8	9	10
FT 10	<u>M</u>	2.252	2.252	2.252	2.252	2.252
	<u>SD</u>	.001	.001	.001	.001	.001
FT 20	<u>M</u>	1.947	1.948	1.947	1.944	1.948
	<u>SD</u>	.002	.002	.002	.000	.002
FT 30	<u>M</u>	1.768	1.768	1.767	1.768	1.767
	<u>SD</u>	.003	.003	.003	.003	.003
VT 10	<u>M</u>	2.253	2.253	2.253	2.253	2.253
	<u>SD</u>	.001	.000	.000	.000	.000
VT 20	<u>M</u>	1.954	1.954	1.954	1.954	1.954
	<u>SD</u>	.000	.000	.000	.000	.000
VT 30	<u>M</u>	1.778	1.778	1.778	1.778	1.778
	<u>SD</u>	.000	.000	.000	.000	.000
DRO 10	<u>M</u>	1.932	1.938	1.927	1.939	1.935
	<u>SD</u>	.013	.013	.019	.007	.015
DRO 20	<u>M</u>	1.928	1.935	1.944	1.943	1.941
	<u>SD</u>	.031	.018	.010	.008	.008
DRO 30	<u>M</u>	1.901	1.923	1.920	1.921	1.926
	<u>SD</u>	.068	.031	.026	.021	.018

		Sessions				
Group		11	12	13	14	15
FT 10	<u>M</u>	2.253	2.252	2.252	2.252	2.253
	<u>SD</u>	.000	.001	.001	.001	.008
FT 20	<u>M</u>	1.948	1.948	1.947	1.948	1.948
	<u>SD</u>	.002	.002	.002	.002	.002
FT 30	<u>M</u>	1.768	1.770	1.768	1.767	1.770
	<u>SD</u>	.003	.002	.003	.003	.002
VT 10	<u>M</u>	2.253	2.253	2.253	2.253	2.253
	<u>SD</u>	.001	.000	.000	.000	.000
VT 20	<u>M</u>	1.954	1.954	1.954	1.954	1.954
	<u>SD</u>	.000	.000	.000	.000	.000
VT 30	<u>M</u>	1.778	1.778	1.778	1.778	1.778
	<u>SD</u>	.000	.000	.000	.000	.000
DRO 10	<u>M</u>	1.944	1.944	1.935	1.939	1.940
	<u>SD</u>	.006	.007	.016	.017	.012
DRO 20	<u>M</u>	1.943	1.941	1.942	1.944	1.941
	<u>SD</u>	.014	.013	.010	.007	.010
DRO 30	<u>M</u>	1.937	1.938	1.940	1.936	1.930
	<u>SD</u>	.014	.015	.013	.007	.022

Figure Caption

Figure 11. Common Log transformed means for reinforcers received for each group across the fifteen sessions during the treatment phase.

significant in light of the fact that the particular parameters for each treatment group were selected in order to deliver different numbers of reinforcements to each treatment group. Of interest therefore, was the pattern of delivered reinforcers earned by the DRO treatment conditions in which the rate of reinforcement for these subjects varied with the animals' response rates. Tukey (hsd) follow-up tests revealed that the FT 10 and VT 10 groups received the most reinforcers followed by the FT 20 and VT 20 groups, followed by the FT 30 and VT 30 animals throughout this phase. For minute one the DRO 10 and DRO 20 animals received equivalent reinforcers but more than the DRO 30 group. During the second session the DRO 20 group received as many reinforcers as the FT 20 and VT 20 group and the DRO 10 group received as many pellets of food as the FT 30 and VT 30 group. During this session the DRO 30 group received fewer reinforcers than all the other groups. For the remainder of this phase (sessions three through 15) there was no difference between the three DRO treatment groups and the FT 20 and VT 20 groups. A graph of the means of the common log transformed number of reinforcers data are presented in Figure 11. Most evident is the fact that the FT 10 and VT 10, FT 20 and VT 20, and FT 30 and VT 30 groups received equal numbers of reinforcers throughout this session. Also, after the first three minutes, during which the DRO groups increased their earned reinforcers, their reinforcement values equaled those for the intermediate non-contingent groups (ie. FT 20 and VT 20).

The response-response interval data for the treatment phase are conveyed in Table 14 and depicted in Figure 12. Again an $E_{\max}$ test indicated violation of homogeneity [$E_{\max}(10,8) = 578,549.030$, $p > .05$] and the data were subsequently transformed using a common log transformation. The transformed data reduced this violation of homogeneity [$E_{\max}(10,8) = 177.374$, $p > .05$]. The transformed data are listed in Table 15 and their means are shown in Figure 13. A 10×15 (treatment group $\times$ session) ANOVA was performed on these data (see Appendix F.1).

Table 14

Means and Standard Deviations of Response-Response Intervals for Each Group During the Treatment Phase

		Sessions				
Group		1	2	3	4	5
FT 10	<u>M</u>	5.412	11.119	9.930	13.438	24.086
	<u>SD</u>	2.963	7.825	5.580	9.986	39.947
FT 20	<u>M</u>	3.044	4.912	3.547	5.212	6.090
	<u>SD</u>	2.011	4.380	2.778	4.725	6.050
FT 30	<u>M</u>	2.982	3.651	4.390	10.275	14.458
	<u>SD</u>	2.444	3.758	5.791	21.587	30.851
EXT	<u>M</u>	8.491	18.951	36.857	54.293	102.156
	<u>SD</u>	7.439	8.691	23.743	56.392	113.651
VT 10	<u>M</u>	4.951	8.510	5.012	6.930	12.336
	<u>SD</u>	3.787	11.411	4.289	6.462	11.039
VT 20	<u>M</u>	3.916	6.193	5.306	7.014	11.370
	<u>SD</u>	2.597	6.751	6.634	8.652	17.536
VT 30	<u>M</u>	2.246	2.656	3.145	4.034	4.942
	<u>SD</u>	.748	.973	1.799	3.321	4.939
DRO 10	<u>M</u>	4.398	38.411	59.484	167.998	112.390
	<u>SD</u>	2.200	45.609	50.399	120.400	44.722
DRO 20	<u>M</u>	5.527	55.518	40.103	126.005	143.617
	<u>SD</u>	2.183	55.723	26.194	163.915	229.553
DRO 30	<u>M</u>	3.421	14.037	36.073	285.854	204.775
	<u>SD</u>	1.211	6.319	21.957	385.614	159.695

		Sessions				
Group		6	7	8	9	10
FT 10	<u>M</u>	37.488	70.263	39.225	40.808	70.128
	<u>SD</u>	58.634	78.816	69.258	62.534	166.986
FT 20	<u>M</u>	9.027	13.015	16.674	14.500	28.189
	<u>SD</u>	11.470	11.226	19.816	15.592	31.748
FT 30	<u>M</u>	11.952	4.469	4.820	98.098	21.611
	<u>SD</u>	22.838	4.366	5.590	236.411	46.199
EXT	<u>M</u>	96.797	74.063	150.279	200.972	179.335
	<u>SD</u>	56.785	62.181	113.588	310.414	186.008
VT 10	<u>M</u>	11.812	14.240	10.497	11.624	12.261
	<u>SD</u>	11.886	16.074	11.125	13.993	12.343
VT 20	<u>M</u>	10.086	9.911	6.559	8.445	8.797
	<u>SD</u>	15.847	11.815	6.708	10.457	9.771
VT 30	<u>M</u>	5.309	6.044	3.454	6.352	5.869
	<u>SD</u>	4.120	5.333	1.909	6.529	6.193
DRO 10	<u>M</u>	130.975	224.037	181.417	146.290	144.512
	<u>SD</u>	104.944	270.145	306.281	134.032	108.942
DRO 20	<u>M</u>	432.728	83.165	68.179	231.665	402.035
	<u>SD</u>	471.375	106.544	91.408	281.448	568.996
DRO 30	<u>M</u>	278.230	188.153	225.743	108.151	237.208
	<u>SD</u>	245.101	275.888	227.555	104.241	233.762

		Sessions				
Group		11	12	13	14	15
FT 10	<u>M</u>	64.476	54.910	35.690	125.918	57.867
	<u>SD</u>	63.472	97.699	63.191	274.486	105.531
FT 20	<u>M</u>	35.104	31.235	22.399	70.345	54.460
	<u>SD</u>	67.270	51.300	31.653	174.109	91.022
FT 30	<u>M</u>	6.137	41.600	7.482	58.327	7.505
	<u>SD</u>	6.296	103.236	7.273	152.165	9.193
EXT	<u>M</u>	128.401	119.735	102.642	142.532	141.392
	<u>SD</u>	91.105	128.081	106.902	79.958	87.771
VT 10	<u>M</u>	12.728	26.173	17.804	24.187	26.191
	<u>SD</u>	14.732	32.990	20.567	40.483	51.956
VT 20	<u>M</u>	11.537	18.766	8.690	13.058	12.288
	<u>SD</u>	15.292	29.195	9.877	14.771	14.227
VT 30	<u>M</u>	6.164	7.078	6.917	6.493	9.252
	<u>SD</u>	5.713	5.492	6.250	6.669	12.154
DRO 10	<u>M</u>	147.387	205.107	158.865	108.259	112.758
	<u>SD</u>	138.696	449.470	160.453	149.921	123.362
DRO 20	<u>M</u>	53.206	99.590	306.131	205.633	134.368
	<u>SD</u>	107.373	177.207	541.664	328.122	230.261
DRO 30	<u>M</u>	167.442	73.463	111.454	245.450	158.024
	<u>SD</u>	203.189	98.673	176.109	226.157	298.511

Figure Caption

Figure 12. Means of response-response intervals in seconds for each group across the fifteen sessions during the treatment phase.

Table 15

Means and Standard Deviations of Common Log Transformed Response-Response Intervals for Each Group During the Treatment Phase

		Sessions				
Group		1	2	3	4	5
FT 10	<u>M</u>	.756	.971	.951	1.036	1.086
	<u>SD</u>	.237	.368	.337	.393	.526
FT 20	<u>M</u>	.568	.681	.600	.705	.733
	<u>SD</u>	.186	.286	.227	.284	.332
FT 30	<u>M</u>	.549	.589	.610	.718	.797
	<u>SD</u>	.206	.249	.298	.456	.508
EXT	<u>M</u>	.906	1.270	1.488	1.579	1.817
	<u>SD</u>	.232	.161	.318	.397	.435
VT 10	<u>M</u>	.706	.790	.702	.791	.969
	<u>SD</u>	.251	.385	.259	.315	.407
VT 20	<u>M</u>	.637	.726	.664	.744	.860
	<u>SD</u>	.235	.343	.329	.374	.427
VT 30	<u>M</u>	.502	.550	.586	.637	.685
	<u>SD</u>	.093	.115	.171	.236	.270
DRO 10	<u>M</u>	.704	1.449	1.652	2.089	2.006
	<u>SD</u>	.162	.332	.369	.413	.251
DRO 20	<u>M</u>	.792	1.507	1.438	1.538	1.204
	<u>SD</u>	.153	.549	.575	.916	1.207
DRO 30	<u>M</u>	.632	1.148	1.496	2.183	2.023
	<u>SD</u>	.110	.162	.275	.500	.774

		Sessions				
Group		6	7	8	9	10
FT 10	<u>M</u>	1.175	1.425	1.141	1.193	.966
	<u>SD</u>	.644	.762	.666	.681	.927
FT 20	<u>M</u>	.814	.971	1.013	.980	1.174
	<u>SD</u>	.412	.455	.499	.486	.609
FT 30	<u>M</u>	.795	.622	.621	1.087	.919
	<u>SD</u>	.470	.344	.370	.856	.554
EXT	<u>M</u>	1.903	1.556	2.046	1.661	2.050
	<u>SD</u>	.328	.758	.379	.945	.461
VT 10	<u>M</u>	.923	.974	.898	.915	.952
	<u>SD</u>	.433	.463	.391	.408	.412
VT 20	<u>M</u>	.806	.856	.750	.780	.803
	<u>SD</u>	.436	.413	.349	.419	.427
VT 30	<u>M</u>	.723	.750	.615	.738	.712
	<u>SD</u>	.271	.298	.179	.337	.332
DRO 10	<u>M</u>	1.867	1.792	1.759	1.701	1.735
	<u>SD</u>	.740	1.072	.825	1.004	1.000
DRO 20	<u>M</u>	1.967	1.001	.965	1.392	1.516
	<u>SD</u>	1.212	1.191	1.128	1.354	1.465
DRO 30	<u>M</u>	2.224	1.516	1.991	1.595	1.884
	<u>SD</u>	.542	1.186	.843	.948	1.086

		Sessions				
Group		11	12	13	14	15
FT 10	<u>M</u>	1.363	1.139	1.016	1.377	1.139
	<u>SD</u>	.879	.837	.774	.871	.856
FT 20	<u>M</u>	.990	1.011	1.068	1.152	1.112
	<u>SD</u>	.757	.743	.559	.725	.853
FT 30	<u>M</u>	.700	.982	.805	1.007	.726
	<u>SD</u>	.405	.654	.343	.706	.450
EXT	<u>M</u>	2.035	1.440	1.770	1.933	1.920
	<u>SD</u>	.262	1.113	.601	.746	.747
VT 10	<u>M</u>	.945	1.130	1.056	1.074	1.028
	<u>SD</u>	.421	.572	.462	.522	.541
VT 20	<u>M</u>	.836	.916	.805	.899	.890
	<u>SD</u>	.491	.585	.420	.507	.485
VT 30	<u>M</u>	.743	.805	.762	.746	.802
	<u>SD</u>	.326	.329	.373	.342	.428
DRO 10	<u>M</u>	1.532	1.122	1.534	1.434	1.388
	<u>SD</u>	1.147	1.227	1.177	.989	1.110
DRO 20	<u>M</u>	.528	.859	1.328	1.143	.952
	<u>SD</u>	1.048	1.189	1.365	1.370	1.235
DRO 30	<u>M</u>	1.381	.985	1.034	1.791	1.272
	<u>SD</u>	1.254	1.148	1.197	1.118	1.203

Figure Caption

Figure 13. Means of Common Log transformed response-response intervals in seconds for each group across the fifteen sessions during the treatment phase.

