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A Comparison of Three Procedures for the Establishment of a Novel Response with Delayed Reinforcement

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A COMPARISON OF THREE PROCEDURES FOR THE ESTABLISHMENT OF A NOVEL RESPONSE WITH DELAYED REINFORCEMENT

by

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Jayson W. Wilkenfield, Ph.D.

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The purpose of the present study was to compare three procedures for examining the degree to which delayed response-dependent presentations of food would result in the acquisition of lever-pressing in rats. Although there is an abundance of research examining the maintenance of behavior with delayed reinforcement, few studies have investigated reinforcement delays in the acquisition of new discrete behaviors. Historically two different procedures have been employed in the study of delayed reinforcement. In a nonresetting delay procedure a response sets up the delivery of a reinforcer to occur after *t* seconds, and responses that may occur during the delay interval have no programmed consequences. In a resetting delay procedure, a response programs reinforcer delivery to occur *t* seconds after the response is emitted, and any response that occurs during the delay interval resets the delay to *t* seconds, thus preventing any response from being followed by a reinforcer in less time than that of the specified delay. These two procedures and a third in which every response programmed delivery of a reinforcer *t* seconds after its occurrence (stacked delay) were employed to examine the effects of 4-, 8-, and 16-second delays of food presentation on the acquisition of lever-pressing. In addition, one group was exposed to a 32- second resetting delay. Two control groups were studied, one that received immediate reinforcement and one that received no reinforcement (extinction). With the exception of the extinction group, responding was established with every procedure at every delay value. In the stacked and resetting delay procedures,

asymptotic responding occurred more rapidly with shorter delays, although this relationship was reversed in the nonresetting delay condition. Although acquisition was established with the resetting delays, response rates were generally not as high as with the other two procedures.

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Jayson W. Wilkenfield

TABLE OF CONTENTS

Table of Contents--Continued

LIST OF TABLES

LIST OF FIGURES

List of Figures--Continued

CHAPTER I

INTRODUCTION AND STATEMENT OF THE PROBLEM

Background of the Problem

The term "reinforcement" refers to the relationship between the type of behavioral postcedent[1] that increases the subsequent frequency of a behavior and the behavior it strengthens. Michael (1989) defines reinforcement in the following way: a stimulus change that occurs immediately after the emission of a member of a response class which results in an increase in the future frequency of responses of that class under similar conditions (ruling out instances where the increased response frequency happens for other reasons, such as elicitation). Although immediacy has not been explicitly included in some widely cited definitions of reinforcement, discussions of the subject typically address the importance of temporal contiguity as a parameter which influences the degree to which behavioral postcedents influence the strength of the responses they follow (e.g., Catania, 1984; Keller & Schoenfeld, 1950). Most recently, popular introductory treatments of the topic of reinforcement specifically include immediacy in their definitions of the term (e.g., Cooper, Heron, & Heward, 1987, p. 269; Martin & Pear, 1988, p. 30.). Williams (1976) has addressed the importance of immediacy of reinforcement in the following way: "Of all parameters of reinforcement, temporal proximity between response and reinforcer is most central to an understanding of the fundamental principles of conditioning" (p.

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[1] The term "postcedent," suggested by Vargas (1984) is used to distinguish an event that immediately follows a behavior but may or may not be caused by the behavior it follows from those events that both follow and are caused by the preceding behavior. The term "consequence" is reserved for those events that are caused by the behaviors they follow. The adjective "consequent" conforms to the same distinction (see Communidad Los Horcones, 1987).

441). Laboratory lore, also, has held that for an event to strengthen (increase the frequency of) some type of behavior, that event must follow that behavior with close temporal contiguity (see Skinner, 1953, p. 96). Exactly what "immediately" means operationally, however, is somewhat controversial and has been given considerable attention by a number of behaviorists, many of whom have addressed the issue of delayed reinforcement (e.g., Ferster, 1953; Hull, 1932, 1943, 1952; Mowrer, 1960; Skinner, 1938; Spence, 1947, 1956), which may be defined as the interpolation of a period of time between the delivery of a reinforcer and the occurrence of the response on which it is contingent (Lattal, 1987).

Research in the Area of Delayed Reinforcement

The behavior-strengthening property attributed to reinforcement can be discussed in terms of two general phenomena, the acquisition of new behavior and the maintenance of some type of behavior after it has already appeared in the organism's repertoire. Acquisition can be thought of as a change from one steady-state behavioral baseline to another (Sidman, 1960). This conceptualization includes the development of new behavior (i.e., where the pretraining baseline level is zero) as well as the further strengthening of preexisting behavior. The term "maintenance" refers to the degree to which responding is perpetuated at some asymptotic level under specified conditions after already having been established in an organism's repertoire.

Response Acquisition

Interest in the acquisition of new behavior per se has not been remarkable among contemporary behaviorists. Lattal and Gleeson (1990) have noted that some early learning theorists (e.g., Guthrie, 1935; Hull, 1943) were specifically interested in examining response acquisition in its own right while others, like Skinner (1938),

acknowledged the importance of variables involved in the development of new behavior but treated problems related to acquisition as technical details which needed to be overcome in order to investigate issues involved in maintenance. Nevertheless, Skinner (1953) was the first to describe response shaping, a procedure whereby operant behavior previously nonexistent in an organism's repertoire could be established when successive approximations to a targeted response form are followed with immediate reinforcement. Brown and Jenkins (1968) demonstrated how novel behavior could be elicited or "autoshaped" with an essentially respondent pairing procedure when such behavior had not been previously emitted. These procedures and others such as response priming (Ferster & Skinner, 1957) and imitation (Neuringer & Neuringer, 1974) were developed to study the establishment of novel behavior, but not a great deal of empirical research has been devoted to the investigation of how a novel operant, once it has occurred, becomes a part of an organism's repertoire. In settings that do not incorporate procedures specifically designed to evoke the initial occurrence of a novel response, variables determining acquisition are confined to factors that are brought to bear on the behavior after it has already occurred once (e.g., rate, delay, magnitude, or quality of reinforcement.) That is, the first occurrence of the response takes place for different reasons than the second and subsequent responses, since the first occurrence cannot be attributed to the conditioning effect of reinforcement (Skinner, 1969).

Continuous versus discrete responses. Lattal and Gleeson (1990) note that most early studies of response acquisition (whether with immediate or delayed reinforcement) have focused on continuous responses like running down an alley or in a wheel. Such responses are continuous in the sense that an instance of one response is not easily identifiable. Continuous responses are contrasted with discrete responses such as lever-pressing or key-pecking, both of which can be measured in

terms of a single occurrence. Studying continuous responses allows examination of the type of acquisition in which the pretraining baseline level of the behavior is greater than zero. Running, for example, is a part of the repertoire of many organisms prior to experimentation (Logan, 1952). Most early studies of delayed reinforcement examined the acquisition of continuous responses.

According to Renner (1964), Watson (1917) was the first to focus on the theoretical significance of delay of reinforcement as an experimental independent variable. He studied the effects of delayed reinforcement on the behavior of rats digging through sawdust (a continuous response) to obtain food, and he reported that a 30-second delay (arranged by detaining subjects in a goal box) did not interfere with acquisition when subjects exposed to delays were compared to those that were reinforced immediately. Warden and Haas (1927) reported similar results with rats detained before receiving food in a maze-learning task. Hamilton (1929), however, reported decreased performance in maze discrimination learning when rats were detained in a chamber that was separate from the goal box. Wolfe (1934), using a similar procedure, also reported delay-produced decrements in maze performance, with most of the effect occurring during the first 60 seconds of delay. Some learning, however, was apparent with delays of up to several minutes. The findings of the Watson (1917) and Warden and Haas (1927) studies suggested that delay seemed not to interfere with the acquisition of continuous responses. These results have been interpreted (e.g., Hull, 1943) as being due to the effects of secondary immediate reinforcement. To the extent that the subjects in these experiments were detained in the presence of stimuli that had been historically correlated with reinforcement (the visual and olfactory stimuli in or near the goal box) their behavior was effectively producing immediate conditioned reinforcers. In the Hamilton (1929) and Wolfe (1934) studies, delays were produced by detaining subjects in chambers separate from those in which food had previously been ingested, but the chambers

entered after correct responses were different from the ones entered after incorrect ones, thereby allowing the stimuli associated with each antechamber to acquire discriminative properties and consequently function as immediate consequences. Perkins (1947) sought to avoid this shortcoming by alternating delay chambers every other trial and found a greater decline in performance but still observed learning with delays as long as 120 seconds.

Grice (1948) criticized the use of maze learning tasks to study the effects of delayed reinforcement on the grounds that response-produced (proprioceptive) stimuli resulting from turning in the right direction could function as immediate conditioned reinforcers. In order to eliminate this source of immediate reinforcement he used a visual discrimination task in which a turn in either direction could be a correct response. Rats were trained in a two-choice apparatus, and reinforcement was correlated with a stimulus that was one of two particular brightnesses. For example, if black as opposed to white was designated as the correct stimulus for a particular subject, the animal would have to pass through a black curtain. After passing through black, the subject would enter a delay compartment of neutral brightness and be confined there for the remainder of the delay interval. Then it would be allowed access to the goal box in which there was food (if the correct choice had been made.) Delay as little as two seconds substantially disrupted learning. With this approach learning was found to decrease more rapidly and to a greater extent than in the studies described earlier.

All of the experiments described above focused on continuous as opposed to discrete responses. According to Lattal and Gleeson (1990), discrete responses require differentiation of form or topography, and although measurement of such topographical differentiation is difficult with respect to acquisition of such behaviors, these responses are highly sensitive to changes in conditions of maintenance and are therefore preferable in the study of maintenance. Although variables affecting the

maintenance of already established discrete behaviors (e.g., key-pecking in pigeons) have been studied in scores of experiments, little attention has been given to the study of factors affecting the acquisition of discrete responses. The effect of delayed reinforcement in particular on the maintenance of behavior already established with immediate reinforcement has been studied extensively; however acquisition of discrete behavior followed by only delayed reinforcement has only recently begun to be examined (Lattal & Gleeson, 1990).

Response Maintenance

Typical experiments investigating the effect of delayed consequences on the rate of discrete responses involve establishing some baseline level of responding with immediate reinforcement, then changing the reinforcement contingency by delaying the consequence for some specified interval and measuring the subsequent effect on response rate. In an early experiment along these lines, Perin (1943) established baseline rates of lever pressing in rats with immediate reinforcement. His subjects were initially reinforced for pressing a horizontal lever in either direction. In the next condition presses only in the less preferred direction were reinforced, with one group receiving immediate reinforcement and the other delayed. In order to ensure that no responses could occur during the specified delay interval (and thereby be reinforced by a shorter obtained delay) the lever was retracted during the delay interval. Speed of acquisition was shown to decline as a function of delay even though the stimuli associated with lever retraction could be considered to function as conditioned reinforcers (since retraction was correlated with delayed food presentation.)