The interaction effect and both main effects for treatment group and sessions were significant at the $p < .05$ level with values of $[F(126,1120) = 1.547]$, $[F(9,80) = 6.898]$, and $[F(14,1120) = 7.284]$ respectively. Omega squared values for this analysis were .026 for the treatment group x session interaction, .174 for the treatment groups main effect, and .033 for the sessions main effect.

Simple effects tests were performed for each session of this phase and can be found in Appendix F.2. Again for each simple effects test computed, the Satterthwaite method (Winer, 1971) was used to compute the degrees of freedom for the denominator. Nonsignificant simple effects tests were found for sessions one and 12 only, with all other sessions showing some differences between treatment groups. Tukey (hsd) follow-up tests were not as consistent as for the two previous analysis. During the first session the DRO 10, DRO 20 and EXT groups had longer response-response intervals than the FT and VT groups, and the DRO 20 group had longer response-response intervals than the DRO 30 group. During the second session the DRO groups' and EXT response-response intervals were equivalent and greater than the FT and VT groups, with the FT 10 group's response-response interval greater than the other two FT groups and the VT 30 group. These data, seen in Figure 13, show variable response-response intervals for the DRO and EXT groups, yet these intervals were almost consistently above those of the FT and VT treatment groups.

The means and standard deviations for the response-reinforcement intervals are reported in Table 16 and depicted in Figure 14. A Hartley's F_{max} test revealed significant heterogeneity of variance $[F_{max}(9,8) = 3,874.663, p > .01]$. The data were transformed using a common log scale and resulted in a reduction of violations of homogeneity of variance $[F_{max}(9,8) = 429.765, p > .01]$. The ANOVA performed on the common log transformed data may be found in Appendix G.1, and the resulting means and standard deviation are reported in Table 17. The treatment group by

Table 16

Means and Standard Deviations of Response-Reinforcement Intervals for Each Group During the Treatment Phase

		Sessions				
Group		1	2	3	4	5
FT 10	<u>M</u>	2.391	2.466	3.132	3.238	3.393
	<u>SD</u>	.624	.843	.848	1.137	1.123
FT 20	<u>M</u>	1.736	2.077	2.335	2.802	3.268
	<u>SD</u>	.917	1.356	1.860	2.029	2.240
FT 30	<u>M</u>	1.563	1.956	2.496	2.702	3.240
	<u>SD</u>	.900	1.299	1.523	1.433	2.642
VT 10	<u>M</u>	3.390	4.946	3.199	5.139	4.427
	<u>SD</u>	1.273	4.546	.909	4.855	2.066
VT 20	<u>M</u>	4.455	4.894	4.374	5.410	7.800
	<u>SD</u>	2.081	2.817	2.456	2.808	6.479
VT 30	<u>M</u>	3.962	4.624	4.991	5.450	5.965
	<u>SD</u>	1.276	1.494	2.330	2.550	2.869
DRO 10	<u>M</u>	17.707	17.801	19.570	20.883	21.051
	<u>SD</u>	2.008	2.188	2.774	2.977	1.650
DRO 20	<u>M</u>	27.840	27.585	31.826	31.436	32.787
	<u>SD</u>	2.127	4.373	4.875	5.476	6.367
DRO 30	<u>M</u>	38.324	34.087	37.288	41.345	41.235
	<u>SD</u>	4.223	11.737	3.042	4.943	3.765

		Sessions				
Group		6	7	8	9	10
FT 10	<u>M</u>	3.346	3.566	3.775	3.443	5.189
	<u>SD</u>	1.304	1.459	1.700	1.192	3.241
FT 20	<u>M</u>	3.770	4.697	4.809	4.263	5.385
	<u>SD</u>	2.355	2.973	3.345	3.251	3.777
FT 30	<u>M</u>	2.649	6.517	4.230	5.342	4.831
	<u>SD</u>	1.040	8.954	2.703	5.143	3.182
VT 10	<u>M</u>	3.956	4.631	4.488	4.321	4.503
	<u>SD</u>	1.640	1.947	1.676	1.742	2.070
VT 20	<u>M</u>	5.465	5.134	5.154	5.291	5.071
	<u>SD</u>	3.464	2.445	3.054	3.206	3.398
VT 30	<u>M</u>	7.485	7.305	5.801	6.337	6.475
	<u>SD</u>	4.300	4.231	2.823	4.000	3.546
DRO 10	<u>M</u>	23.397	25.225	22.331	22.921	23.996
	<u>SD</u>	3.123	4.848	3.493	3.392	3.867
DRO 20	<u>M</u>	33.877	33.415	34.592	34.181	34.406
	<u>SD</u>	4.096	5.243	4.747	5.106	4.132
DRO 30	<u>M</u>	40.906	44.695	41.470	42.094	42.437
	<u>SD</u>	3.813	6.228	2.833	4.206	4.709

		Sessions				
Group		11	12	13	14	15
FT 10	<u>M</u>	4.544	4.383	4.618	3.975	4.461
	<u>SD</u>	2.172	2.494	2.406	1.544	2.632
FT 20	<u>M</u>	4.851	5.921	6.236	6.421	5.135
	<u>SD</u>	2.643	5.614	3.984	3.529	2.282
FT 30	<u>M</u>	4.705	5.044	5.628	6.006	7.114
	<u>SD</u>	3.148	3.319	3.608	5.823	9.106
VT 10	<u>M</u>	4.138	18.197	4.359	5.416	4.322
	<u>SD</u>	1.366	38.842	1.366	2.122	1.222
VT 20	<u>M</u>	5.932	7.404	5.722	6.594	6.670
	<u>SD</u>	4.959	6.229	3.896	4.293	4.210
VT 30	<u>M</u>	6.922	8.389	6.616	8.440	9.923
	<u>SD</u>	3.681	5.225	4.299	6.677	10.678
DRO 10	<u>M</u>	24.005	22.441	23.527	23.758	25.330
	<u>SD</u>	4.015	4.006	4.102	7.561	3.661
DRO 20	<u>M</u>	37.546	35.011	36.507	35.763	33.669
	<u>SD</u>	3.606	4.277	4.102	4.590	5.872
DRO 30	<u>M</u>	45.494	45.228	44.056	42.248	42.621
	<u>SD</u>	2.780	4.898	4.901	3.399	4.570

Figure Caption

Figure 14. Means of response-reinforcement intervals in seconds for each group across the fifteen sessions during the treatment phase.

Table 17

Means and Standard Deviations of Common Log Transformed Response-Reinforcement Intervals for Each Group During the Treatment Phase

		Sessions				
Group		1	2	3	4	5
FT 10	<u>M</u>	.361	.366	.478	.484	.502
	<u>SD</u>	.140	.167	.143	.165	.182
FT 20	<u>M</u>	.187	.245	.265	.358	.420
	<u>SD</u>	.228	.257	.305	.290	.314
FT 30	<u>M</u>	.146	.229	.340	.375	.413
	<u>SD</u>	.204	.233	.224	.238	.298
VT 10	<u>M</u>	.502	.594	.486	.617	.603
	<u>SD</u>	.169	.279	.146	.260	.209
VT 20	<u>M</u>	.606	.613	.575	.668	.783
	<u>SD</u>	.207	.288	.260	.268	.317
VT 30	<u>M</u>	.576	.642	.656	.694	.731
	<u>SD</u>	.149	.157	.204	.206	.211
DRO 10	<u>M</u>	1.246	1.248	1.288	1.315	1.322
	<u>SD</u>	.051	.051	.062	.072	.035
DRO 20	<u>M</u>	1.444	1.436	1.499	1.491	1.508
	<u>SD</u>	.033	.067	.063	.077	.089
DRO 30	<u>M</u>	1.581	1.461	1.570	1.614	1.614
	<u>SD</u>	.045	.354	.036	.051	.040

		Sessions				
Group		6	7	8	9	10
FT 10	<u>M</u>	.491	.515	.538	.508	.630
	<u>SD</u>	.190	.198	.198	.177	.300
FT 20	<u>M</u>	.473	.570	.576	.510	.613
	<u>SD</u>	.344	.340	.337	.355	.367
FT 30	<u>M</u>	.390	.614	.538	.570	.582
	<u>SD</u>	.186	.385	.309	.392	.333
VT 10	<u>M</u>	.562	.629	.625	.607	.615
	<u>SD</u>	.189	.194	.161	.165	.194
VT 20	<u>M</u>	.660	.661	.639	.639	.599
	<u>SD</u>	.280	.229	.272	.302	.347
VT 30	<u>M</u>	.810	.801	.709	.729	.737
	<u>SD</u>	.251	.246	.245	.266	.286
DRO 10	<u>M</u>	1.366	1.395	1.345	1.356	1.375
	<u>SD</u>	.056	.079	.064	.063	.068
DRO 20	<u>M</u>	1.527	1.519	1.535	1.529	1.534
	<u>SD</u>	.052	.067	.061	.067	.052
DRO 30	<u>M</u>	1.610	1.646	1.617	1.622	1.625
	<u>SD</u>	.043	.064	.030	.043	.049

		Sessions				
Group		11	12	13	14	15
FT 10	<u>M</u>	.608	.582	.602	.565	.587
	<u>SD</u>	.230	.245	.259	.190	.246
FT 20	<u>M</u>	.606	.643	.707	.735	.653
	<u>SD</u>	.309	.348	.308	.295	.265
FT 30	<u>M</u>	.569	.600	.645	.618	.615
	<u>SD</u>	.333	.333	.346	.397	.465
VT 10	<u>M</u>	.593	.809	.619	.701	.620
	<u>SD</u>	.157	.539	.147	.183	.123
VT 20	<u>M</u>	.656	.727	.632	.724	.750
	<u>SD</u>	.336	.377	.387	.320	.272
VT 30	<u>M</u>	.781	.838	.735	.791	.835
	<u>SD</u>	.245	.300	.291	.379	.373
DRO 10	<u>M</u>	1.375	1.344	1.366	1.360	1.400
	<u>SD</u>	.072	.084	.073	.118	.062
DRO 20	<u>M</u>	1.573	1.541	1.560	1.550	1.521
	<u>SD</u>	.043	.054	.051	.058	.079
DRO 30	<u>M</u>	1.657	1.653	1.642	1.625	1.627
	<u>SD</u>	.026	.048	.048	.033	.049

Figure Caption

Figure 15. Means of Common Log transformed response-reinforcement intervals in seconds for each group across the fifteen sessions during the treatment phase.

sessions interaction effect was found to be significant [$F(112,1008) = 2.473$, $p < .05$]. The main effect for treatment group was also significant [$F(8,72) = 50.223$, $p < .05$], as was the main effect for sessions [$F(14,1008) = 28.495$, $p < .05$]. Omega squared values for this analysis were .009 for the interaction effect, .758 for the treatment groups effect and .020 for the sessions effect.

Simple effects tests for this analysis were significant for all 15 sessions indicating differences between treatment groups throughout this phase (see Appendix G.2 for the computed simple effects tests' values). Tukey (hsd) follow-up tests for session one showed that the DRO 30 group had longer response-reinforcement intervals than the DRO 10 and DRO 20 groups who had longer response-reinforcement intervals than the VT groups and the FT 10 and FT 20 groups. Also the FT 10 and VT 30 group had longer response-reinforcement intervals than the FT 30 group for this session. For session two all the DRO groups had longer response-reinforcement intervals than the VT groups who in turn had longer response-reinforcement intervals than the FT groups. During session three the order for response-reinforcement intervals showed the DRO 30 greater than the DRO 10 and DRO 20 groups, greater than the all three VT and the FT 10 group, greater than the two remaining FT groups. For the remainder of this phase the DRO 20 and DRO 30 groups did not differ but had consistently longer response-reinforcement intervals than the other groups. The order of groups was similar during session four as session three. Session five data indicated longer response-reinforcement intervals for the DRO 10 and DRO 20 groups than the VT 20 and VT 30 groups, who were significantly higher than the three FT groups. During the sixth session only the DRO 10 group had longer response-reinforcement intervals than the VT 30 group, which had longer response-reinforcement intervals than the VT 10 and the three FT groups. Session 7 data indicated longer response-reinforcement intervals for the DRO 10 group than the FT and VT groups, and that the VT 30 group had longer intervals than the FT 10

and FT 20 groups. The same is true for sessions eight through 14 with the exception that during session nine and 12 and 14 the VT 30 group was significantly higher than the FT 10 group, and during session 12 and 14 the VT 10 group had longer response-reinforcement intervals than the FT 10 group and the VT 30 group was also higher than the FT 30 group. During the last session of this phase the same order was again true except that the VT 30 group had longer response-reinforcement intervals than the FT 10, FT 30, and VT 10 groups. These data, depicted in Figure 15, then show that the the DRO groups had consistently longer response-reinforcement intervals than the other groups and that during the latter two thirds of the phase the VT 30 group had greater response-reinforcement intervals than the other five non-contingent treatment groups. Figure 15 supports the finding that the DRO 30 group had consistently longer intervals between a response and the next delivered reinforcer than the other groups. Also, the two other DRO groups had longer intervals between response and reinforcement than the other groups.