Signaled versus unsignaled delays. A methodological problem common to all the aforementioned studies involves the presence of stimuli at the onset of the delay interval that were correlated with the delivery of reinforcement. Procedures that do

not specifically eliminate such stimuli are referred to as "signaled" delay procedures. When the delay is signaled, correct responses are ensured immediate contact with these stimuli which may function as conditioned reinforcers.

Signaled delays have been used extensively to study the effects of delayed reinforcement on the maintenance of discrete responses. Such procedures typically consist of chained schedules (in which the initiation of the second component is accompanied by an exteroceptive stimulus change.) For example, Ferster (1953) studied the effect of a 60-second signaled delay imposed on the key-pecking of pigeons responding under a variable interval (VI) one-minute schedule. After baseline responding had been well established on the VI 1-min, a blackout was introduced which initiated a 60-second delay before reinforcement. This procedure resulted in a substantial decrease in the rate of responding from that seen under the VI. In a subsequent experiment, the blackout at first initiated a short delay, which was gradually increased to 60 seconds. This procedure did not result in a decrease in response rates. Ferster concluded that a gradual change in the length of the delay could attenuate the disruption in responding caused by the absence of contiguity between responding and reinforcement. He suggested that response-produced stimuli arising from behavior that occurred during the delay functioned as conditioned reinforcers for earlier responses. The gradual change in the length of the delay interval ostensibly allowed the behavior that occurred during the delay to be established superstitiously. Due to the presence of the blackout at the beginning of the delay interval, however, this procedure is subject to the criticism that responding is followed by a stimulus change that is correlated with the onset of the delay and inevitably, delivery of reinforcement. In addition to this problem, the fact that responding during the delay has no programmed consequences gives rise to another confound. The procedure for imposing the delay in these experiments consisted of a chain arrangement in which the second component was a fixed-time (FT) schedule.

In a FT schedule, reinforcement occurs after the passage of a specified period of time, independent of whether or not responses occur during that period; consequently, a response that occurs during the delay period can contact reinforcement in a time shorter than the nominal delay.

Nonresetting versus resetting delays. Any procedure used to study delayed reinforcement that incorporates a fixed-time schedule in its second (delay) component allows for the possibility of the obtained delay being shorter than the programmed delay. Such procedures can be referred to as "nonresetting" delays. Some experimenters have sought to eliminate this confound by substituting a no-responding-for-greater-than-t (non $R > t$) schedule for the FT component. In the non $R > t$ arrangement a response initiates a specified period of time to reinforcer delivery during which any further responses have the consequence of resetting the time interval to its specified value. With this procedure, no response can be followed by a reinforcer by a time shorter than that of the nominal delay. Procedures which incorporate a non $R > t$ schedule in the delay component can be called "resetting" delay procedures. Resetting delays may also be either signaled or unsignaled depending on whether or not a programmed stimulus change is correlated with the onset of the delay period. Unsignaled delay procedures involve tandem (as opposed to chained) schedules which are distinguished by the absence of a stimulus change with the onset of the delay link.

Dews (1960) compared the performances of pigeons responding in unsignaled resetting and nonresetting delay procedures with equal delay values and found appreciably higher rates of responding maintained with the nonresetting delays. This finding would be predicted, however, since the non $R > t$ contingency in the resetting arrangement would be expected to have the effect of reducing response rates (responding during the delay interval in these schedules further postpones

reinforcement.) In the nonresetting procedure, obtained delays can be shorter than nominal values. Azzi, Fix, Keller, and Rocha e Silva (1964) compared the effects of signaled and unsignaled resetting delays on responding established and maintained with continuous immediate reinforcement (CRF). In the signaled delay procedure (chained CRF non R > *t*) a blackout occurred with the onset of the non R > *t* component. Although response rates decreased as a function of delay length in both arrangements, consistently lower rates occurred in the unsignaled (tandem CRF DRO) procedure. These results may be explained from two different perspectives. First, the correlation of the blackout with the onset of the delay interval in the signaled condition would establish the blackout as an immediate conditioned reinforcer which would be expected to maintain higher response rates. The alternate explanation focuses on the discriminative function of the blackout and the relative frequency of contact with the non R > *t* contingency. Since responding during the blackout (in the signaled condition) had characteristically postponed reinforcer delivery, little responding would be expected during the blackout; consequently, the response-inhibiting non R > *t* contingency would make contact with responses more frequently in the unsignaled condition and thereby have a greater weakening effect on responding.

Methodological Shortcomings in Procedures Used to Study Delayed Reinforcement

Both resetting and nonresetting delay procedures contain features that confound the examination of delayed reinforcement. In an ideal assay of delayed consequences the reinforcer would be isomorphically related to the response in question (i.e., one response, one reinforcer, with no stimulus change occurring between the two events.) This arrangement is impossible to create, however. If one is to arrange for a reinforcer to follow a response only after the passage of a specified time period, he must be concerned with what follows responses that occur between the response that

initiates the delay and the delivery of the reinforcer. In the nonresetting delay there is the problem of interim responses potentially contacting reinforcement in a time shorter than that of the programmed delay. This precludes accurate study of the effects of a consistent delay value. Removing the opportunity to respond (retracting the response manipulandum) during the delay produces stimuli that are correlated with delayed reinforcer delivery. Such procedures add the confound of secondary reinforcement which would be expected to artificially enhance responding. The use of resetting delays obviates the problem of interim responses being reinforced by shorter obtained delays, but such arrangements make postponement of reinforcement the consequence of interim responding, which would be expected to have an explicit decreasing effect on response rates.

An additional problem in the interpretation of delayed reinforcement effects on response maintenance concerns the degree to which adding a delay interval to a reinforcement schedule creates changes in schedule structure. Lattal (1987) explained that this issue must be examined in order to separate the effects of decreasing the temporal contiguity between response and reinforcer (delaying reinforcement) from the effects of altering reinforcer frequency and distribution. He suggests that although this problem may be minor with shorter delays, it must be acknowledged and examined when delays are long enough to allow for substantial variability in the number and location of response-reinforcer dependencies, which may also have effects on response rates. The problem necessitates appropriate control procedures in which the frequency and distribution of reinforcers are not confounded with delays (Lattal, 1987, p. 113).

The experiments described above reflect a variety of approaches to the examination of delayed reinforcement. Studies have looked at signaled and unsignaled delays, resetting and nonresetting delays, and maintenance versus acquisition of discrete and continuous responses. If one sought to confine the focus

of this research to the establishment of novel behavior with delayed reinforcement, however, some of these approaches would necessarily be ruled out. As mentioned earlier, signaled delay procedures incorporate stimuli that both follow the response in question immediately and are correlated with food delivery (putative conditioned reinforcers); consequently such procedures would not qualify technically as assays of delayed reinforcement. Studies of response maintenance with delayed reinforcement typically introduce delays only after baseline performances have been established with immediate reinforcement. Results from these studies would therefore offer little in regard to the effects of delayed consequences on response acquisition. The area that has received the least attention in this literature involves the acquisition of discrete responses with unsignaled delayed reinforcement. As Lattal and Gleeson (1990) have noted, in all of the previous attempts to demonstrate this phenomenon that can be found in the literature either the response has been followed by an immediate consequence (e.g., Harker, 1956; Logan, 1952) or the details of the experiments have not been clear from the published reports (e.g., Skinner, 1938). These authors (i.e., Lattal & Gleeson, 1990) provide the one exception. They demonstrated acquisition of discrete responses (key-pecks in pigeons and lever-presses in rats) with unsignaled delayed reinforcement. Their examination included resetting as well as nonresetting delays. In the first of their six experiments, a 30-second unsignaled nonresetting delay resulted in clear acquisition of key-pecking in pigeons. Subjects exposed to a matched frequency of response-independent reinforcement (yoked to the response-dependent subjects) did not learn the behavior. A second experiment incorporated an unsignaled resetting delay procedure in which the obtained delay was always the value of the programmed one. Acquisition of key-pecking occurred with 10-second delays in spite of the DRO contingency inherent in the resetting delay procedure. In the balance of this report the authors demonstrated that the location of the food source was not a critical determinant of responding, that the type and

location of the response manipulandum was not a factor, and that rats could also acquire a discrete response (a lever-press) with up to 30-second resetting delays.

Statement of the Problem

The present report is an attempt to expand on the findings of the Lattal and Gleeson (1990) studies by systematically examining the effects of different delay values on response acquisition and the maintenance of responses originally established with delayed reinforcement. Unsignaled delays were used to eliminate the effects of programmed immediate reinforcement. In light of the attendant confounds in both the resetting and nonresetting delay arrangements (i.e., neither procedure, on its own, offers a "pure" assay), experiments involving both procedures plus a third for imposing delays were conducted. By examining different procedures it was possible to compare the effects of different frequencies and distributions of reinforcement in addition to different delay values.

In the first experiment, 4-, 8-, and 16-second unsignaled nonresetting delays were arranged to follow the lever-press responses of experimentally-naive rats. In this arrangement, lever-presses occurring between the response that initiated the delay and the delivery of the reinforcer had no programmed consequences. This procedure is less than optimal as an assay of delayed reinforcement for at least two reasons. The first is that responses emitted during the delay interval contact obtained delays that are shorter than programmed delays and therefore the effects of the nominal delay become contaminated. These interim responses could ostensibly contact immediate reinforcement.

In an attempt to offset the problem of shorter obtained delays, a second experiment examined the effects of 4-, 8-, 16-, and 32-second unsignaled resetting delays. In this arrangement, responses that occurred during the delay interval reset the delay period to its programmed value so that obtained delays could not be shorter

than the nominal values. As explained previously, this procedure also contains a shortcoming insofar as the resetting contingency for interim responses would postpone reinforcer delivery and consequently be expected to decrease responding.

The second problem with the nonresetting delay procedure involves the status of responses that occur during the delay interval. If reinforcement is defined by contiguity, then all responses other than the ones closest in time to reinforcer delivery would be going unreinforced (see Skinner, 1938 p. 73). In the study of delayed reinforcement, however, contiguity is a confound rather than a defining characteristic of the relationship between the response and the reinforcer. Ideally, every response would result in a reinforcer being delivered in a time not less than that of the programmed delay but without the necessity of the resetting contingency. In the present study, a third experiment arranged response-dependent delayed reinforcer delivery following every response that occurred in the session, with no resetting contingency. In this procedure each response programmed a reinforcer to be delivered t seconds after the response occurred. This arrangement eliminated the problem of unreinforced responses and was therefore an improvement over the nonresetting delay; however, it did nothing to protect the integrity of the programmed delay values and in fact increased the opportunity for contiguous reinforcement. This procedure, herein called "stacked delay," also involved examining the effects of 4-, 8- and 16-second unsignaled delays following lever-pressing. In addition to within- and between-procedure comparisons for each of the delay values listed above, the performances of rats exposed to extinction and immediate reinforcement were also examined and compared to those established with delayed reinforcement. Finally, in all procedures rates of responding were recorded on an additional lever for which no consequences were programmed. This lever (R2) was positioned symmetrically to the active lever in each chamber. Responding on the R2 lever was considered

indicative of the effects of an increase in activity resulting from the subjects being fed and also stood as a measure of the effects of response-independent food delivery.

The purpose of the present study was to extend the findings of the Lattal and Gleeson (1990) experiments by examining the effects of delayed reinforcement on response acquisition and maintenance, using three different procedures for arranging delays. Answers were sought to the following questions. Using unsignaled delays: (1) What are the effects of 4-, 8-, 16- and 32-second delays of reinforcement on the acquisition of lever-pressing and the maintenance of lever-pressing established with delayed reinforcement? (2) To what degree do patterns of acquisition and maintenance differ when delays involve different contingencies for responses occurring during programmed delay intervals? (3) Does response-dependent delayed reinforcement facilitate acquisition and maintain responding to a greater degree than response-independent reinforcement?

CHAPTER II

EXPERIMENTAL PROCEDURES AND RESULTS

Experiment I: Nonresetting Delays

Method

Subjects

Twenty-seven experimentally naive, 90 day-old male Sprague-Dawley rats were used. They were maintained at 80% of their free-feeding weights (range across subjects 350-445 g) and individually housed with unlimited access to water in a constantly-illuminated colony area. Permission to expose subjects to the procedures used in this experiment and the ones described below was obtained from the Western Michigan University Institutional Animal Care and Use Committee prior to the commencement of the research.

Apparatus

Three Plexiglass and aluminum operant conditioning chambers 12 cm wide by 20 cm long by 15 cm high were used. The work panel in each chamber was equipped with two response levers approximately 3 cm apart and 7.5 cm above the floor, and an automatic food dispenser which delivered 45 mg. Noyes food pellets (P.J. Noyes Co., Inc., Lancaster, NH) into a tray centered on the front wall approximately 4.5 cm above the floor in each chamber. Constant ambient illumination was provided during experimental sessions by 7-w white houselights located on the left walls of the chambers. Exhaust fans provided ventilation and

masked extraneous noise. The levers could be operated by a downward force of approximately 20 N. During magazine training, subjects were prevented access to the levers by a grating fashioned out of flexible hardware wire which was fitted over the levers in each chamber during this training but removed during experimental sessions. The left lever in each chamber remained inoperative throughout the experiment. Programming of experimental events and recording of data were controlled by a PDP-8/A computer (Digital Equipment Co., Inc., Maynard, MA) equipped with interfacing and software (SUPERSKED) supplied by State Systems, Inc. (Kalamazoo, MI).

Procedure

Magazine training. Subjects were divided into three groups with nine subjects in each. Each subject was initially placed in a chamber with a wire grating installed over the work panel, preventing access to the levers. The houselight was then illuminated and a variable-time (VT) 60-s schedule of food presentation was implemented which lasted for a period of 60 minutes. Since the subjects could not manipulate the levers during magazine training, there was no concern that food presentations would inadvertently strengthen lever-pressing. Each subject was observed to go to and eat from the food tray each of the last five times food was presented during magazine training. Magazine training sessions were conducted from 6 to 7 p.m., and experimental sessions were conducted between 7 p.m. and 3 a.m., seven days a week.

Delay procedure. Twenty-four hours after magazine training was completed, each subject was returned to the chamber, this time with the wire grating removed from the work panel, and a tandem fixed ratio (FR) 1 fixed time *t*" schedule of reinforcement was programmed contingent on presses of the right lever (Figure 1).

The first depression of the right lever and each subsequent first right lever-press after delivery of a reinforcer initiated the FT interval which, when exhausted, resulted in the delivery of another reinforcer. Lever-presses that occurred when the FT component was in effect had no programmed consequences, nor did responses at any time on the left lever. This procedure has sometimes been referred to as a "nonresetting" delay. Three FT values, 4, 8, and 16 seconds were arranged. Nine rats, selected at random, were exposed to each FT value. Each subject was tested in one 480 min (8 hr) session.

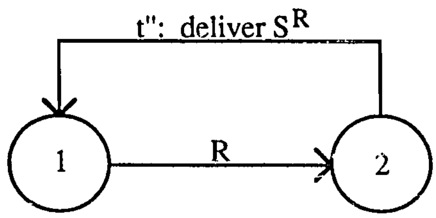


Figure 1. State Diagram of TAN FR1 FT

Results

Figure 2 shows the mean cumulative responses across time for the group of nine subjects at each (4-, 8-, and 16-second) delay value in the nonresetting (NR) delay condition, for the full (480-minute) session. Each data point represents the average of the total responses in each 5-minute bin for all nine subjects exposed to a particular delay value. Also shown are the mean cumulative responses for subjects in the extinction and zero delay (immediate reinforcement) groups, also tallied in 5-minute bins. From the first 5-minute bin, average responses were at the highest level for subjects exposed to the 16-second delay and continued at higher levels than the other groups throughout the session. Subjects exposed to the 8-second delay responded (on average) at higher levels than the 4-second delay subjects, whose curve looks almost identical to the average performance of the zero-delay group. The average performance of the extinction group, as would be expected, did not demonstrate

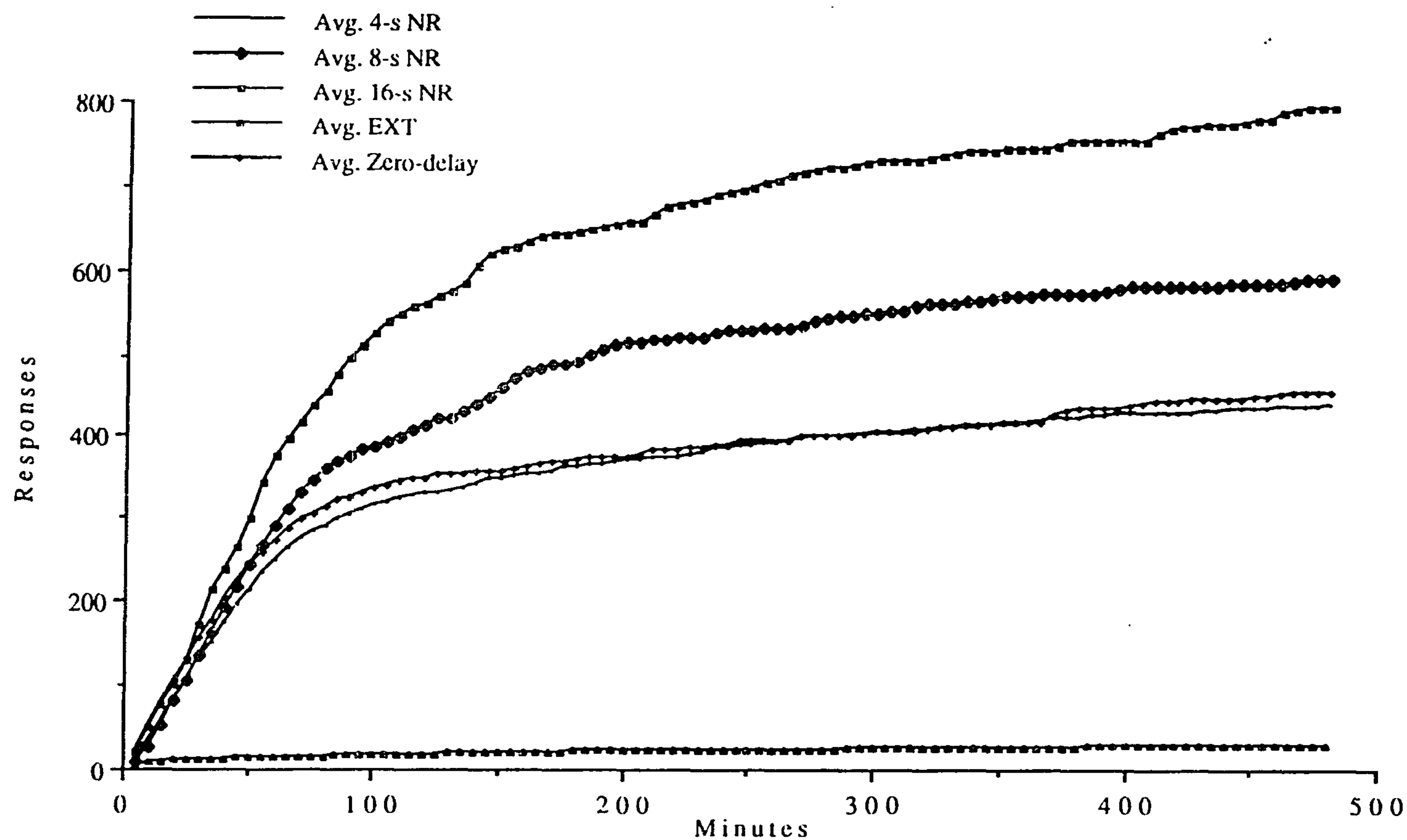


Figure 2. Average Cumulative Responding for 0-delay, 4-, 8-, and 16-second Nonresetting Delay, and Extinction Groups Over the Entire 480-minute Session.

acquisition of the response. Responding began to drop off for all delay values within the first 100 minutes of the session.

Figure 3 shows the first 100 minutes of the 8-hour session for all values of resetting delays plus the extinction and zero-delay subjects. Again each data point represents the average responding of all nine subjects run at a delay for each 5-minute bin. Little difference can be seen in the shapes of the curves in the first 25 minutes of the session. Thereafter, the 16- and 8-second delays generated steeper slopes than the 4-second delay.

Figure 4 shows the individual performances for all subjects run at the 0-, 4-, 8-, and 16-second nonresetting delays, respectively for the first 100 minutes of the session. The longer the programmed delay, the greater the variability in rates of responding within groups.

Table 1 shows the averaged obtained delays on the operative lever, response rates on the operative (R1) and inoperative (R2) levers, and the number of reinforcers delivered for each subject at each value of the nonresetting delay procedure over the entire 480-minute session. Subjects were run in "squads" of three each day due to the length of the sessions and the availability of equipment. Each subject was assigned an identification number based on three characteristics: the delay value to which it was exposed, whether it was in the first, second, or third squad run at a particular delay, and whether it was run in box 0, 1, or 3. Subject 4-3-0 NR, for example, was run at four seconds nonresetting delay in the third squad of three subjects in box 0. At each delay value, the average obtained delays were shorter than the programmed values. For all subjects at all values in the nonresetting condition response rates on the active lever exceeded rates of pressing the inactive lever[2] even

[2] Response rates on the active lever were calculated both for the first 100 minutes of the session and over the entire 480 minutes (see Tables 1-4). Because of limitations with the recording equipment, response rates on the inactive lever were calculated only for the entire session. Unless otherwise specified, comparisons of R1 and R2 response rates refer to those calculated over the full 480 minutes.