Subjects were compared for the number of responses per reinforcement-reinforcement interval. These data are reported in Table 18 and graphically represented in Figure 16. Again the data were transformed using a common log transformation due to violations of homogeneity of variance [$E_{\max}(9,8) = 81,195.357$, $p > .05$]. The transformed data again reduced violations of homogeneity of variance $E_{\max}(9,8) = 48.325$, $p > .05$] and these data may be found in Table 19 and Figure 17. A 9×15 (treatment group $\times$ session) ANOVA summary table for these data may be found in Appendix H.1. Again all the effects were significant at the $p < .05$ level. For these effects calculated values were [$E(112,1008) = 11.726$] for the treatment group by session interaction effect, [$E(8,72) = 13.328$] for the treatment group main effect, and [$E(14,1008) = 89.47$] for the session main effect. Omega squared values of .111 for the treatment group by session

Table 18

Means and Standard Deviations of the Number of Responses Per Reinforcement-Reinforcement Interval for Each Group During the Treatment Phase

		Sessions				
Group		1	2	3	4	5
FT 10	<u>M</u>	4.037	3.280	3.450	3.264	3.308
	<u>SD</u>	2.557	2.421	2.355	2.411	2.435
FT 20	<u>M</u>	9.067	7.969	9.033	8.210	8.253
	<u>SD</u>	4.434	4.741	4.840	5.050	6.302
FT 30	<u>M</u>	14.799	13.846	13.300	12.624	11.052
	<u>SD</u>	8.035	8.056	9.277	9.901	8.564
VT 10	<u>M</u>	8.194	7.639	8.359	8.136	7.685
	<u>SD</u>	2.849	2.927	3.418	4.199	5.845
VT 20	<u>M</u>	17.876	15.785	17.394	17.234	14.124
	<u>SD</u>	11.141	12.612	12.610	17.780	14.529
VT 30	<u>M</u>	30.178	26.612	25.510	23.273	21.344
	<u>SD</u>	7.855	10.084	10.866	11.603	11.760
DRO 10	<u>M</u>	47.298	5.463	3.392	2.087	1.869
	<u>SD</u>	24.165	1.778	1.853	1.268	.423
DRO 20	<u>M</u>	53.696	5.142	4.291	4.185	1.167
	<u>SD</u>	42.794	5.752	2.253	4.247	1.302
DRO 30	<u>M</u>	154.552	17.534	10.509	2.444	2.096
	<u>SD</u>	120.533	12.399	9.526	1.473	1.042

		Sessions				
Group		6	7	8	9	10
FT 10	<u>M</u>	3.685	3.183	3.920	4.098	3.585
	<u>SD</u>	2.840	2.616	3.377	3.853	4.525
FT 20	<u>M</u>	8.119	7.040	6.999	7.501	7.449
	<u>SD</u>	6.439	6.543	6.304	6.819	6.742
FT 30	<u>M</u>	10.413	9.111	10.229	9.290	8.814
	<u>SD</u>	7.896	6.592	6.878	8.334	7.561
VT 10	<u>M</u>	6.493	6.453	5.928	6.238	6.281
	<u>SD</u>	3.666	3.783	3.440	3.123	3.043
VT 20	<u>M</u>	14.324	13.308	15.123	15.494	15.826
	<u>SD</u>	12.876	13.287	13.495	13.721	15.045
VT 30	<u>M</u>	19.997	19.122	23.488	21.272	22.667
	<u>SD</u>	12.684	10.168	12.513	13.020	14.983
DRO 10	<u>M</u>	1.897	1.389	2.098	1.813	1.389
	<u>SD</u>	1.027	.939	1.326	1.016	.914
DRO 20	<u>M</u>	1.231	.917	1.361	1.278	.991
	<u>SD</u>	.843	.738	1.376	1.202	.638
DRO 30	<u>M</u>	2.262	1.239	2.216	1.918	1.202
	<u>SD</u>	1.909	1.090	1.876	1.328	.575

		Sessions				
Group		11	12	13	14	15
FT 10	<u>M</u>	3.722	4.132	4.165	4.194	4.248
	<u>SD</u>	5.129	6.008	4.492	4.330	4.541
FT 20	<u>M</u>	7.468	6.641	7.383	6.936	6.959
	<u>SD</u>	6.949	7.905	6.507	6.878	7.098
FT 30	<u>M</u>	8.298	8.367	9.443	8.387	8.214
	<u>SD</u>	6.849	7.768	7.333	6.809	7.714
VT 10	<u>M</u>	6.249	6.665	5.874	5.266	5.683
	<u>SD</u>	2.870	3.870	2.836	2.969	2.330
VT 20	<u>M</u>	15.921	14.523	15.984	14.288	14.608
	<u>SD</u>	16.359	13.553	16.148	14.687	15.879
VT 30	<u>M</u>	21.012	18.555	22.740	21.442	21.591
	<u>SD</u>	16.912	15.022	19.687	16.241	18.092
DRO 10	<u>M</u>	1.909	1.344	1.228	1.710	1.194
	<u>SD</u>	1.327	.740	.817	.863	.749
DRO 20	<u>M</u>	.513	.956	1.407	1.370	1.252
	<u>SD</u>	.618	.778	1.770	2.233	1.286
DRO 30	<u>M</u>	2.704	1.574	3.000	1.167	1.722
	<u>SD</u>	4.046	1.382	6.431	.612	1.349

Figure Caption

Figure 16. Means of the number of responses per reinforcement-reinforcement interval for each group across the fifteen sessions during the treatment phase.

Table 19

Means and Standard Deviations of Common Log Transformed Number of Responses Per Reinforcement-Reinforcement Interval for Each Group During the Treatment Phase

		Sessions				
Group		1	2	3	4	5
FT 10	<u>M</u>	.656	.582	.603	.578	.583
	<u>SD</u>	.209	.210	.201	.214	.213
FT 20	<u>M</u>	.954	.899	.954	.908	.880
	<u>SD</u>	.237	.232	.222	.235	.289
FT 30	<u>M</u>	1.145	1.108	1.078	1.032	.973
	<u>SD</u>	.239	.264	.288	.332	.341
VT 10	<u>M</u>	.942	.913	.943	.915	.865
	<u>SD</u>	.149	.154	.173	.222	.262
VT 20	<u>M</u>	1.215	1.117	1.165	1.113	1.041
	<u>SD</u>	.238	.327	.327	.375	.356
VT 30	<u>M</u>	1.480	1.417	1.387	1.326	1.290
	<u>SD</u>	.121	.152	.196	.263	.248
DRO 10	<u>M</u>	1.630	.790	.612	.465	.454
	<u>SD</u>	.244	.152	.169	.145	.062
DRO 20	<u>M</u>	1.623	.662	.665	.611	.273
	<u>SD</u>	.330	.326	.279	.300	.245
DRO 30	<u>M</u>	2.083	1.186	.936	.503	.472
	<u>SD</u>	.328	.282	.346	.182	.129

		Sessions				
Group		6	7	8	9	10
FT 10	<u>M</u>	.610	.562	.620	.630	.506
	<u>SD</u>	.234	.227	.251	.252	.385
FT 20	<u>M</u>	.867	.788	.808	.829	.814
	<u>SD</u>	.301	.334	.295	.300	.329
FT 30	<u>M</u>	.952	.883	.955	.874	.877
	<u>SD</u>	.339	.403	.336	.378	.336
VT 10	<u>M</u>	.827	.818	.793	.821	.826
	<u>SD</u>	.219	.238	.216	.201	.194
VT 20	<u>M</u>	1.061	1.023	1.081	1.086	1.095
	<u>SD</u>	.347	.343	.352	.362	.350
VT 30	<u>M</u>	1.242	1.245	1.342	1.271	1.283
	<u>SD</u>	.289	.252	.212	.284	.312
DRO 10	<u>M</u>	.431	.340	.449	.417	.341
	<u>SD</u>	.187	.208	.215	.192	.207
DRO 20	<u>M</u>	.314	.248	.306	.307	.274
	<u>SD</u>	.195	.192	.261	.222	.165
DRO 30	<u>M</u>	.463	.296	.463	.423	.326
	<u>SD</u>	.208	.240	.189	.211	.139

		Sessions				
Group		11	12	13	14	15
FT 10	<u>M</u>	.552	.549	.602	.630	.600
	<u>SD</u>	.294	.361	.308	.259	.342
FT 20	<u>M</u>	.803	.697	.821	.790	.761
	<u>SD</u>	.355	.431	.312	.310	.368
FT 30	<u>M</u>	.854	.855	.926	.877	.810
	<u>SD</u>	.343	.335	.302	.301	.421
VT 10	<u>M</u>	.824	.818	.801	.750	.798
	<u>SD</u>	.199	.276	.194	.221	.168
VT 20	<u>M</u>	1.067	1.048	1.077	1.011	1.024
	<u>SD</u>	.395	.376	.382	.413	.399
VT 30	<u>M</u>	1.221	1.177	1.231	1.248	1.218
	<u>SD</u>	.359	.338	.386	.322	.374
DRO 10	<u>M</u>	.421	.347	.315	.415	.311
	<u>SD</u>	.212	.158	.192	.129	.185
DRO 20	<u>M</u>	.148	.254	.285	.261	.291
	<u>SD</u>	.177	.198	.303	.305	.247
DRO 30	<u>M</u>	.419	.341	.351	.317	.389
	<u>SD</u>	.353	.276	.413	.141	.214

Figure Caption

Figure 17. Means of Common Log transformed number of responses per reinforcement-reinforcement interval for each group across the fifteen sessions during the treatment phase.

interaction effect, .035 for the treatment group main effect, and .515 for the session main effect were computed for this analysis.

Simple effects tests were again computed and found to be significant for all 15 sessions of this phase indicating different levels of responding within the reinforcement-reinforcement intervals among the different treatment groups. The computed values are given in Appendix H.2. Tukey (hsd) follow-up tests for session one indicated that the DRO 30 group had the highest number of responses between successive reinforcers. This is followed by the the DRO 10 and DRO 20 and VT 30, followed by the FT 20, FT 30, VT 10, and VT 20 groups. The FT 10 group had the fewest number of responses per reinforcement-reinforcement interval. For the remainder of this phase the VT 30 group maintained the greatest number of responses per reinforcement-reinforcement interval with the exception of sessions 7, 8, and 13 where the data are equal to the VT 20 group. Session two data indicated that the VT 20 group had higher rates than the DRO 10 and DRO 20 groups, that the DRO 10 and DRO 20 groups had higher rates than the FT 10 and FT 30 groups, that the DRO 30 group had higher rates than the FT 10, FT 20, and the other two DRO groups. Finally, during this session the FT 10 group had the lowest number of responses per reinforcement-reinforcement interval but not less than the DRO 10 and DRO 20 groups. The same was true for the third session with the exception that the DRO 30 group had higher rates than only the DRO 10 and not DRO 20 group. Tukey tests for sessions four through 15 consistently found significantly greater responses per reinforcement-reinforcement intervals for the FT 20, FT 30, VT 10 and VT 20 groups than the DRO and FT 10 groups. After session four the FT 10 group had the same number of responses per reinforcement-reinforcement interval as the DRO 10 and DRO 30 groups except for during session 13 where the DRO 20 group was higher than the FT 10 group, and session 14 and 15 when the FT 10 group had higher responses per reinforcement-reinforcement interval than the DRO 20 and DRO 30 groups.

Figure 17 shows a decrease in the number of responses per reinforcement-reinforcement interval for all groups with a small decrease for the FT and VT treatment groups, and a sharp decrease and leveling out for the DRO treatment groups.

The final ANOVA performed on data collected during the treatment phase was on the reinforcement-reinforcement intervals for the DRO groups. Only these three groups were included because for the the FT groups the time between reinforcers was fixed at their particular t value, and for the VT groups the time between reinforcers was equal to the particular variable time schedule the particular group was exposed to. The means and standard deviations for these three groups is reported in Table 20 and the means are plotted in Figure 18. An $F_{\max}$ test showed gross violations of homogeneity [$F_{\max}(3,8) = 1,998,891.000$, $p > .05$]. The data were subsequently transformed using a common log transformation which reduced the violations of homogeneity [$F_{\max}(3,8) = 8949.160$, $p > .05$], and are reported in Table 21. The treatment groups by session ANOVA (see Appendix I.1 for the summary table) was significant for the interaction effect [$F(28,336) = 5.932$, $p < .05$], and for the two main effects, [$F(2,24) = 13.666$, $p < .05$] for treatment groups, and [$F(14,336) = 46.885$, $p < .05$] for sessions. The Omega squared value for the interaction effect was .111, .035 for the treatment group effect, and .515 for the sessions effect.

Simple effects tests (see Appendix I.2) showed significant differences between the three DRO treatment groups for the first two sessions only. Tukey (hsd) follow-up tests for these two significant simple effects tests indicated longer intervals between reinforcements for the DRO 30 groups for both sessions one and two. Figure 19 shows a marked decrease for all three DRO treatment groups during the first four sessions and the DRO 30 group was considerably higher than the DRO 20 and DRO 10 groups for the first two sessions of this phase.

Table 20

Means and Standard Deviations of Reinforcement-Reinforcement Intervals for Each Group During the Treatment Phase

		Sessions				
Group		1	2	3	4	5
DRO 10	<u>M</u>	45.917	25.032	23.690	21.458	21.108
	<u>SD</u>	20.266	2.475	2.950	1.237	.380
DRO 20	<u>M</u>	45.180	24.452	23.433	22.116	21.259
	<u>SD</u>	27.516	4.669	2.744	2.891	2.320
DRO 30	<u>M</u>	223.579	50.374	27.591	24.119	22.919
	<u>SD</u>	356.283	19.914	3.145	5.675	3.573
Group		6	7	8	9	10
DRO 10	<u>M</u>	20.994	20.691	21.251	20.598	20.778
	<u>SD</u>	.610	.593	.930	.320	.648
DRO 20	<u>M</u>	21.200	20.811	20.444	20.427	20.575
	<u>SD</u>	1.629	.786	.471	.313	.497
DRO 30	<u>M</u>	22.743	21.353	21.522	21.464	21.251
	<u>SD</u>	4.240	1.458	1.212	.928	.870
Group		11	12	13	14	15
DRO 10	<u>M</u>	20.365	20.448	20.785	20.699	20.561
	<u>SD</u>	.252	.352	.737	.837	.520
DRO 20	<u>M</u>	20.456	20.507	20.463	20.366	20.477
	<u>SD</u>	.712	.610	.460	.317	.384
DRO 30	<u>M</u>	20.654	20.693	20.561	20.788	21.104
	<u>SD</u>	.574	.725	.575	.411	1.055

Figure Caption

Figure 18. Means of reinforcement-reinforcement intervals in seconds for each group across the fifteen sessions during the treatment phase.