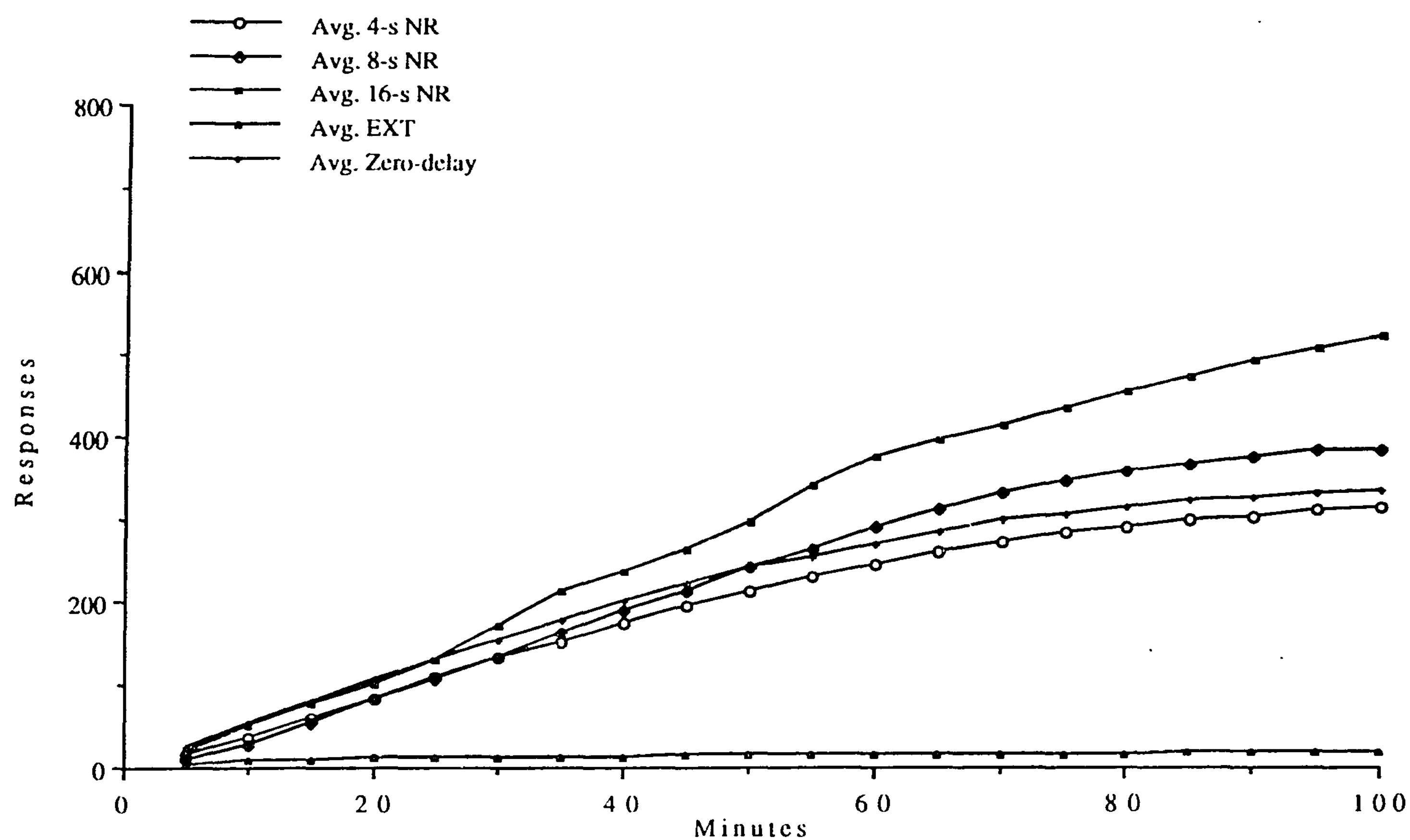


Figure 3. Average Cumulative Responding for 0-delay, 4-, 8-, and 16-second Nonresetting Delay, and Extinction Groups for the First 100 Minutes of the 480-minute Session.

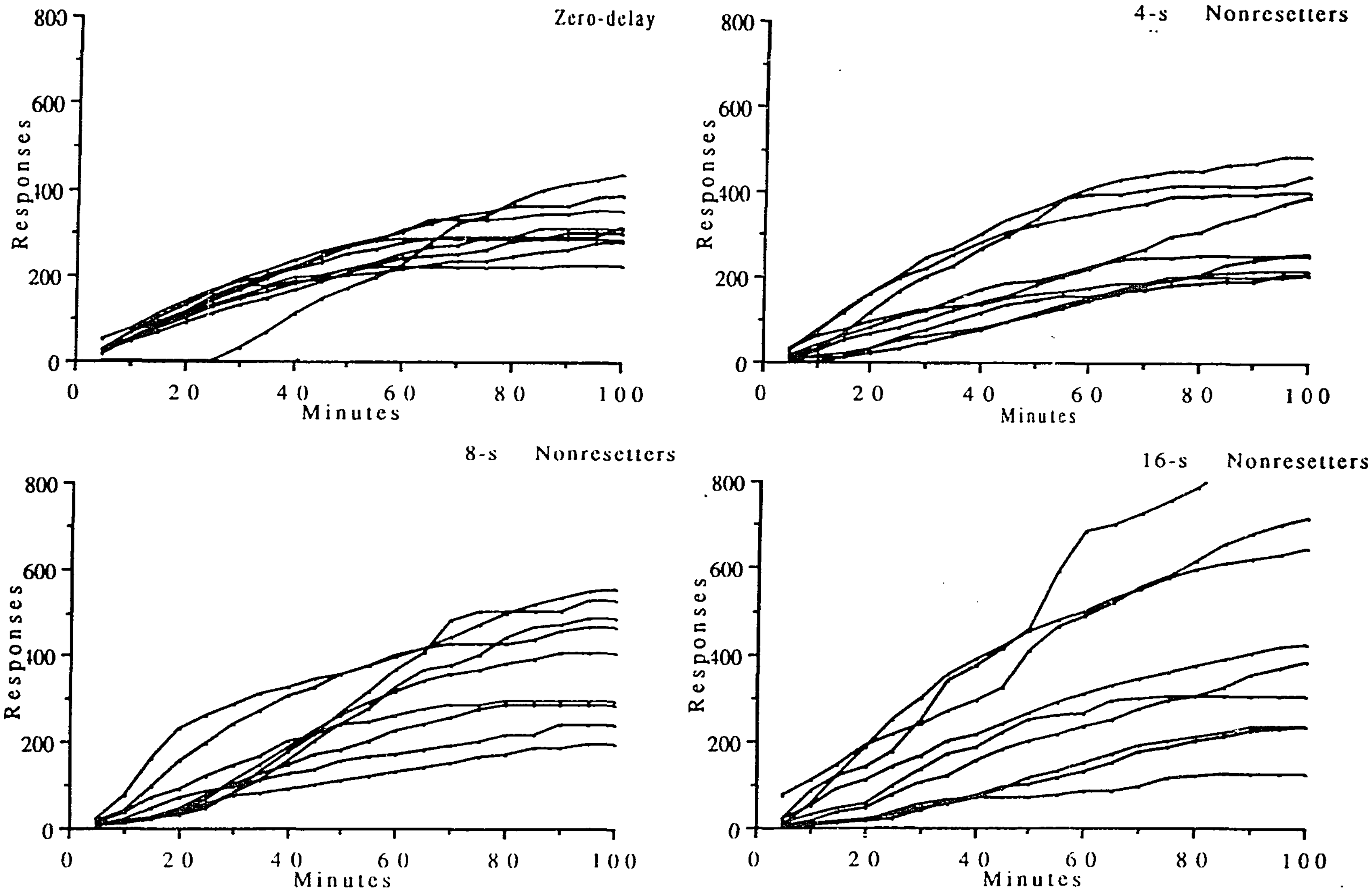


Figure 4. Cumulative Response Curves for Individual Subjects Tested in the 0-delay, and 4-, 8-, and 16-second Nonresetting Delay Conditions for the First 100 Minutes of the 480-minute Session.

Table 1

Average Obtained Delays, Response Rates, and Reinforcers per Session for Nonresetting Delay Subjects

Subject	Obtained Delay (sec)	R1s/min (1st 100 min)	R1s/min (480 min)	R2s/min	# of S^Rs
4-1-0 NR	3.57	2.48	.74	.10	324
4-1-1 NR	3.83	3.89	1.29	.14	530
4-1-3 NR	3.96	2.03	.49	.15	222
4-2-0 NR	3.42	3.99	.96	.15	321
4-2-1 NR	3.87	2.04	.61	.07	266
4-2-3 NR	3.41	4.84	1.33	.29	436
4-3-0 NR	3.67	2.13	.61	.07	226
4-3-1 NR	3.66	2.54	.89	.40	298
4-3-3 NR	3.57	4.42	1.29	.04	424
8-1-0 NR	5.23	2.39	.67	.06	143
8-1-1 NR	5.87	1.98	.61	.17	163
8-1-3 NR	5.99	4.08	1.17	.71	305
8-2-0 NR	6.13	5.52	1.40	.45	330
8-2-1 NR	6.02	5.26	1.69	.73	432
8-2-3 NR	5.75	4.89	1.46	.34	334
8-3-0 NR	5.78	2.99	.80	.39	205
8-3-1 NR	5.38	2.88	2.04	.09	223
8-3-3 NR	5.64	4.69	1.25	.23	292
16-1-0 NR	9.19	9.44	2.74	.83	238
16-1-1 NR	11.54	2.36	.62	.51	119
16-1-3 NR	10.80	3.07	.96	.50	168
16-2-0 NR	10.32	7.13	1.92	.67	264
16-2-1 NR	10.57	2.36	.60	.07	110
16-2-3 NR	10.50	6.47	1.90	.78	284
16-3-0 NR	11.46	4.27	1.64	.74	332
16-3-1 NR	10.14	3.85	1.36	.18	229
16-3-3 NR	13.22	1.26	.94	.11	217

though the probability of receiving food contiguously following a press of either lever was equal, once a response on the operative lever programmed a food delivery to occur after the specified delay.

Experiment II: Resetting Delays

Method

Subjects

Twenty-seven experimentally naive, 90 day-old male Sprague-Dawley rats were used. They were maintained at 80% of their ad libitum weights (range across subjects 370-455 g) and individually housed with unlimited access to water in a constantly-illuminated colony area.

Apparatus

The operant conditioning chambers and the recording equipment used in the present study were the same as those used in Experiment I, described above.

Procedure

Magazine training was identical to that described in the first experiment. Twenty-four hours after magazine training was completed, the grating preventing access to the levers was removed, each subject was returned to the chamber, and a tandem FR 1 non R > t schedule was programmed for presses on the right lever (Figure 5). In this schedule, the first lever-press initiated a delay of either 4, 8, 16, or 32 seconds (a group of nine subjects was exposed to each of these t values for the non R > t component of the schedule) before a food pellet would be presented. Any response that occurred during the delay period postponed food delivery until the programmed delay interval had transpired with no responses having taken place. The next response eligible for reinforcement was the first response following the last reinforcer delivery. This procedure, sometimes called a resetting delay, ensured that the obtained delay between a lever-press and food presentation was never shorter than the programmed delay value. No other stimulus changes were programmed

following responses on the right lever, and no consequences were programmed for pressing the left lever. Each subject was tested in one 480-min (8-hr) session.

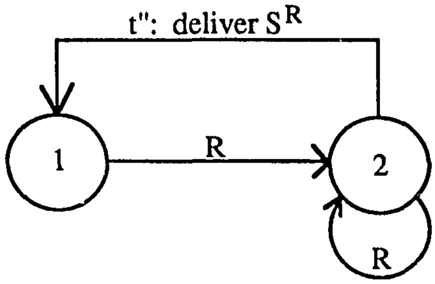


Figure 5. State Diagram of TAN FR1 Non R >*t*- sec

Results

Figure 6 shows the mean cumulative responses for the nine subjects exposed to each (4-, 8-, 16-, and 32-second) delay value in the resetting (RS) delay condition, for the full (480-minute) session. Also shown is the averaged responding for the zero-delay and the extinction subjects. Each data point represents the average of the total responses in each 5-minute bin for all nine subjects exposed to a particular delay value. These curves demonstrate a clear relationship between acquisition and delay length with the average acquisition occurring at the highest rate for the zero-delay group followed by the 4-, 8-, 16-,and 32-second groups, in that ord^r. Lever-pressing was not acquired by the extinction group. Responding also began to decelerate at the earliest point in the session (around 50 minutes) for the zero-delay group followed in order by the 4- and 8-second groups. The curves representing the average responding of the 16- and 32-second groups demonstrate the continuation of stable response rates even at the end of the session. Figure 7 shows the average responding for all subjects at each delay for the first 100 minutes of the session. Figure 8 shows cumulative curves for the individual performances of all subjects run in the 4-, 8-, 16-, and 32-second resetting delay conditions, respectively, for the first

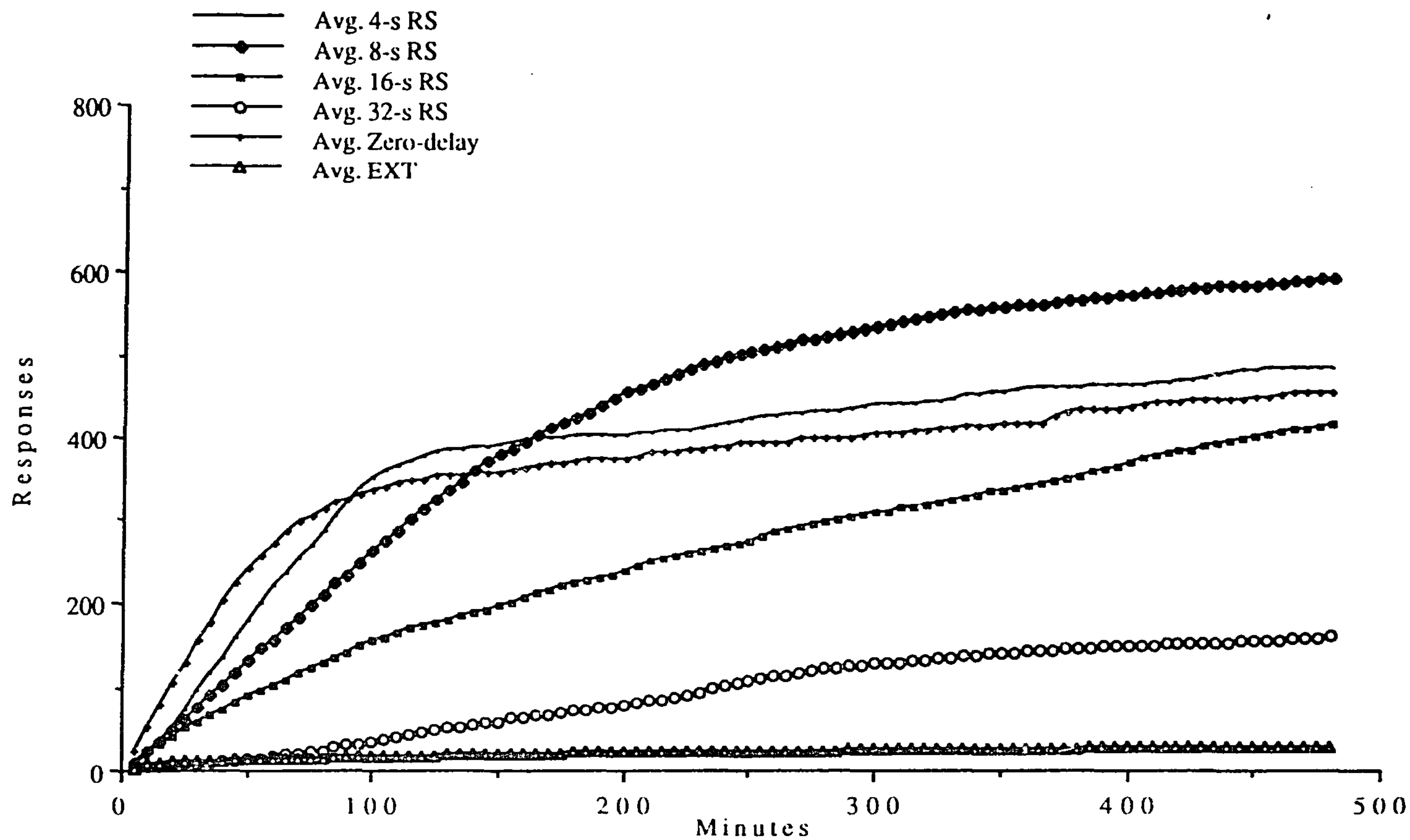


Figure 6. Average Cumulative Responding for 0-delay, 4-, 8-, 16-, and 32-second Resetting Delay, and Extinction Groups for the Full 480-minute Session.

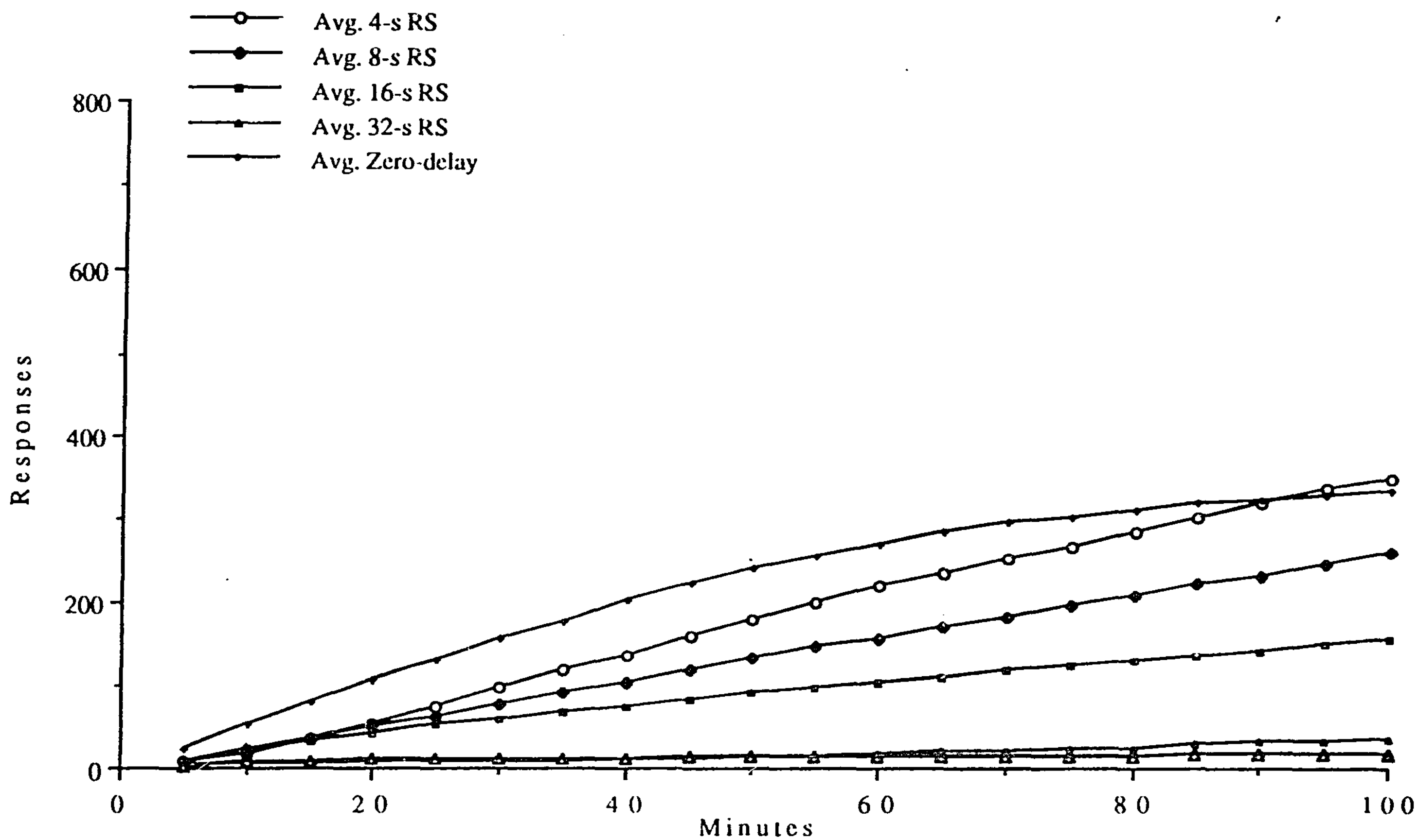


Figure 7. Average Cumulative Responding for 0-delay, 4-, 8-, 16-, and 32-second Resetting Delay, and Extinction Groups for the First 100 Minutes of the 480-minute Session.