Table 21

Means and Standard Deviations of Common Log Transformed
Reinforcement-Reinforcement Intervals for Each Group During the
Treatment Phase

		Sessions				
Group		1	2	3	4	5
DRO 10	<u>M</u>	1.628	1.397	1.372	1.331	1.324
	<u>SD</u>	.179	.044	.051	.024	.007
DRO 20	<u>M</u>	1.600	1.382	1.367	1.342	1.326
	<u>SD</u>	.217	.080	.050	.051	.043
DRO 30	<u>M</u>	2.058	1.670	1.438	1.374	1.356
	<u>SD</u>	.473	.180	.048	.087	.063
Group		6	7	8	9	10
DRO 10	<u>M</u>	1.322	1.316	1.327	1.314	1.317
	<u>SD</u>	.013	.012	.019	.006	.013
DRO 20	<u>M</u>	1.325	1.318	1.310	1.310	1.313
	<u>SD</u>	.031	.016	.010	.006	.010
DRO 30	<u>M</u>	1.351	1.329	1.332	1.331	1.327
	<u>SD</u>	.069	.029	.024	.019	.018
Group		11	12	13	14	15
DRO 10	<u>M</u>	1.309	1.311	1.318	1.316	1.313
	<u>SD</u>	.005	.007	.015	.017	.011
DRO 20	<u>M</u>	1.311	1.312	1.311	1.309	1.311
	<u>SD</u>	.015	.013	.010	.006	.008
DRO 30	<u>M</u>	1.315	1.316	1.313	1.318	1.324
	<u>SD</u>	.012	.015	.012	.008	.021

Figure Caption

Figure 19. Means of Common Log transformed reinforcement-reinforcement intervals in seconds for each group across the fifteen sessions during the treatment phase.

Reacquisition. The same data measures were collected during the reacquisition as during the acquisition phase with the exception that the number of responses each animal made was recorded and analyzed minute by minute. Means and standard deviations of lever responding during each minute of this session are reported in Table 22 and Figure 20. An $F_{\max}$ test of homogeneity of variance was found to be significant for these data, [$F_{\max}(10,8) = 10,753.005, p > .01$]. A common log transformation was performed and the means and standard deviations are reported in Table 23 and Figure 21. Again a $F_{\max}$ test was found to be significant [$F_{\max}(10,8) = 53.876, p > .01$]. A 10×30 (group $\times$ minute) ANOVA was computed on the transformed minute by minute data (see Appendix J.1 for the summary table). The group by minute interaction effect was found to be significant [$F(261,2320) = 4.706, p < .05$], as was the main effect for treatment groups [$F(9,80) = 5.598, p < .05$], as well as the main effect for minutes [$F(29,2320) = 51.620, p < .05$]. Omega squared values were calculated for this analysis. The values for the group by minute interaction effect, the treatment group main effect and minute main effect were .099, .153, and .150 respectively. This indicated that most of the accounted for variance was due to the differences between the groups and to the increase in responding over minutes.

Simple effects tests were performed for each minute during this phase. As previously, for each test computed, the Satterthwaite method (Winer, 1971) was used to compute the degrees of freedom for the denominator. The simple effects tests showed differences throughout this phase except during minute 29 (see Appendix J.2 for calculated values). Tukey (hsd) follow-up tests for minutes one through three indicated higher response rates for the FT and VT groups compared to the DRO and EXT groups. The same is true for minutes four and five with the DRO 10 group responding more than the DRO 20 group during minute four, and the DRO 30 group responding more than the EXT and DRO 20 group during

Table 22

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

		Minutes				
Group		1	2	3	4	5
FT 10	<u>M</u>	11.667	16.889	20.556	28.000	22.222
	<u>SD</u>	18.527	22.491	18.311	24.182	26.555
FT 20	<u>M</u>	12.556	17.111	21.778	22.222	24.000
	<u>SD</u>	14.492	34.531	31.104	24.768	32.004
FT 30	<u>M</u>	12.444	15.222	18.111	19.667	20.111
	<u>SD</u>	10.345	11.200	14.811	15.764	16.298
EXT	<u>M</u>	.778	.444	3.333	6.333	4.667
	<u>SD</u>	.972	1.014	6.690	12.767	9.274
VT 10	<u>M</u>	11.667	15.667	23.556	25.778	31.333
	<u>SD</u>	14.595	9.836	10.783	15.189	15.716
VT 20	<u>M</u>	16.778	18.000	20.444	22.778	27.778
	<u>SD</u>	16.939	18.111	23.791	21.159	27.463
VT 30	<u>M</u>	6.444	13.444	15.111	23.000	20.889
	<u>SD</u>	8.531	11.695	12.995	16.109	16.707
DRO 10	<u>M</u>	.444	.222	.111	5.889	5.667
	<u>SD</u>	.527	.667	.333	8.283	6.344
DRO 20	<u>M</u>	.222	.111	.111	0.000	1.667
	<u>SD</u>	.441	.333	.333	0.000	2.693
DRO 30	<u>M</u>	.444	0.000	.778	.889	12.444
	<u>SD</u>	.527	0.000	1.563	1.167	15.067

		Minutes				
Group		6	7	8	9	10
FT 10	<u>M</u>	25.667	31.556	32.000	27.556	29.111
	<u>SD</u>	19.170	22.361	26.819	26.020	19.394
FT 20	<u>M</u>	22.222	26.667	24.333	24.444	23.556
	<u>SD</u>	30.679	25.204	21.465	24.105	25.846
FT 30	<u>M</u>	16.778	18.778	16.667	25.333	26.333
	<u>SD</u>	15.699	16.664	16.355	21.018	19.046
EXT	<u>M</u>	3.889	4.444	6.222	4.222	5.333
	<u>SD</u>	7.817	9.043	13.953	8.511	9.708
VT 10	<u>M</u>	29.667	32.667	31.444	36.667	34.667
	<u>SD</u>	14.107	15.403	11.642	17.407	15.898
VT 20	<u>M</u>	21.222	26.222	26.667	21.111	27.556
	<u>SD</u>	16.185	20.333	20.365	16.556	24.006
VT 30	<u>M</u>	23.889	23.667	21.000	22.556	24.444
	<u>SD</u>	16.397	15.508	12.369	11.897	16.218
DRO 10	<u>M</u>	12.556	20.556	18.222	20.556	17.000
	<u>SD</u>	12.218	14.414	15.344	16.727	11.269
DRO 20	<u>M</u>	2.667	6.444	9.222	6.889	15.111
	<u>SD</u>	3.391	10.442	12.538	9.597	19.219
DRO 30	<u>M</u>	16.667	20.333	21.222	21.889	28.333
	<u>SD</u>	13.323	15.716	13.989	11.602	18.173

 Minutes

Group		11	12	13	14	15
FT 10	<u>M</u>	24.667	32.333	28.889	32.667	27.556
	<u>SD</u>	16.882	26.344	23.013	22.136	16.786
FT 20	<u>M</u>	22.444	28.222	26.222	21.667	27.889
	<u>SD</u>	23.152	22.912	23.626	19.956	28.963
FT 30	<u>M</u>	20.444	20.778	22.444	21.444	24.778
	<u>SD</u>	14.440	17.283	18.756	16.831	20.444
EXT	<u>M</u>	7.222	8.333	8.222	9.667	8.889
	<u>SD</u>	9.052	10.161	12.296	12.933	10.764
VT 10	<u>M</u>	33.333	31.222	31.333	34.667	27.222
	<u>SD</u>	19.449	18.267	10.247	16.583	8.786
VT 20	<u>M</u>	29.000	24.889	23.222	24.444	28.667
	<u>SD</u>	20.922	16.692	19.595	19.191	18.762
VT 30	<u>M</u>	25.222	27.222	25.222	26.000	25.889
	<u>SD</u>	16.169	20.867	11.998	20.031	13.989
DRO 10	<u>M</u>	23.556	26.111	31.222	32.222	33.111
	<u>SD</u>	14.081	13.606	15.393	19.766	19.846
DRO 20	<u>M</u>	18.222	16.111	19.222	18.889	18.778
	<u>SD</u>	19.273	16.541	16.761	24.451	17.174
DRO 30	<u>M</u>	30.556	25.778	27.444	20.778	23.667
	<u>SD</u>	16.234	15.810	14.698	11.388	13.048

		Minutes				
Group		16	17	18	19	20
FT 10	<u>M</u>	31.333	28.778	24.889	30.222	28.667
	<u>SD</u>	20.603	21.335	14.718	18.512	24.469
FT 20	<u>M</u>	25.444	21.556	22.333	21.333	23.667
	<u>SD</u>	25.299	22.484	28.134	27.074	28.447
FT 30	<u>M</u>	20.778	20.222	18.111	20.222	22.000
	<u>SD</u>	16.115	20.867	19.445	18.600	19.900
EXT	<u>M</u>	10.667	11.333	13.000	18.333	19.222
	<u>SD</u>	13.295	13.105	13.592	14.612	18.301
VT 10	<u>M</u>	37.778	24.556	31.222	26.778	32.667
	<u>SD</u>	16.269	14.063	9.808	11.660	12.659
VT 20	<u>M</u>	25.778	26.333	29.778	26.111	26.889
	<u>SD</u>	15.474	23.065	21.382	23.961	20.084
VT 30	<u>M</u>	30.444	26.778	27.778	30.222	31.000
	<u>SD</u>	18.649	8.182	16.843	12.677	16.171
DRO 10	<u>M</u>	36.222	23.222	25.667	30.667	28.667
	<u>SD</u>	18.005	13.700	16.332	17.607	14.414
DRO 20	<u>M</u>	18.000	16.778	15.667	11.000	12.222
	<u>SD</u>	17.578	19.930	15.652	10.840	9.846
DRO 30	<u>M</u>	27.333	17.889	26.556	22.111	25.556
	<u>SD</u>	8.789	4.167	11.588	9.117	12.501

		Minutes				
Group		21	22	23	24	25
FT 10	<u>M</u>	30.889	24.667	34.778	29.000	31.778
	<u>SD</u>	26.728	8.276	33.659	25.500	20.705
FT 20	<u>M</u>	18.667	17.444	20.000	19.889	12.111
	<u>SD</u>	24.627	17.140	18.344	17.723	13.138
FT 30	<u>M</u>	25.667	19.667	24.444	21.778	23.000
	<u>SD</u>	23.958	15.716	28.983	19.639	19.962
EXT	<u>M</u>	20.778	22.222	20.111	24.889	25.222
	<u>SD</u>	19.652	19.123	18.313	22.575	17.145
VT 10	<u>M</u>	36.556	33.889	29.889	32.889	38.444
	<u>SD</u>	20.044	7.322	9.545	15.839	11.886
VT 20	<u>M</u>	31.111	25.333	27.333	23.556	27.111
	<u>SD</u>	25.300	16.163	18.262	27.409	26.194
VT 30	<u>M</u>	26.667	26.444	26.889	26.111	26.444
	<u>SD</u>	14.309	16.110	17.208	20.642	12.581
DRO 10	<u>M</u>	23.667	31.333	28.222	27.000	25.778
	<u>SD</u>	14.874	13.766	19.829	18.828	15.967
DRO 20	<u>M</u>	12.333	21.778	13.556	16.667	11.000
	<u>SD</u>	12.787	20.602	16.531	17.059	8.201
DRO 30	<u>M</u>	19.444	20.222	22.667	21.778	25.556
	<u>SD</u>	11.791	7.726	9.474	11.020	14.081

 Minutes

Group		26	27	28	29	30
FT 10	<u>M</u>	32.000	28.111	27.000	27.667	30.667
	<u>SD</u>	21.863	16.259	18.042	18.594	19.944
FT 20	<u>M</u>	18.778	23.111	20.333	22.333	21.444
	<u>SD</u>	18.390	24.034	25.529	23.146	17.140
FT 30	<u>M</u>	21.556	24.778	25.222	22.667	28.111
	<u>SD</u>	22.097	20.831	23.488	22.293	28.933
EXT	<u>M</u>	23.333	24.222	25.444	25.889	21.889
	<u>SD</u>	16.078	21.719	24.073	23.143	21.363
VT 10	<u>M</u>	24.667	33.778	33.778	32.778	37.556
	<u>SD</u>	9.447	14.122	16.536	14.342	17.945
VT 20	<u>M</u>	25.667	27.444	29.444	27.222	28.667
	<u>SD</u>	22.372	19.119	21.772	30.028	21.483
VT 30	<u>M</u>	22.000	30.111	28.444	28.111	30.667
	<u>SD</u>	10.665	18.811	12.300	11.152	19.131
DRO 10	<u>M</u>	27.222	28.778	26.556	26.222	27.111
	<u>SD</u>	17.254	18.054	12.238	16.185	14.777
DRO 20	<u>M</u>	14.333	15.333	14.889	16.667	17.778
	<u>SD</u>	11.705	14.405	16.081	13.257	17.319
DRO 30	<u>M</u>	24.000	20.111	25.778	27.000	29.889
	<u>SD</u>	12.460	8.992	7.014	13.416	11.527

Figure Caption

Figure 20. Means for lever responding for each group across the 30 minutes of the reacquisition phase.

responding occurred within one second of reinforcement and that during days five and ten one quarter of the total relative frequency of responding occurred within one second of reinforcement but that by day 15 only one sixth of the responses were occurring within one second of reinforcement. These shifts from shorter to longer response-reinforcement intervals are most dramatic for the DRO treatment groups. For the DRO 10 group the greatest proportion of responding on day one of this phase occurred between 10 and 20 seconds prior to reinforcement. By day ten and especially day 15 the greatest amount of responding was occurring between 20 and 25 seconds prior to reinforcer delivery. The DRO 20 animals also show that three quarters of all responses for day 1 occurred less than 26 seconds from reinforcement, and that by day 10 all responses had occurred at response-reinforcement intervals greater than 26 seconds. The same is true for the DRO 30 groups where by the end of the treatment phase all responding was occurring at response-reinforcer intervals greater than 36 seconds. It is important to remember that for all the animals, when the R-R intervals increased to values greater than the SR . SR interval, two reinforcers may have occurred without an intervening response. This implies that as response rate decreased over the sessions the relative frequency of interreinforcement intervals without a response increased while that of the shortest response-reinforcer interval decreased.