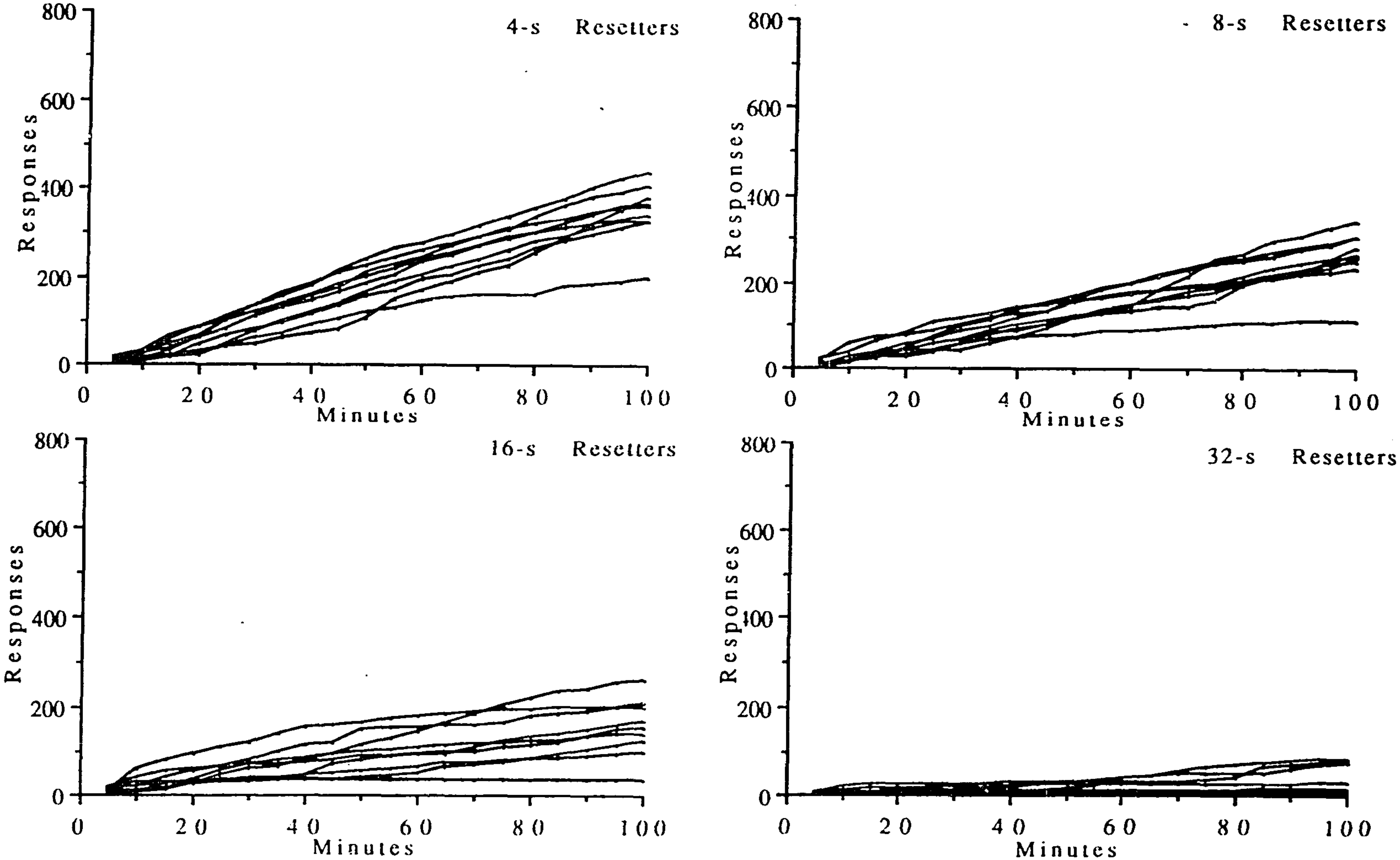


Figure 8. Cumulative Response Curves for Individual Subjects Tested in the 4-, 8-, 16-, and 32-second Resetting Delay Conditions for the First 100 Minutes of the 480-minute Session.

100 minutes of the session. Although some overlap in rates of responding between delays is evident from these curves, variability was much less within groups in the resetting condition than in the nonresetting delay procedure.

Table 2 shows the average obtained delay on the operative lever, response rates on the operative and inoperative levers, and the number of reinforcers delivered for each subject at each value of the resetting delay procedure over the entire 480-minute session. The non R > *t* contingency in the second link of the resetting delay procedure ensured that in each case the obtained delay value was equal to that of the programmed delay. With the exception of subject 4-1-1 RS, response rates were greater on the active lever than the inactive one in the 4-second condition. In the 8-second group three of the nine subjects (8-1-1 RS, 8-2-1 RS, and 8-2-3 RS) pressed the inactive lever more frequently than the one that programmed food delivery. Responding was higher on the inactive lever for all subjects in the 16-second group and for all but two (32-1-3 RS and 32-3-0 RS) in the 32-second group, suggesting the response-inhibiting effect of the resetting contingency in the longer delays.

Table 2

Average Obtained Delays, Response Rates and Reinforcers per Session for Resetting Delay Subjects

Subject	Obtained Delay (sec)	R1s/min (1st 100 min)	R1s/min (480 min)	R2s/min	# of S^Rs
4-1-0 RS	4.0	3.40	.78	.20	375
4-1-1 RS	4.0	4.06	.66	.84	316
4-1-3 RS	4.0	3.64	.74	.13	355
4-2-0 RS	4.0	4.39	.72	.15	346
4-2-1 RS	4.0	3.25	.91	.26	435
4-2-3 RS	4.0	3.66	.90	.21	432
4-3-0 RS	4.0	3.28	.99	.06	389
4-3-1 RS	4.0	3.83	1.15	.35	316
4-3-3 RS	4.0	1.99	.77	.06	343
8-1-0 RS	8.0	3.41	.80	.19	384
8-1-1 RS	8.0	2.36	.48	2.89	228
8-1-3 RS	8.0	2.81	.69	.33	331
8-2-0 RS	8.0	3.06	.88	.17	424
8-2-1 RS	8.0	1.12	.70	1.49	336
8-2-3 RS	8.0	2.63	.92	2.19	440
8-3-0 RS	8.0	2.61	1.28	.57	381
8-3-1 RS	8.0	2.51	1.5	1.12	410
8-3-3 RS	8.0	3.04	1.27	.21	357
16-1-0 RS	16.0	1.68	.34	1.39	164
16-1-1 RS	16.0	1.25	.44	.99	209
16-1-3 RS	16.0	2.60	.57	2.09	275
16-2-0 RS	16.0	2.10	.36	2.03	173
16-2-1 RS	16.0	1.02	.41	1.61	196
16-2-3 RS	16.0	.37	.26	.35	125
16-3-0 RS	16.0	1.98	.50	8.96	240
16-3-1 RS	16.0	1.41	.36	1.53	171
16-3-3 RS	16.0	1.56	.56	1.44	270
32-1-0 RS	32.0	.82	.59	.70	141
32-1-1 RS	32.0	.88	.33	.73	59
32-1-3 RS	32.0	.31	.07	.07	15
32-2-0 RS	32.0	.09	.64	.99	116
32-2-1 RS	32.0	.02	.01	.03	2
32-2-3 RS	32.0	.07	.40	.61	64
32-3-0 RS	32.0	.74	.55	.28	144
32-3-1 RS	32.0	.17	.41	.56	76
32-3-3 RS	32.0	.09	.03	.04	11

Experiment III: Stacked Delays

Method

Subjects

Forty-five experimentally naive, 90-day old, male Sprague-Dawley rats were used. They were maintained at 80% of their free-feeding weights (range across subjects 340-445 g) and individually housed with unlimited access to water in a constantly-illuminated colony area.

Apparatus

The three operant conditioning chambers and the recording equipment used in the present study were the same as those used in experiments I and II, described above.

Procedure

Magazine training was identical to that described in the first two experiments. Twenty-four hours after magazine training was completed, the grating preventing access to the levers was removed, each subject was returned to the chamber, and a schedule of reinforcement was implemented wherein every response on the right lever initiated a fixed period of time which, when exhausted, would result in delivery of a reinforcer. This schedule can be referred to as a "stacked" delay schedule in which the first link is a FR 1 schedule and the second is a FT *t* -sec schedule (stack FR 1 FT *t* -sec). With nine subjects per group, each of three groups was exposed to the FR 1 and one of three different values of the delay component with the values consisting of 4, 8, and 16 seconds. For the group exposed to the stack FR 1 FT 4-sec schedule, for example, each depression of the right lever programmed a reinforcer presentation four seconds from the occurrence of that lever press so that a reinforcer was

presented four seconds from the time of every response irrespective of whether any other responses occurred during the four-second delay (see Figure 9.). No other consequence was programmed following presses of the active lever nor were any consequences programmed for pressing the left lever.

The stacked delay procedure differed from the nonresetting delay (used in Experiment I) in the following way. In the stacked procedure each and every response initiated a FT interval which terminated with a reinforcer delivery whereas in the nonresetting delay responses occurring once a response initiated the FT link had no programmed consequences. In the stacked delay procedure the frequency of reinforcement in a session was equal to the frequency of right lever-presses.

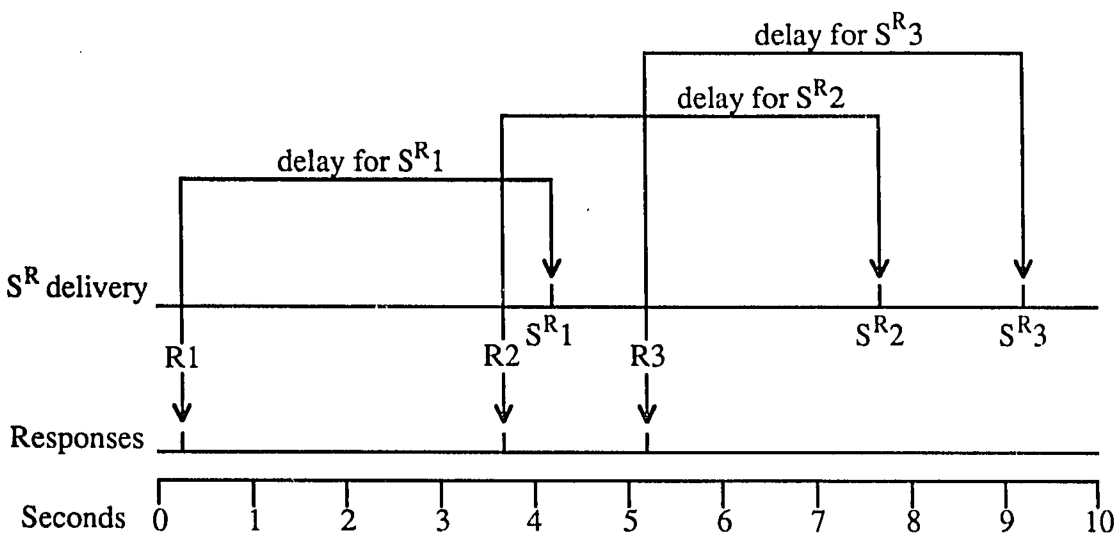


Figure 9. Diagram of Stacked Delay Procedure.

One additional group of nine subjects was exposed to an FR 1 schedule with no delay between lever-pressing and food presentation (the zero-delay group) and another group was allowed to press the lever with no programmed consequences (the extinction group). Each subject was tested in one 480-min (8-hr) session.

Results

Figure 10 shows the mean cumulative responses for all nine subjects at each (4-, 8-, and 16-second) delay value in the stacked delay (SD) condition, for the full (480-minute) session. Also shown are averaged cumulative responses for subjects in the extinction and zero delay groups, also tallied in 5-minute bins. Each data point represents the average of the total responses in each 5-minute bin for all nine subjects run at a particular delay value. Responding was evident by the end of the first five minutes of the session for subjects in all delays. The slopes of the curves for average rates of responding for the 4-, 8-, and 16-second subjects vary with the length of programmed delays. The steepest slope is apparent in the curve for the 4-second group. The average patterns of responding for the 8- and 16-second groups differed negligibly. For the average total number of responses over the entire session, the lower the programmed delay value, the greater the average number of total responses emitted at the end of 480 minutes. The greatest difference between delays can be seen in the curves generated by the 4-second and 8-second groups.

Figure 11 shows average cumulative responses for all groups of subjects at each delay value for the first 100 minutes of the 8-hour session for all values of the stacked delays plus the extinction and zero-delay subjects. As was seen with the resetting delay (albeit to a lesser degree), the appearance of decreases in the steepness of the average curves generated by the stacked delay procedure is related to length of the programmed delay values. The curve representing the average of responding associated with the 4-second delay begins to appear more gradual at the earliest point in the session (around 55 minutes) while those generated by the 8- and 16-second delays do not begin to flatten until later in the session (around 80 and 110 minutes, respectively). Figure 12 shows the individual performances of all subjects tested at each value in the stacked delay condition for the first 100 minutes of the session. Although this procedure allowed ample opportunity for obtained delays to be shorter

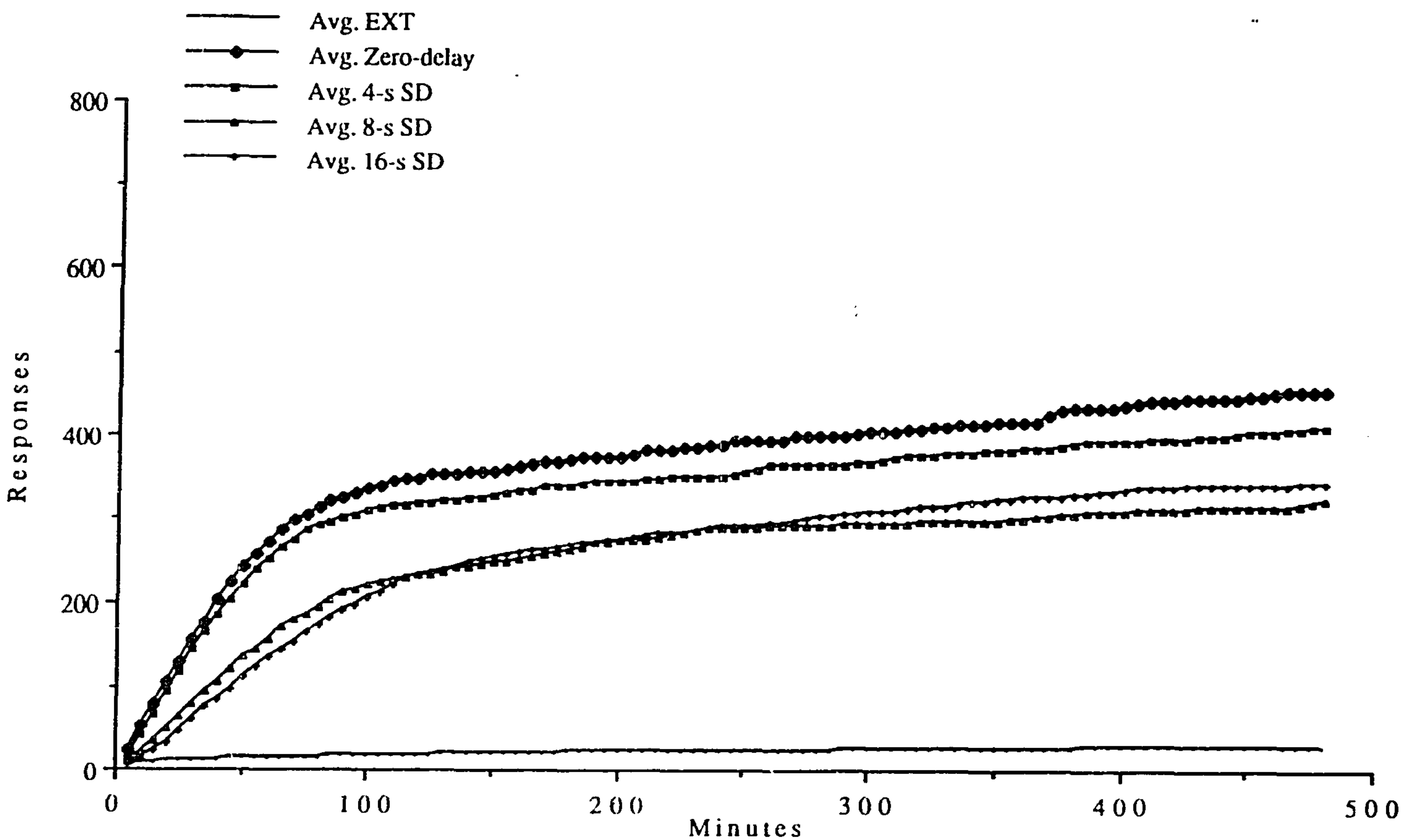


Figure 10. Average Cumulative Responding for 0-delay, 4-, 8-, and 16-second Stacked Delay, and Extinction Groups Over the Full 480-minute Session.

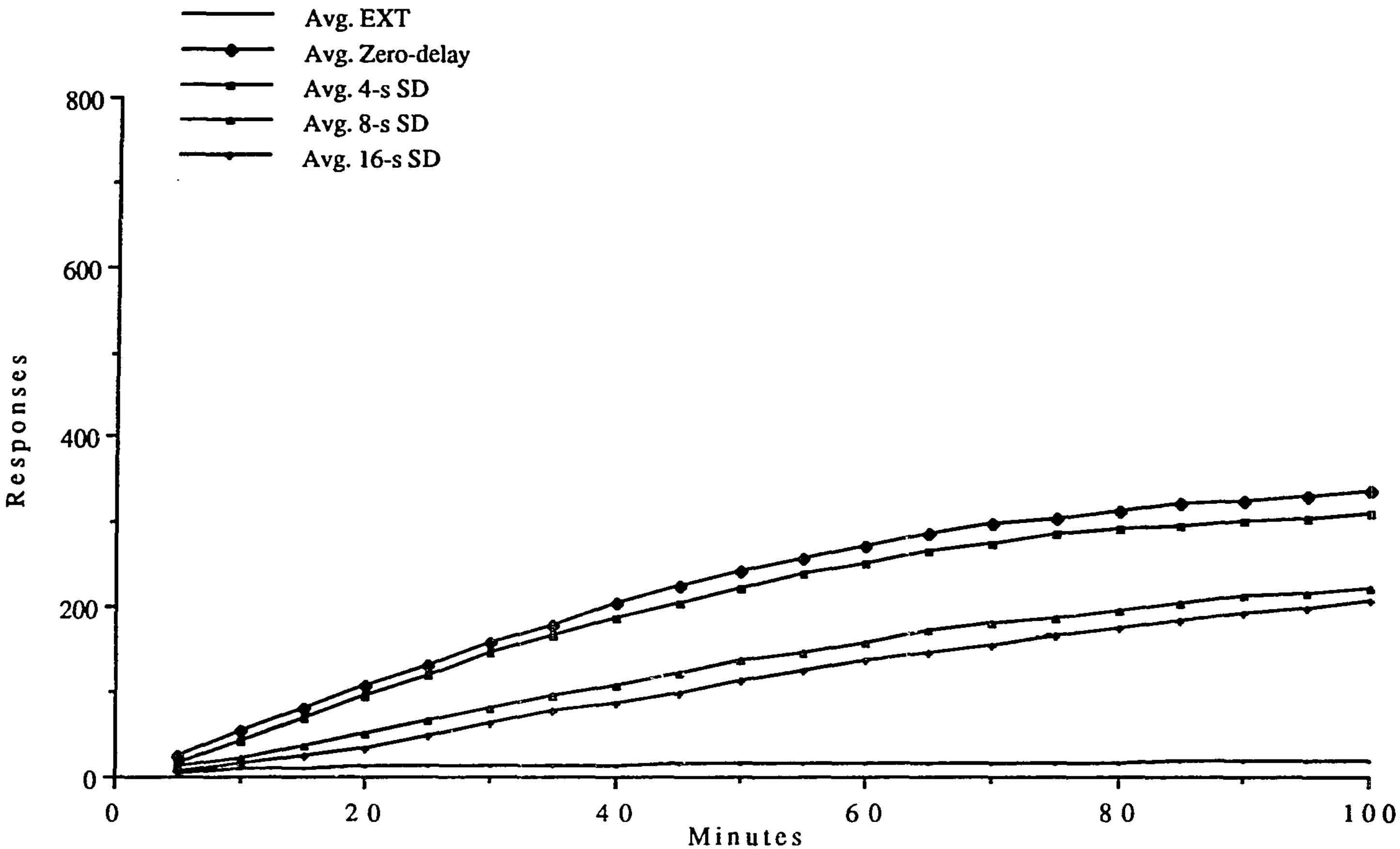


Figure 11. Average Cumulative Responding for 0-delay, 4-, 8-, and 16-second Stacked Delay, and Extinction Groups for the First 100 Minutes of the 480-minute Session.

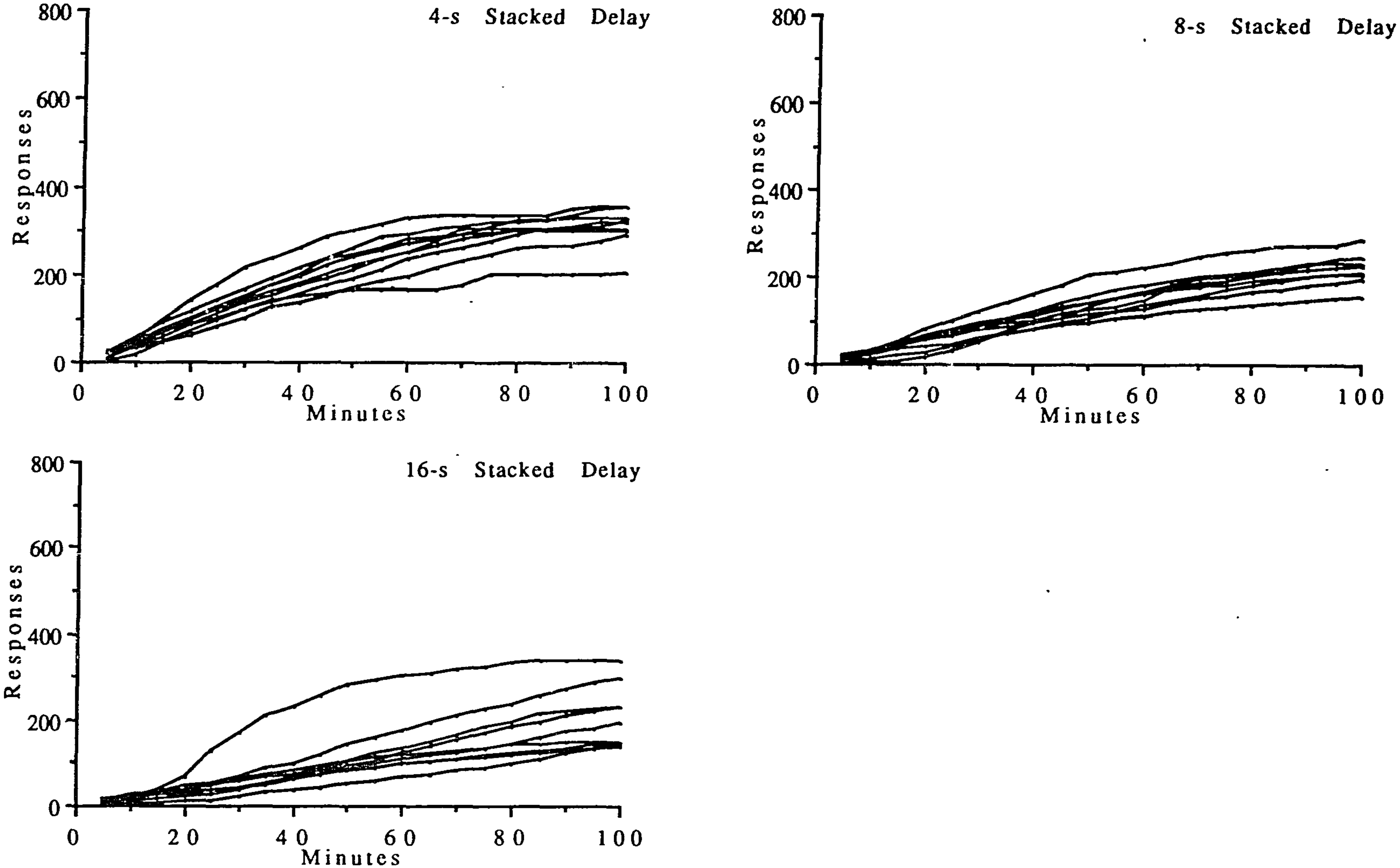


Figure 12. Cumulative Response Curves for Individual Subjects Tested in the 4-, 8-, and 16-second Stacked Delay Conditions for the First 100 Minutes of the 480-minute Session.

than programmed delays, variability in the patterns of responding within groups for the first 100 minutes of sessions was negligible when compared to that seen in the nonresetting delay procedure.