Lever Response Pattern Analysis

The following is a presentation of the cumulative records collected throughout this experiment. The limited selection of representative records was necessary as a total of 2160 records were collected during the course of the experiment. In general the records were selected on the basis of several criteria. Each record is considered representative of response patterns observed in the animals within that treatment condition unless otherwise noted. Furthermore, the response total of any one record did not

deviate more than .5 standard deviations from the mean of that represented group. In each record the upper line shows the lever responding over time. In all the records, a steeper line indicates a higher rate of responding, and a shallower line is indicative of lower response rates. The downward slashes on the top line indicate when a reinforcer was delivered. When approximately 500 responses were emitted by the subject the recorder reset and the cumulative record continued again close to the bottom line. The bottom line is an event record for the passage of time, each session lasting 30 minutes, with slashes on this line representing the beginning and end of each session. Unless otherwise noted record 1 represents FT 10; record 2, FT 20; record 3, FT 30; record 4, EXT; record 5, VT 10; record 6, VT 20; record 7, VT 30; record 8, DRO 10; record 9, DRO 20; and record 10, DRO 30.

Figures 31a, 31b and 31c, records 1 through 10, typify responding by subjects on an FI 20 sec schedule of reinforcement on the last day of the acquisition phase. Characteristic of animals responding on a FI schedule is a distinct scalloping effect in the cumulative record (Ferster & Skinner, 1957). The fact that perfect scalloped shaped records were not achieved in the present study, (although, cumulative records 2 and 7 come close to exhibiting this effect) may be due to the fact that the 20 sec interval used was probably not long enough for the pattern to emerge (Ferster, et al., 1957).

Figures 32a, 32b, and 32c, depict representative cumulative records for subjects during the first session of the treatment phase. Records 1 through 3 show FT schedule responding with equally spaced but from record to record longer reinforcement-reinforcement intervals. Interesting to note is record 2 where for the last 100 sec the animal did not make any lever responses. It is this particular characteristic of the record that makes it different from those of the acquisition phase. That is, the records from the last day of the acquisition phase and this first day of the treatment phase

Figure Caption

Figure 31. Representative cumulative records for subjects' lever responding during the final session of the acquisition phase. Cumulative record 1 represents FT 10; record 2, FT 20; record 3, FT 30; record 4, EXT; record 5, VT 10; record 6, VT 20; record 7, VT 30; record 8, DRO 10; record 9, DRO 20; and record 10, DRO 30 treatment groups.

Figure Caption

Figure 32. Representative cumulative records for subjects' lever responding during the first session of the treatment phase. Cumulative record 1 represents FT 10; record 2, FT 20; record 3, FT 30; record 4, EXT; record 5, VT 10; record 6, VT 20; record 7, VT 30; record 8, DRO 10; record 9, DRO 20; and record 10, DRO 30 treatment groups.

look similar, except when the animal does not make the target response during acquisition the record has no slashes and during treatment the animal continues to be reinforced. Record 4 shows the typical extinction curve (Skinner, 1938) with an initial burst of responding early in the session and longer and longer periods without a response towards the end of the session. Records 5 through 7 show response and reinforcement patterns for the three VT scheduled groups. Particularly record 5 shows again that over the course of the session periods may occur during which no lever response is made but reinforcements are delivered. The last three cumulative records (records 8 through 10) represent those of animals within the three DRO conditions. When comparing these three records it is evident that with higher response-reinforcement intervals fewer reinforcements are achieved. This is of course due to the longer delay intervals imposed on the schedule when the animal responds. An interesting observation can be made when comparing records from the animal in the EXT and that of the one from the DRO 10 group (records 4 and 8). The records are very similar. That is, initial bursts of responding are followed by longer periods of time with no lever pressing occurring. The distinction is that for the EXT animal no reinforcer is ever delivered and for the DRO animal reinforcers are delivered every 20 seconds when no lever press occurred. When comparing all the records it is clear that the time based schedules maintained responding at higher levels than did the contingency based and non-reinforcement based schedules, and this occurred within the first session of this phase.

Figures 33a, 33b, and 33c, show records for subjects during the last session of the treatment phase. Characteristic of records from both the FT and VT groups (records 1 through 3 and records 5 through 7) is continued responding even after 15 sessions on this schedule. However, it appears that for these animals two distinct patterns emerged. The first, reflected in records 2, 3, and 6, show a stable state and continuous response pattern.

Figure Caption

Figure 33. Representative cumulative records for subjects' lever responding during the final session of the treatment phase. Cumulative record 1 represents FT 10; record 2, FT 20; record 3, FT 30; record 4, EXT; record 5, VT 10; record 6, VT 20; record 7, VT 30; record 8, DRO 10; record 9, DRO 20; and record 10, DRO 30 treatment groups.

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The other three records (1, 4, and 5) show stable responding with periods during which few or no lever responses occur followed again by bursts of continuous lever responding. The cumulative records for subjects on EXT (record 4) and DRO (records 8 through 10) show that responding was suppressed with no reinforcement delivery for the EXT groups and reinforcements being delivered every 20 secs for the DRO subjects. All three DRO records have breaks in the 20 sec reinforcement interval indicating that the subjects made some responses distributed throughout the session. An interesting differentiation between FT groups, VT groups and the DRO groups, is that for the DRO treatment groups generally only one or two responses occurred followed by long periods of other behaviors; whereas the time based treatment groups with irregular response patterns showed series of non-lever responding followed by runs or bursts of responding.

Figures 34a, 34b, and 34c show representative cumulative records for subjects from each of the ten treatment groups during the reacquisition phase. It is clear from these records that by the end of this one session all the treatment groups were responding at rates similar to those at the end of the acquisition phase (see Figures 31a, 31b, and 31c). An interesting observation is that within five reinforcements all animals were responding at levels which they maintained until the end of the session. However, there are noticeable differences at the beginning of this session. All subjects showed a lower slope, or slower rate, early in the session. This is particularly true for the EXT animals (record 4) where the first response did not occur until 17 minutes into the session. This finding supports the statistically significant results of the ANOVA (Appendix J.1) showing lower rates for this group well into the session. The DRO animals (records 8 through 10) also showed suppressed responding early in the session with recovery earlier than that of the EXT group.

Figure Caption

Figure 34. Representative cumulative records for subjects' lever responding during the reacquisition phase. Cumulative record 1 represents FT 10; record 2, FT 20; record 3, FT 30; record 4, EXT; record 5, VT 10; record 6, VT 20; record 7, VT 30; record 8, DRO 10; record 9, DRO 20; and record 10, DRO 30 treatment groups.

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Discussion

As with almost any research study the results from the present experiment both support and question previous experimental findings achieved from this lab and reported in the literature. At the same time the project answers some of the original questions that this project attempted to unravel. The findings obtained when comparing various schedules of reinforcement present the opportunity to investigate and draw implications about theoretical and practical issues in operant situations. The primary focus of this study was to investigate the relationship between response and reinforcer and to determine whether contiguity or contingency between these maintains behavior. The information gathered may also be used to address the topic of operant methodology. This may be accomplished by differentiating the results obtained when collecting and analyzing the data at molar and molecular levels. Finally, if the reason for basic research on lower animals is to help better predict human behavior then the results should provide possible implications for the applied setting.

Several statements can be made about the general findings from the data collected in this experiment. Analysis of the acquisition phase clearly established equivalent rates of responding for all the animals in the ten treatment groups prior to the experimental manipulation of interest. The results from the treatment phase showed that all of the schedules used in the present study lead to response suppression. However, a comparison between the contingent treatment groups (DRO) with non-contingent treatment groups (FT and VT) in terms of overall responding showed that providing for a contingency between not making the targeted response and reinforcement, greatly effects the subjects' responding (see Figure 9). At the same time the mean interval between responses increased for all the groups with those of the DRO animals becoming variable (see Figure 14). Furthermore, the time between the last response and the next scheduled

reinforcer increased for all of the animals, with the change in the contingent delay treatment groups showing less of an increase (see Figure 15). Finally, data from the reacquisition phase when reinforcement is again made contingent on responding, indicated that the EXT animals were the slowest to recover, followed by the DRO subjects, and finally the FT and VT animals which showed very little duration of suppression during the reacquisition phase (see Figure 21).

The results from the treatment phase do not entirely support findings from previous studies which had shown that the longer the response-reinforcement interval the greater the degree of response suppression during treatment (Rieg, et al., 1987; Rieg, et al., 1986). These papers had indicated that the sequence from shorter to longer delay intervals in the DRO condition also produced lesser to greater response elimination during treatment. The data depicted in Figure 9 do not support this conclusion. That is, the greatest amount of response suppression was shown in the DRO 20 group during the middle half of the treatment phase. This group had a response-reinforcement interval equal to the reinforcement-reinforcement interval. Furthermore, previous results had indicated that for DRO schedules, when the response-reinforcement interval was shorter than the reinforcement-reinforcement interval, less response suppression was observed when compared to an EXT schedule. This was not true in the present study. However, the particular DRO procedure used in the present study differed slightly than the one defined by Uhl and Garcia (1969). Previously, when the delay interval was shorter than the inter-reinforcement interval then responding up to the reinforcement-reinforcement interval minus the response-reinforcement interval had no effect on setting up a delay for an animal. For example, in the Rieg et al. study (1986) when a subject in the DRO 2 group responded up to eight seconds after the last delivered reinforcer (with reinforcement-reinforcement intervals of 10 sec) no delay of reinforcement was incurred.

Only during the last two seconds prior to the next scheduled reinforcement was a delay incurred. The net effect of this procedure was that the subject was allowed to continue to respond during these eight seconds without setting the occasion for the next reinforcer to be delayed. The differences between previous studies and the present study is that each response during the reinforcement-reinforcement interval had a contingency associated with it. That is, no matter when the response was made within the reinforcement-reinforcement interval, the delay interval was juxtaposed onto the inter-reinforcement interval. In the Rieg et al. studies (1986; 1987; 1988) where the response-reinforcement interval was shorter than the reinforcement-reinforcement interval any response up to the delay value had no contingency associated with it. Therefore, the present procedure which made each response during the inter-reinforcement interval contingent on delaying reinforcement, resulted in greater suppression for all the DRO groups compared to the EXT groups. It was probably due to the fact that a greater proportion of responding was paired with delays that greater suppressive effects were observed in the DRO treatment groups than the EXT treatment groups. The implication of this differentiation between the procedure used here and that used previously was that when the contingency between response and reinforcement was consistent, ie. every response delayed the next scheduled reinforcer, greater response suppression was observed than when only partial pairing between response and reinforcement delay was in effect. Therefore, the particular findings of this experiment compared to earlier studies may be explained through a contingency explanation alone without the necessity of contiguity arguments.

The animals in all the FT and VT treatment groups decreased their target response rates slightly yet significantly. As stated above the sequencing effect of response suppression based on the length of the DRO interval was not as predicted for the DRO animals, Figure 9 shows that for

the time based schedules the longer the period between reinforcers the less the response suppression. The question becomes, of course, what mechanism produces the lower response rates. That is, why does some "other" response besides lever pressing get started. An obvious explanation might be the adventitious reinforcement of what has been described as the stereotypical postreinforcement pause (Ferster, et al., 1957). That is, subjects exposed to most temporal schedules of reinforcement exhibit behaviors such as grooming, investigating, and consummatory behavior just after reinforcement. Generally, it has been found that this postreinforcement pause is one-half to about two-thirds the average duration of the inter-reinforcement interval (Schneider, 1969; Staddon & Simmelhag, 1971). These findings hold true for inter-reinforcement intervals between 16 and 512 seconds (Innis, 1981). Furthermore, studies investigating the delay of reinforcement, clearly show that the longer the interval between response and reinforcement the less the conditioning (de Villiers, 1977; Rachlin, 1989). In the present study, if we assume that behaviors during the postreinforcement pause lasted up to seven, 14 and 21 seconds for the three temporal parameters of the non-contingent treatment groups (ie. FT and VT intervals of 10, 20, and 30 seconds), then the delay between non-lever responding and reinforcement is much shorter for the 10 second FT and VT groups. This argument would be true if the data had shown greater response suppression for animals with shorter inter-reinforcement intervals than longer inter-reinforcement intervals. However, the analysis on response data do not show this to be true (see Appendix D.1 and subsequent follow-up tests). The implication of this is that contiguity between non-lever responding and reinforcement may not account for the suppressive effects observed in animals exposed to non-contingent schedules of reinforcement.

Skinner's early demonstration of superstition (1948) was explained in terms of conditioning merely through temporal terms. He suggested that behaviors could be conditioned through temporal pairings alone, and this would happen without a contingency between response and reinforcement (1948, p168). In the present study, animals with lower values of t and therefore with significantly more exposures to reinforcement (see Figure 11) and no associated contingency showed the greatest amount of non target responding, ie. greater suppression of the target response. According to Skinner's early explanation then, animals with more pairings between some response other than lever pressing and reinforcement, compared to animals with fewer non-contingent response-reinforcement pairings, should be more likely to acquire the other response. The reason of course being the greater number of pairings between non lever press responding and reinforcement. One has to remember that while significant, there was not a lot of suppression in any of the FT and VT treatment groups.

An implication of this idea that greater response suppression for the 10 sec FT and VT treatment groups was due to greater densities of reinforcement for the FT 10 and VT 10 groups is that if the animals in the FT 20, FT 30, VT 20, and VT 30 treatment groups had been run for an additional week or two so that the total number of reinforcers were equal to the FT and VT 10 sec treatment groups, they would have levels of response suppression equivalent to the FT 10 and VT 10 treatment groups. One way to assess this idea would be to run the animals each day so that they received equal numbers of reinforcers during each session. This was not done in the present study, because each session lasted 30 minutes, and therefore the total reinforcers received varied as a function of the schedule the animals were on (see Table 12). It is possible though to look at the last day of the treatment phase for the $t = 30$ sec FT and VT animals and compare those response data with response data from the $t = 10$ sec FT and VT animals

when the number of reinforcements were equal. At the end of 15 sessions the FT 30 and VT 30 animals had received 675 reinforcements and at the end of four sessions the FT 10 and VT 10 animals had received 720 reinforcements. When we compare sessions 4 for the FT 10 and VT 10 treatment groups with session 15 for the FT 30 and VT 30 treatment groups the $t = 10$ groups made 359 and 485 responses during session 4 and the $t = 30$ groups made 467 and 598 responses during session 15 respectively (see Table 10 for the number of responses made per session). When we compare session 14 for the FT 20 and VT 20 treatment groups with with 1260 reinforcements delivered and session 7 for the FT 10 and VT 10 groups with 1260 reinforcement delivered we can see that the $t = 10$ groups had made 308 and 405 responses and the $t = 20$ groups had made 434 and 582 responses. In both cases with a larger parameter of t , but equivalent numbers of reinforcers delivered, higher response rates were observed. The implication of this analysis is that the increased suppressive effects of shorter reinforcement-reinforcement intervals is not due to an increase in the number of temporal pairings between non-lever responding and reinforcement. That is the animals in the FT and VT treatment groups were not learning a temporal contiguity between responses other than the target response and reinforcement. The results here are then empirical arguments against the notion of superstitious conditioning based on adventitious reinforcement and its emphasis on response-reinforcer temporal contiguity as the reinforcement effect.

An interesting finding of the present study is that all three DRO groups modified their responding in such a way so that by the third session they were receiving as many reinforcers as the FT 20 and VT 20 groups and were earning close to the maximum number of reinforcers possible during any one session. The implication of this observation is that behavioral maximization had taken place. Maximization theory postulates that an animal given a choice between two alternatives will choose among them so

as to maximize reinforcement. Furthermore, given only one targeted response, maximization occurs when the level of responding maximizes the probability of reinforcement (Catania, 1984). For the DRO animals, in order to maximize their rate of reinforcement they had to make any non-target response. This occurred within just three sessions in the present study.

Herrnstein (1961) demonstrated that when reinforcement is available on two separate schedules of reinforcement animals responded so that the relative response rates on the two schedules equalled the relative reinforcement frequency of the two alternatives. This relationship was quantified by Herrnstein in 1970, and has been shown to hold in different types of concurrent schedules across several species of animals (de Villiers, 1977). In the research literature on schedules, one of the most debated issues is the relationship between matching and maximization (Commons, Mazur, Nevin, & Rachlin, 1987; de Villiers, 1977). Some authors have argued that maximization is fundamental in that matching will only occur when it conforms to maximization (Shimp, 1969) and others have postulated the opposite (Herrnstein, 1961; Herrnstein, 1970). Some authors have stated that matching can only be studied if two responses are measured and one can estimate the relative frequencies of each (Catania, 1984). However, it is not impossible to conceive of animals matching based on the amount of time they spend on one schedule of reinforcement (Baum & Rachlin, 1969; de Villiers, 1977; Herrnstein, 1971).

Baum and Rachlin (1969) studied matching which could only be measured in terms of the time allocated to each response, that of standing in one specific location. Their results indicated that the ratio of time spent in one specific location varied as a proportion of the reinforcement ratios. The argument can therefore be made that with standard lever responding the time spent responding determines the number of reinforcements earned. The data collected in the present experiment can then be said to conform to the matching law. It is clear that the animals in the DRO

conditions responded so as to match their responding to the available reinforcement rate. Furthermore, by spending time emitting other responses than lever pressing these subjects were able to maximize their rates of reinforcement because responding on the lever actually decreased the density of reinforcement (to zero if an additional response occurred within the response-reinforcement interval).

The data comparing response-response intervals showed that the animals exposed to the DRO contingency had longer inter-response intervals than those exposed to the time based schedules. In general, with the exception of three sessions the animals in the DRO 30 group had the longest times between responses (see figure 12 for absolute response-response intervals). Furthermore, the transformed data depicted in Figure 13 show that the most dramatic increase in response-response times occurred within the first half of the treatment phase, especially for the DRO and EXT treatment groups. When one compares this observation with cumulative records collected for these animals (see Figures 32, Cumulative Records 8, 9, and 10), we see bursts of responding where the time allocation of responding is clearly distributed between "other" behaviors and lever pressing. These data suggest that the DRO animals were responding in such a way as to maximize their reinforcement rates.

The data comparing response-response intervals also showed that with the exception of the FT 10 group, all other non-contingent treatment groups showed only a slight increase in their times between responses, and that these intervals were relatively consistent throughout the session (see Figure 13). The question whether matching or maximizing was occurring or not is more difficult if not impossible to apply to non-contingent schedules. That is, with these schedules, either responding or not responding yielded the same amount of reinforcement, and it is therefore difficult to assay if the animals are responding in order to maximize reinforcement. The question then results in a descriptive analysis of what

the animals were doing when the schedule was in effect. The group data show a great deal of variability during this phase. Some of the animals in each of the FT and VT groups were maintaining their response rates from the acquisition phase, hence shorter response-response intervals, while at the same time some of the animals were emitting non-lever response behaviors. When one looks at the raw data for lever responding it is evident that some of the animals dramatically reduced their response rates and some increased their rates of responding. For the FT 10 group for example, six of the nine animals had made less than 150 responses during the final session of the treatment phase. Five of these six had emitted less than 50 responses during this last session. Similar observations can be made for the FT 20 group, where seven of the nine animals had response rates of less than 150 per 30 minute session, five of which responded fewer than 50 times. The data for the three VT groups are less dramatic. However, one third of the animals responded less than 150 times during the last session of the treatment phase (see Figure 35, Cumulative records 1 and 2). The reason that the response suppression effects were not as dramatic for the time based treatment groups as they were for the contingency based treatment groups was that several of the animals increased their response rates throughout the session. As a matter of fact, nine of the 27 animals in the FT and the VT groups had over 1,000 responses per session during the treatment phase. It was not uncommon to observe over 2000 responses during any one 30 min session, with 3087 responses recorded during a single session (see Figure 35, Cumulative Record 3). Response rates of this magnitude are characteristic of a pigeon's response rates not those of a rat's.

The raw data and cumulative records, then, indicate that the FT and VT schedules produced two types of responding in the animals, one group that increased their response rates, and one that decreased their response rates. This is a very significant finding as studies comparing contingent and

Figure Caption

Figure 35. Representative cumulative records for subjects' lever responding during the treatment phase. Record 1 shows response patterns of an animal on an FT 20 schedule of reinforcement on the last day of treatment. Record 2 shows bursts of responding for a representative time based animal early during the treatment phase. Characteristic especially for animals with longer parameters of t are scalloped patterns of responding between reinforcements. Records 3 and 4 shows maintenance of responding for animals toward the end of the treatment phase.

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non-contingent schedules generally begin their investigation with the premise that what others had reported could not be correct in light of their own findings. Additionally, this supposition is usually based on single subject research involving stable states of responding. The data here then support both results showing both increased (Fenner, 1969; Neuringer, 1970; Rachlin, et al., 1972), and decreased responding (Henton & Iversen, 1978; Lachter, 1971; Lattal, et al., 1971; Zeiler, 1968; Zeiler, 1976) with non contingent reinforcement.

When one contrasts the cumulative records of the animals whose response rates decreased over the course of the treatment phase with those of the DRO animals the dramatic drop in responding is evident for the DRO animals only (see Figure 8). The FT and VT animals decrease their responding much more gradually (see Figure 35, Cumulative Records 2 and 4) than the DRO animals (see Figure 32, Cumulative Records 8 through 10). By the end of the treatment phase, almost half the animals in the FT and one third the animals in the VT treatment condition had cumulative records similar to those of Figure 35, Cumulative Record 1. These response patterns are not unlike those of the DRO treatment groups (see Figure 33, Cumulative Records 8 through 10). The only difference was that when the DRO animals made a response a delay to the next scheduled reinforcer was incurred. This is evidenced by a break in the downward slashes of the reinforcement pen. This then suggests that the differences in these two patterns of behavior are the result of the accidental contiguity of the "other" behavior in some of the animals and lever pressing in others.

One additional pattern of outcome warrants comment in light of maximization analysis and because of the fixed nature of the scheduled reinforcement delivery. The analysis comparing groups in terms of the number of responses made between two successive reinforcers is interesting. The sequencing pattern here is identical to that of the total number of responses made by each group during the treatment phase.

That is, the longer the FT and VT parameter the higher the number of responses per reinforcement-reinforcement interval. For the DRO subjects the same is true early during the phase until response rates had decreased to such an extent that only very few responses were occurring between reinforcements (see Figure 16). This indicates that if the number of responses per reinforcement-reinforcement interval remained constant while at the same time the total number of responses also reaches an asymptote then the pattern of responding throughout each individual session should be constant. However, it should be stated that the DRO animals' behavior dictated the interval between reinforcers. For the DRO treatment groups each response reset the delay interval, which in effect lengthens the effective reinforcement-reinforcement interval. Therefore the initially high response rates of the DRO animals led to more responses per reinforcement-reinforcement intervals further increasing the likelihood that their responses per reinforcement interval would be inflated when they again emitted a response. Again, in order for the DRO animals to increase the likelihood of reinforcement they had to decrease the effective number of responses per reinforcement-reinforcement interval. Here, this occurred within four sessions for the DRO 30 animals.

The prediction based on the findings by others (Staddon, et al., 1971) that the VT treatment groups would show less suppression than FT treatment groups was supported by the data. Staddon and Simmelhag (1971) report perseverance of "interim" activities for animal with fixed reinforcement-reinforcement intervals versus earlier resumption of "terminal" activities for animals scheduled with variable reinforcement-reinforcement intervals. In their study, interim activities were defined as those related to adjunctive behavior generally occurring just after food delivery, and terminal activities were described as discriminated operants occurring toward the end of the reinforcement-reinforcement interval and continuing until food delivery (generally lever responding or key

pecking). In the present study, where only terminal activities were measured, the animals with fixed values of t showed greater suppression of responding. Molecular analysis of cumulative records collected during the treatment phase support this finding. Figure 35, Cumulative Record 2, shows that a scalloped effect characteristic of FI responding (Ferster, et al., 1957) is evidenced by the FT 20 animal. Just after reinforcement, no responses occurred, and toward the end of the reinforcement-reinforcement interval the probability of responding increased. Furthermore, comparison of FT and VT groups in terms of their response-reinforcement intervals showed that the animals with fixed inter-reinforcement intervals, with more predictability as to when the next reinforcer would be delivered, had shorter response-reinforcement intervals. This finding raises the possibility that the animals might have been using temporal cues as the occurrence of the next reinforcer. And if the temporal relationship between response and reinforcement is more predictable, as is the case in the FT animals, then greater response suppression is to be expected in those treatment groups over the variable time treatment groups. This finding is indeed supported by the response suppression data (see Figure 9). Finally, if this type of temporal discrimination was indeed being learned by both the FT and VT animals then the fact some animals continued to respond throughout the treatment phase may be explained by the maintenance of a short temporal contiguity of adventitious responding and reinforcement. The bin data (Figures 22 through 27) do indeed show that the relative frequency of lever responding remained distributed around the shorter response-reinforcement intervals.

The comparison between contingent (DRO groups) and non-contingent (FT and VT groups) treatment groups in terms of overall responding supported the prediction by showing that providing for a contingency of not making the targeted response and reinforcement

greatly effects the subject's responding. That is, the DRO groups showed dramatically greater suppression during the treatment phase than either the FT or VT groups (see Figure 8 for absolute rates of responding during the treatment phase). The particular findings of this study comparing the animals exposed to the contingent schedules with non-contingent schedules do not support those of Rachlin and Baum (1972). In that study the data indicated that responding was equivalent in animals exposed either to a DRO contingency or VT schedule. However, others (Henton, et al., 1978; Zeiler, 1976) comparing DRO and VT using conjoint schedules showed that the DRO schedule reduced the probability of a lever press more than the VT schedule. The present study is the first to replicate these findings using a between subjects design and only with one schedule in effect at a time. Looking at the molar analysis of lever responding (see Appendix D.1) we can conclude that the removal of a response-reinforcer dependency maintains behavior and the change to a dependency involving not responding and reinforcement quickly reduces behavior.

The molar data that was collected to directly assess the response-reinforcement contiguity was the one comparing the response-reinforcement intervals for the different treatment conditions. The animals with no contingency showed that initially they were responding within seconds of the next reinforcer and the interval between responding and reinforcement continued to grow throughout the treatment phase (see Figure 15). The results for animals with a specified contingency of not making the target response and reinforcement showed that the interval from response to reinforcer was maintained. This finding is also supportive of a contiguity analysis. The animals in the FT and VT conditions had short temporal pairings between response and reinforcement. That is, if they continued to respond, the interval between response and reinforcement could have been very short as reinforcement was delivered independent of responding. However, animals in the DRO

condition had response-reinforcement intervals of at least 10 seconds for the DRO 10 treatment group and at least 20 seconds for the DRO 20 and at least 30 seconds for the DRO 30 treatment groups. Therefore, for the DRO animals the interval or contiguity between response and reinforcement was necessarily extended. For the DRO animals the behaviors that were most contiguous with reinforcement were necessarily "other" behaviors than lever pressing.

Because this experiment used a between groups design, did not wait for stable states to emerge, and collected predominantly molar dependent measures, the conventional studies comparing response-dependent and response-independent schedules may arguably not be the most adequate for comparison to the present results (Gamzu & Schwartz, 1973; Lattal, et al., 1971; Zeiler, 1977). However, there exists a body of literature that has focused on the transition of response-dependent to response-independent schedules (Catania & Keller, 1981; Herrnstein, et al., 1966; Imam & Lattal, 1988; Lachter, 1971; Lattal, 1972; Zeiler & Solano, 1982). A criticism to studying just those transitions from response-produced to response-independent reinforcement is that just after the transition, responding will continue to be maintained due to the contiguities between responses and reinforcers. That is, if contiguity is what maintains animals responding and the animals continue to respond on a response independent schedule they will experience sufficient adventitious pairings of response and reinforcer to maintain responding. The procedures used in the present study were designed to assess this argument. This was achieved by directly comparing time schedules with no contingency and no experimenter-specified contiguity, with DRO schedules with a contingency and a fixed minimum or artificial contiguity. The molar analysis of total response rates showed that this had a dramatic effect with greater response suppression seen in the DRO and EXT groups (see Figure 9).

The question then becomes, what happened to the animals' distribution of responding. Molar measures comparing the response-reinforcement intervals between all of the reinforced treatment groups showed that the time between response and reinforcer remained relatively constant over this phase for the DRO treatment groups (see Figure 15). By definition of the parameters of the DRO schedule the response-reinforcer interval for the DRO treatment groups will necessarily be greater than the non-contingent time based treatment groups. What is evident in Figure 15 is that the interval from response to reinforcer increased for the FT and VT groups through the treatment phase. Furthermore, the figure shows that the interval was very short for these time based treatment groups.

The molecular data collected throughout the treatment phase did not indicate the same pattern as the molar analysis. The response-reinforcement bin analysis did show that the interval between lever press and food delivery gets longer over the 15 session treatment phase (see Figures 22-24 for the three FT treatment groups, and Figures 25-26 for the three VT treatment groups). That is, while early in this phase, sessions one and five, most of the responding occurred within three seconds of the next reinforcer, responding during sessions 10 and 15 continued to occur early in the session, with only a marginal increase in the relative frequency toward longer response-reinforcement bins. However, Figures 27 through 30 show a dramatic increase of responding away from the next reinforcer for the DRO animals. This point is most dramatically displayed in Figure 30 (data from the DRO 30 treatment group), where no minimal response-reinforcement intervals were recorded for the latter sessions and during sessions 10 and 15 most of the responding was occurring more than 40 seconds before the next scheduled reinforcer. Of course, by definition, no response-reinforcement interval of less than 30 seconds was possible in this group.

The differences between molar and molecular analysis findings invite further comment. One reason that has been proposed for the greater suppressive effects of the DRO over the FT and VT schedules is that the contiguity between lever response and reinforcement for the DRO animals is exaggerated. In addition, the only short temporal relations possible would reinforce the "other" behavior in the DRO animals. Thus the level of analysis focusing on contiguity can best be explained using a molecular analysis. The other reason that has been presented as an account for the greatly suppressive effects of the DRO animals involves a contingency analysis. For the DRO animals, every response resets the interval to the next scheduled reinforcer. That is when the DRO animals decreased their mean rates of responding, they necessarily increased their rate of reinforcement. The data then, collected on schedules with a delayed contiguity and specified contingency between responding and reinforcement, conform best to a molar analysis. This finding leaves the researcher in a quandary as to what type of data to collect, and once the data is obtained, what is the best way to analyze that data. Molar measures tend to focus on data collected over longer periods of time rather than smaller segments as the molecular orientation does. It seems that neither molar nor molecular approaches to understanding behavior are better, but that the advantage of one cannot be determined without an understanding about how a particular process operates (Zeiler, 1989). If different processes of behavior operate at different time spans then understanding these dictates the analysis of choice. That is, for the present experiment, investigating contiguity would best be achieved using molecular response bin analysis, while determinants of contingency will be best ascertained using group means on response-reinforcer intervals.

The analyses from the acquisition phase show that all groups were responding at equivalent rates prior to exposure to the treatment condition. This finding was necessary to establish in order to draw conclusions from

the effectiveness of each treatment condition. Several researchers have argued that at least initially, the particular dependency the subject was exposed to would effect response patterns when that dependency was removed (Lattal, 1972; Rescorla & Skucy, 1969; Rieg, et al., 1987; Zeiler, 1968). That is, the baseline schedule during an acquisition phase will determine the degree to which responding will be effected during a treatment phase. Lattal (1972) presents the observation that with an FI schedule the response rate is much higher than a VI schedule of reinforcement. The effectiveness of a subsequent non-contingent schedule in reducing responding, will be greater for those previously exposed to the VI schedule. The argument is that if animals are emitting behaviors other than lever responding prior to treatment then once response independent reinforcement is initiated they will have a higher probability of adventitious pairing of non-lever behaviors and reinforcement. The present study clearly established the equivalence of response rates prior to exposure to the experimental manipulations of interest. In the present study when animals exposed to a schedule of reinforcement that is both contiguous and contingent (ie. FI schedule) and are subsequently exposed to response-independent schedules, with no contingency or contiguity (EXT schedule) or no contingency and a non-specified contiguity (Time schedules), then the removal of a contingency between response and reinforcer may allow for the maintenance of responding. That is, the effectiveness of EXT and DRO over both FT and VT as response elimination techniques may be due to the high response probability schedule used during the acquisition phase. If a schedule had been used with a lower rate of reinforcement or one that generates slower rates of responding the suppressive effects for the FT and VT groups might have been enhanced.

The analysis comparing lever responding between treatment groups during the reacquisition phase establishes the temporary effects of these

response elimination procedures. For all the groups responding at the end of the treatment phase had been depressed, but when reinforcement was again made contingent on responding, resurgence of responding was noticed. Throughout the first seven minutes those animals that had been exposed to the non-contingent schedules tended to recover faster than those exposed to the contingent schedules. When responding began for individual animals their rates quickly became similar to those of the last day of the acquisition phase. This supports previous assertions that EXT and DRO procedures do not "eliminate" responding but rather "suppress" responding (Boe & Church, 1967; Rieg, et al., 1986). Again, the point should be made that these techniques should not be labeled response elimination procedures but response suppression techniques.

It is interesting that the particular pattern of recovery observed when comparing the DRO and EXT treatment groups is dissimilar to those of previous studies (Rieg, et al., 1988; Rieg, et al., 1986). These studies had found that DRO animals whose response-reinforcement interval were shorter than the reinforcement-reinforcement interval recovered as fast or faster than EXT animals, and that when the response-reinforcement was greater than the reinforcement-reinforcement interval recovery was slower than EXT animals. Although this pattern was true for the first three minutes of this phase, this was not the case for minutes five through 18 (see Figure 21). The difference between the present study and those reported earlier is that the length of each session was twice those of the previous studies and the treatment phase consisted of an additional five sessions. A frequent criticism of our previous findings was that the treatment phase was too short, having been five or ten, 15 minute sessions. In the present study the session lengths were doubled and extended to fifteen days. The present results therefore indicate that as the treatment phase is extended the suppressive effects of EXT conditioning surpass those of DRO conditions with response-reinforcement intervals both longer and

shorter than the reinforcement-reinforcement intervals. However, the suppressive effects of the intermediate DRO delay group, whose response-reinforcement interval equaled the reinforcement-reinforcement interval, showed greater suppression for the first half of this phase than its shorter and longer response-reinforcement interval counterparts.

The two analyses comparing mean response rates during the last day of acquisition and during reacquisition invite comment. While a simple comparison of response rates between acquisition and reacquisition showed overall slower rates during reacquisition, the lack of differences observed at the end of the acquisition phase was also evident in the reacquisition phase. To that end, after reinforcement was again made contingent and immediately contiguous with responding, no treatment group showed greater response suppression than any other over an entire 30 minute period. When the response data from the reacquisition phase were broken down into five minute intervals and compared to session eight of the acquisition phase, different results become apparent. For all of the time based treatment groups no suppression of responding was observed. For the DRO and EXT treatment groups differences were found for the first four of the five minute intervals. The data indicated that at least initially the EXT and DRO groups were responding at lower levels during reacquisition than during acquisition. After 15 minutes these treatment groups were responding at the same level that they had been prior to treatment. These analyses, in conjunction with the minute by minute analysis described above, have several implications for the ongoing effectiveness of response elimination procedures. One way to view the reacquisition phase is to interpret it as a test of the effectiveness of the treatment conditions. In this way, animals exposed to response independent reinforcement during treatment show no suppression of responding when the dependence between response and reinforcer is again initiated. At the same time, behavior for animals whose dependency

was maintained, yet for which the temporality between targeted response and reinforcer was lengthened, show greatly reduced levels of responding when the targeted behavior was again made temporally contiguous with reinforcement. In the present study not only were the DRO and EXT treatment groups responding less than the FT and VT groups during reacquisition, but they also responded less during the early part of the session compared to the acquisition session.

Previously, researchers have argued that the increased effectiveness of DRO when compared to EXT is due to the fact that subjects learn not to emit the target response and that the response alternate to responding is strengthened, and that during EXT response suppression without conditioning of other behaviors occurs (Uhl, et al., 1969; Zeiler, 1971). The same argument as for the DRO treatment groups is of course true for the FT and VT treatment groups where no specified response was conditioned. The implication of this reasoning would hold true only for comparisons between the DRO and time based treatment groups. For the DRO animals, during treatment, all reinforcers followed a non response, and for the FT and VT for some of the animals reinforcement delivered after lever responding and for some after emitting some "other" behavior. Hence, during the reacquisition phase, greater suppression of responding should occur for the DRO treated groups compared to the FT and VT treated groups. This is because all the DRO animals would have to be reconditioned to stop making the "other" behavior. The findings from the present study support this proposition.

The fact that slowest reacquisition was observed for the EXT treatment group may be explained by the extinction properties of the schedule used during reacquisition. During treatment the EXT animals learned that responding would no longer yield reinforcement, and the DRO subjects learned that making alternate responses produced reinforcement. When subsequent to the treatment phase, animals are again exposed to a schedule,

both contingent and contiguous with responding, the properties of the schedule are different. For the EXT animals, not responding still does not yield reinforcement. However, for the DRO and the time based animals, not responding now no longer delivers reinforcement. That is for the DRO animals an appreciable change had occurred. The phenomenon of "resurgence" will then explain their recovery of responding (Epstein, 1983; Epstein & Skinner, 1980). The observation is that when recently reinforced behavior is no longer reinforced, that behaviors previously reinforced will tend to occur. Therefore, the early recovery of the DRO animals may be attributable to the resurgence of the previously reinforced response. The same argument may explain the recovery of the FT and VT subjects. While their response rates were not as dramatically suppressed as those of the contingent groups, they too showed resurgence of lever responding. That is, for the animals that had decreased their lever responding and were emitting other behaviors, the changes in the schedule from free reinforcement to contingent reinforcement tended to produce resurgence of lever responding.

There are several implications that this research project has for response suppression when used in applied settings. Most general is the importance basic research has for applied applications. It is inevitable that the plethora of research comparing treatment conditions will produce a series of different solutions. The question then becomes if two different studies comparing the same treatment procedures yield different findings, which is the most valid, and more importantly, what are the causes for those particular differences. This argument has been raised before by Sidman (1960). Furthermore, is the issue of the particular parameters employed when comparing different treatment conditions (Van Houten, 1987). For example, unless the optimal temporal parameter of a schedule is employed, conclusions about the efficacy of any one treatment over another should be regarded with skepticism. There is no doubt that the

operant chamber with its accurately controlled environment and response alternatives allows for a setting in which the relations between response and reinforcer can empirically be manipulated and studied. There is very little doubt that the experimental laboratory is a contrived setting. That is, the experimenter has the maximum control in setting up the occasion for a reinforcer, and also specifying the exact temporal relationship between response and reinforcer. In the applied setting excessive behaviors generally involve a long chain of behaviors and the targeted response may not be as discrete as a switch closure due to a lever press. For example, O'Neil, White, King, and Carek (1979) decreased the probability of rumination using both EXT and DRO procedures. However, rumination involves a long chain of behaviors culminating in the ejection or reswallowing of food. As O'Neil et al. (1979) point out treating different parts of the behavioral chain will have differential effect. It is therefore difficult to assess the exact contingency between reinforcement and any one of the ongoing behaviors. Furthermore, because the behaviors are internalized it may be even more difficult to assess the temporal relationship between response and reinforcer. It is for these three reasons that experimental laboratory research on schedule parameters can provide the greatest benefit for applied researchers.

The effectiveness of extinction for the suppression of responding was clearly established in the treatment phase and especially during the reacquisition phase. At the same time, schedules which involve a contingency between not responding and reinforcement are also effective in reducing responding. A comparison between EXT and DRO showed only slight differences during treatment. While some studies comparing DRO and EXT have shown DRO to be more effective than EXT (O'Neil et al., 1979), others have found the opposite to be true (Redd, 1986), while still others have shown no differences between DRO and EXT (Heidorn & Jensen, 1984).

The comparison between contingent and non-contingent schedules from the present study also have implications for applied settings. In the present study providing for a contingency between not responding and reinforcement (DRO) was more effective in reducing unwanted behaviors than no contingency between response and reinforcer (FT and VT). In the applied settings comparisons between contingent and non-contingent reinforcement generally involve the implementation of a contingent relationship where previously there had been none. That is, these are generally A-B type designs where because of ethical considerations a reinstitution of pre-treatment conditions is never implemented. The results from the present study are indeed supportive of the findings (George & Hopkins, 1989; Johnson, McGlynn, & Topping, 1973). It seems clear that as a response suppression technique, DRO is clearly superior to both FT and VT schedules. At the same time, if exposure to the treatment phase is sufficiently long then EXT should be the treatment of choice.

In addition to conclusions about differences between particular schedule over another this project has furnished considerable information about the underlying processes involved in learning. First is the comparison between the four types of schedules compared. The data showed that both DRO and EXT schedules were more effective at reducing responding than were either FT and VT schedules. As a measure of the durability of the response suppression procedures, results from the reacquisition phase indicated that EXT followed by DRO produced the slowest recovery to pre-treatment levels. Second is the comparison between the underlying processes hypothesized to be the contributing factors for reinforcement theory. Generally, it might be said that merely removing a contingency between an established response and its reinforcer will not greatly effect the behavior. In the present study the response suppression was not as great for the two time based schedules as for DRO or EXT. However, a second contributing factor in addition to the contingency

between not responding and reinforcement, it may be argued, for the effectiveness of DRO, was the lengthening of the interval between the targeted response and reinforcement. It must therefore be concluded that a combination of contingency between not responding and reinforcement concurrent with and longer response reinforcer contiguity will greatly enhance the effectiveness of applied response suppression techniques. Finally, the differential effectiveness of the treatment conditions needs to be assessed in terms of the level of data collection and analysis. The present analyses showed different effects for molar and molecular interpretations especially for the response-reinforcer interval data. Some important implications that this study has for the applied literature is that both contingency and contiguity are important aspects of reinforcement and should be considered in determining treatment programs. Furthermore, time based schedules are poor and at least unpredictable methods for reducing behavior. Also, DRO does not seem to suppress behavior as effectively as EXT if the treatment program is extended over long periods of time. At the same time, for short treatment programs, DRO may be more effective. Finally, all three techniques used here must be considered "suppression" techniques and not elimination techniques, because as treatment is discontinued and reinforcement is again made contingent and contiguous with responding the behavior will recover to its original levels very rapidly.

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Appendix A

Mixed Design Analysis of Variance Summary Table for Common Log
Transformed Lever Responses During the Acquisition Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Group	.918	9	.102	.683
Error	11.939	80	.149	
Within				
Session	4.927	6	.821	93.335
Group x				
Sessions	.505	54	.009	1.064
Error	4.223	480	.008	
Total	22.512	629		

Appendix B
Mixed Design Analysis of Variance Summary Table for Common Log
Transformed Reinforcers Received During the Acquisition Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Group	.025	9	.002	.763
Error	.285	80	.003	
Within				
Session	.285	6	.003	42.805
Group x				
Sessions	.053	54	.0009	.916
Error	.518	480	.001	
Total	1.158	629		

Appendix C

Mixed Design Analysis of Variance Summary Table for Common Log
Transformed Response-Response Intervals During the Acquisition Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Group	.918	9	.102	.687
Error	11.881	80	.149	
Within				
Session	4.767	6	.794	89.919
Group x Sessions	.489	54	.009	1.025
Error	4.241	480	.008	
Total	22.296	629		

Appendix D.1

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

Source	Sum of Squares	df	Mean Square	F
Between				
Group	717.332	9	79.704	25.257
Error	252.459	80	3.156	
Within				
Session	133.840	14	9.560	97.192
Group x				
Sessions	66.243	126	.526	5.345
Error	110.165	1120	.098	
Total	1280.039	1349		

Appendix D.2

Simple Effects Tests Results for Lever Responding During the 15 Sessions of
the Treatment Phase

Session	df	F	p
1	(9,207)	1.472	> .05
2	(9,207)	12.676	< .05
3	(9,207)	17.911	< .05
4	(9,207)	28.728	< .05
5	(9,207)	33.106	< .05
6	(9,207)	32.640	< .05
7	(9,207)	35.271	< .05
8	(9,207)	14.339	< .05
9	(9,207)	16.302	< .05
10	(9,207)	16.877	< .05
11	(9,207)	19.903	< .05
12	(9,207)	21.525	< .05
13	(9,207)	17.953	< .05
14	(9,207)	19.710	< .05
15	(9,207)	17.883	< .05

Appendix E.1

Mixed Design Analysis of Variance Summary Table for Common Log
Transformed Reinforcers Received During the Treatment Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Group	35.597	8	4.450	1053.673
Error	.304	72	.004	
Within				
Session	2.470	14	.176	78.450
Group x				
Sessions	6.355	112	.057	25.234
Error	2.267	1008	.002	
Total	46.993	1214		

Appendix E.2

Simple Effects Tests Results for Reinforcers Delivered During the 15
Sessions of the Treatment Phase

Session	df	F	p
1	(8,3321)	2,480.161	< .05
2	(8,3321)	917.856	< .05
3	(8,3321)	647.716	< .05
4	(8,3321)	585.725	< .05
5	(8,3321)	570.889	< .05
6	(8,3321)	570.155	< .05
7	(8,3321)	561.895	< .05
8	(8,3321)	564.308	< .05
9	(8,3321)	561.478	< .05
10	(8,3321)	561.721	< .05
11	(8,3321)	558.152	< .05
12	(8,3321)	555.088	< .05
13	(8,3321)	558.110	< .05
14	(8,3321)	558.635	< .05
15	(8,3321)	558.493	< .05

Appendix F.1

Mixed Design Analysis of Variance Summary Table for Common Log
Transformed Response-Response Intervals During the Treatment Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Group	165.568	9	18.396	6.898
Error	213.348	80	2.667	
Within				
Session	31.190	14	2.228	7.284
Group x				
Sessions	39.608	126	.473	1.547
Error	342.565	1120	.306	
Total	812.279	1349		

Appendix F.2

Simple Effects Tests Results for Response-Response Intervals During the 15
Sessions of the Treatment Phase

Session	df	F	p
1	(9,597)	.762	> .05
2	(9,597)	6.371	< .05
3	(9,597)	10.008	< .05
4	(9,597)	18.000	< .05
5	(9,597)	14.195	< .05
6	(9,597)	17.972	< .05
7	(9,597)	7.831	< .05
8	(9,597)	15.219	< .05
9	(9,597)	6.663	< .05
10	(9,597)	11.871	< .05
11	(9,597)	10.815	> .05
12	(9,597)	1.655	< .05
13	(9,597)	5.543	< .05
14	(9,597)	7.272	< .05
15	(9,597)	6.061	< .05

Appendix G.1

Mixed Design Analysis of Variance Summary Table for Common Log
Transformed Response-Reinforcement Intervals During the Treatment
Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Group	232.103	8	29.013	50.223
Error	41.593	72	.578	
Within				
Session	6.100	14	.436	28.495
Group x				
Sessions	4.236	112	.038	2.473
Error	15.414	1008	.015	
Total	46.992	1214		

Appendix G.2

Simple Effects Tests Results for Response Reinforcement Intervals During
the 15 Sessions of the Treatment Phase

Session	df	F	p
1	(8,175)	59.765	< .05
2	(8,175)	49.337	< .05
3	(8,175)	52.890	< .05
4	(8,175)	48.670	< .05
5	(8,175)	45.768	< .05
6	(8,175)	48.038	< .05
7	(8,175)	41.915	< .05
8	(8,175)	42.055	< .05
9	(8,175)	43.574	< .05
10	(8,175)	40.550	< .05
11	(8,175)	42.738	< .05
12	(8,175)	36.151	< .05
13	(8,175)	39.306	< .05
14	(8,175)	36.050	< .05
15	(8,175)	37.458	< .05

Appendix H.1

Mixed Design Analysis of Variance Summary Table for Common Log
Transformed Responses Per Reinforcement-Reinforcement Interval
During the Treatment Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Group	86.984	8	10.873	13.328
Error	58.739	72	.816	
Within				
Session	30.956	14	2.211	89.470
Group x Sessions	32.458	112	.290	11.726
Error	24.911	1008	.025	
Total	234.048	1214		

Appendix H.2

Simple Effects Tests Results for the Number of Responses per
Reinforcement-Reinforcement Interval During the 15 Sessions of the
Treatment Phase

Session	df	F	p
1	(9,186)	27.690	< .05
2	(9,186)	10.218	< .05
3	(9,186)	10.077	< .05
4	(9,186)	13.052	< .05
5	(9,186)	15.619	< .05
6	(9,186)	14.144	< .05
7	(9,186)	17.330	< .05
8	(9,186)	15.941	< .05
9	(9,186)	14.956	< .05
10	(9,186)	18.617	< .05
11	(9,186)	16.752	< .05
12	(9,186)	15.280	< .05
13	(9,186)	16.954	< .05
14	(9,186)	15.419	< .05
15	(9,186)	14.679	< .05

Appendix I.1

Mixed Design Analysis of Variance Summary Table for Common Log
Transformed Reinforcement-Reinforcement Intervals During the
Treatment Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Group	.379	2	.189	13.666
Error	.333	24	.014	
Within				
Session	5.278	14	.377	46.885
Group x Sessions	1.335	28	.048	5.932
Error	2.702	336	.008	
Total	10.027	404		

Appendix I.2

Simple Effects Tests Results for Reinforcement-Reinforcement Intervals
for the three DRO Treatment Groups During the 15 Sessions of the
Treatment Phase

Session	df	F	p
1	(2,554)	29.903	< .05
2	(2,554)	11.925	< .05
3	(2,554)	.713	> .05
4	(2,554)	.226	> .05
5	(2,554)	.146	> .05
6	(2,554)	.115	> .05
7	(2,554)	.022	> .05
8	(2,554)	.060	> .05
9	(2,554)	.056	> .05
10	(2,554)	.024	> .05
11	(2,554)	.004	> .05
12	(2,554)	.003	> .05
13	(2,554)	.006	> .05
14	(2,554)	.010	> .05
15	(2,554)	.022	> .05

Appendix J.1

Mixed Design Analysis of Variance Summary Table for Common Log
Transformed Lever Responses During Each Minute of the Reacquisition
Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Group	132.980	9	14.776	5.598
Error	211.137	80	2.639	
Within				
Session	108.836	29	3.753	51.620
Group x Sessions	89.304	261	.342	4.706
Error	168.671	2320	.073	
Total	710.928	2699		

Appendix J.2

Simple Effects Tests Results for Lever Responding During the 30 Minutes of
the Reacquisition Phase

Minute	df	F	p
1	(9,385)	17.053	< .05
2	(9,385)	28.800	< .05
3	(9,385)	32.746	< .05
4	(9,385)	31.031	< .05
5	(9,385)	20.689	< .05
6	(9,385)	17.628	< .05
7	(9,385)	17.579	< .05
8	(9,385)	14.619	< .05
9	(9,385)	15.840	< .05
10	(9,385)	11.395	< .05
11	(9,385)	8.078	< .05
12	(9,385)	7.789	< .05
13	(9,385)	8.002	< .05
14	(9,385)	7.794	< .05
15	(9,385)	7.380	< .05

Minute	df	F	p
16	(9,385)	8.629	< .05
17	(9,385)	5.485	< .05
18	(9,385)	5.417	< .05
19	(9,385)	4.851	< .05
20	(9,385)	3.874	< .05
21	(9,385)	4.827	< .05
22	(9,385)	22.868	< .05
23	(9,385)	2.799	< .05
24	(9,385)	2.084	< .05
25	(9,385)	4.845	< .05
26	(9,385)	2.071	< .05
27	(9,385)	2.625	< .05
28	(9,385)	2.870	< .05
29	(9,385)	1.818	> .05
30	(9,385)	24.615	< .05

Appendix K

Mixed Design Analysis of Variance Summary Table for Lever Responses per
Minute During the Last day of the Acquisition Phase and the
Reacquisition Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Group	14450.720	9	160.564	.517
Error	24866.383	80	310.830	
Within				
Day	2748.215	1	2748.215	47.291
Group x Day	1321.788	9	146.865	2.527
Error	4649.038	80	58.113	
Total	35030.496	179		

Appendix L.1

Mixed Design Analysis of Variance Summary Table for Lever Responses for
the Last Session of the Acquisition Phase and Five Minute Interval Bins
During the Reacquisition Phase

Source	Sum of Squares	df	Mean Square	F
Between				
Group	20.827	9	2.314	4.675
Error	39.600	80	.495	
Within				
Bin	21.119	6	3.520	74.169
Group x Bin	16.974	54	.314	6.624
Error	22.779	480	.047	
Total	121.298	629		

Appendix L.2

Simple Effects Tests Results for Lever Responses for the Last Session of the
Acquisition Phase and Five Minute Interval Bins During the
Reacquisition Phase

Interval	df	F	p
Acquisition			
Session:	(9,79)	.011	> .05
Reacquisition			
Session:			
Min 1-5	(9,79)	5.803	< .05
Min 6-10	(9,79)	3.650	< .05
Min 11-15	(9,79)	2.037	< .05
Min 16-20	(9,79)	1.032	> .05
Min 21-25	(9,79)	.732	> .05
Min 26-30	(9,79)	.547	> .05

Appendix L.3

Simple Effects Tests Results for Lever Responses for the Last Session of the
Acquisition Phase and the Reacquisition Phase Separated by Treatment
group

Condition	df	F	p
FT 10	(9,79)	.229	> .05
FT 20	(9,79)	.385	> .05
FT 30	(9,79)	.174	> .05
EXT	(9,79)	4.279	< .05
VT 10	(9,79)	.107	> .05
VT 20	(9,79)	.080	> .05
VT 30	(9,79)	.271	> .05
DRO 10	(9,79)	2.731	< .05
DRO 20	(9,79)	3.421	< .05
DRO 30	(9,79)	2.257	< .05