Table 3 shows the average obtained delay on the operative lever, response rates on the operative and inoperative levers, and the number of reinforcers delivered for each subject at each value of the stacked delay procedure over the entire 480-minute session. At each delay value, obtained delays were shorter than the programmed values. For all subjects at all values in the stacked condition response rates on the active lever exceeded rates of pressing the inactive lever even though the probability of receiving food contiguously following a press of either lever was equal, once a response on the operative lever programmed a food delivery to occur after the specified delay interval had elapsed.

Table 3

Average Obtained Delays, Response Rates, and Reinforcers per Session for Stacked Delay Subjects

Subject	Obtained Delay (sec)	R1s/min (1st 100 min)	R1s/min (480 min)	R2s/min	# of S^Rs
4-1-0 SD	3.36	3.21	1.03	.09	493
4-1-1 SD	3.46	3.26	.98	.15	470
4-1-3 SD	3.50	2.90	.81	.08	389
4-2-0 SD	2.95	3.02	.81	.06	399
4-2-1 SD	3.19	3.32	.92	.25	442
4-2-3 SD	2.80	3.53	1.06	.09	504
4-3-0 SD	2.90	3.05	.76	.04	366
4-3-1 SD	3.08	3.55	.85	.39	410
4-3-3 SD	3.08	2.04	.55	.11	263
8-1-0 SD	5.43	2.31	.59	.15	280
8-1-1 SD	7.06	1.56	.68	.44	325
8-1-3 SD	6.46	2.07	.51	.22	247
8-2-0 SD	5.56	2.11	.74	.12	355
8-2-1 SD	5.77	2.45	.79	.28	380
8-2-3 SD	5.10	1.95	.71	.09	341
8-3-0 SD	5.99	2.32	.55	.18	265
8-3-1 SD	6.77	2.25	.80	.26	383
8-3-3 SD	4.85	2.85	.64	.10	305
16-1-0 SD	10.10	2.93	1.01	.45	487
16-1-1 SD	12.56	1.50	.42	.21	202
16-1-3 SD	8.82	3.34	1.39	.14	575
16-2-0 SD	11.69	2.29	.85	.39	409
16-2-1 SD	11.22	1.48	.74	.69	353
16-2-3 SD	11.80	1.37	.66	.26	319
16-3-0 SD	-------	1.92	.74	.34	357
16-3-1 SD	13.26	1.43	.55	.39	265
16-1-3 SD	10.78	2.27	.72	.25	347

Note. Dashes indicate missing data.

Table 4 shows the response rates on the operative and inoperative levers and the number of reinforcers delivered for each subject in the extinction and zero-delay groups over the entire 480-minute session.

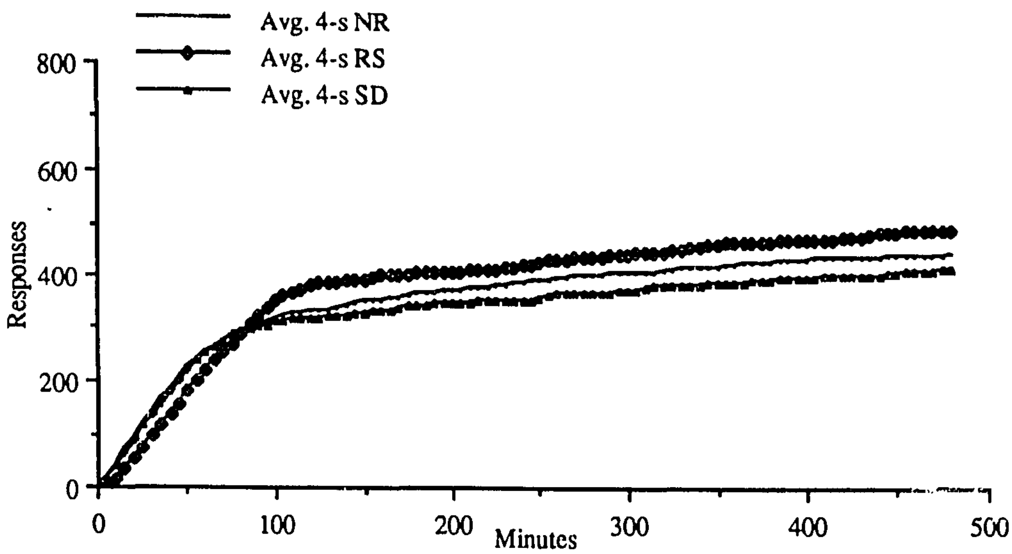
Table 4

Response Rates for Extinction and Immediate Reinforcement Subjects

Subject	Obtained Delay (sec)	R1s/min 1st 100 min	R1s/min 480 minutes	R2s/min	# of S^Rs
E-1-0	no S^R	.26	.08	.18	0
E-1-1	no S^R	.29	.13	.11	0
E-1-3	no S^R	.12	.06	.04	0
E-2-0	no S^R	.17	.05	.06	0
E-2-1	no S^R	.33	.10	.08	0
E-2-3	no S^R	.07	.02	.04	0
E-3-0	no S^R	.08	.01	.01	0
E-3-1	no S^R	.22	.10	.06	0
E-3-3	no S^R	.06	.06	.04	0
0-1-0	.01	4.36	1.53	--	735
0-1-1	.01	3.90	1.02	--	493
0-1-3	.01	3.06	1.01	--	486
0-2-0	.01	2.82	.74	.08	356
0-2-1	.01	4.63	1.14	.07	545
0-2-3	.01	2.34	.58	.03	277
0-3-0	.01	2.78	.91	.07	438
0-3-1	.01	3.52	1.07	.11	512
0-3-3	.01	2.82	.66	.03	319

Note. Dashes indicate missing data.

Figures 13, 14 and 15 show comparisons between the average patterns of responding for all nine subjects run at each delay value in each different procedure. The top graph in Figure 13 shows the average patterns of responding of all subjects in the 4-second nonresetting, 4-second resetting, and 4-second stacked delay conditions for the full 480 minutes. The bottom graph shows an expansion of the



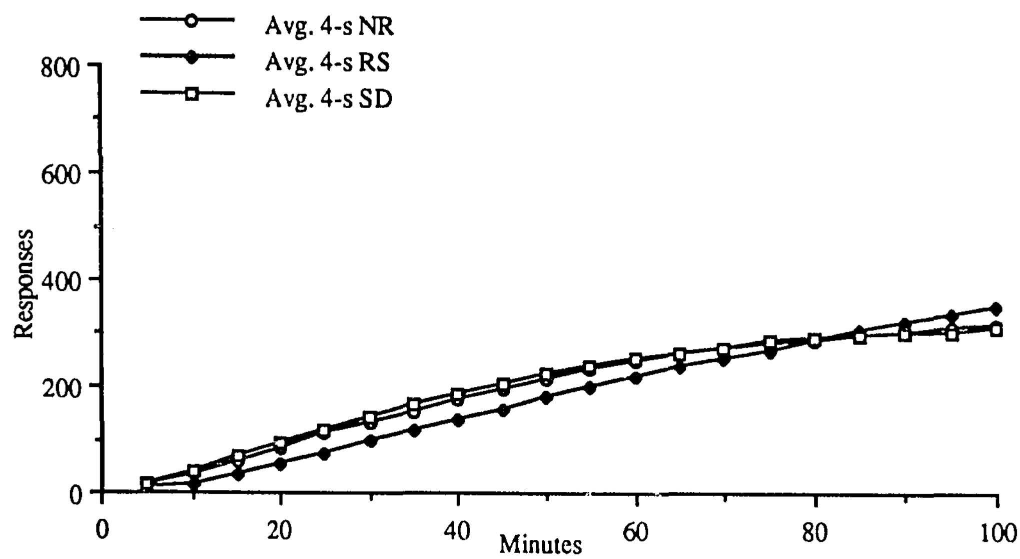
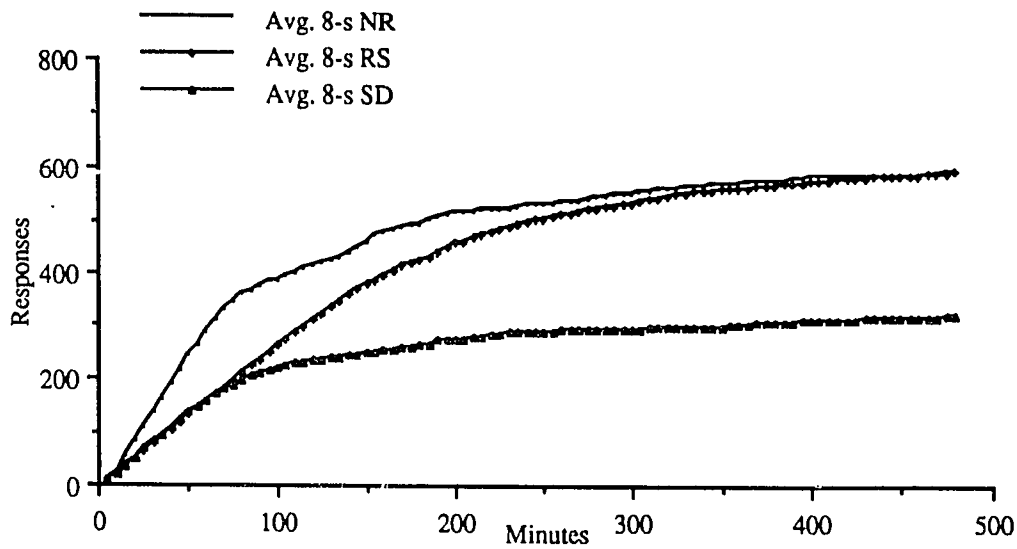


Figure 13. Comparisons Among Average Response Patterns for Subjects Tested at 4-second Delays in Each Delay Procedure.



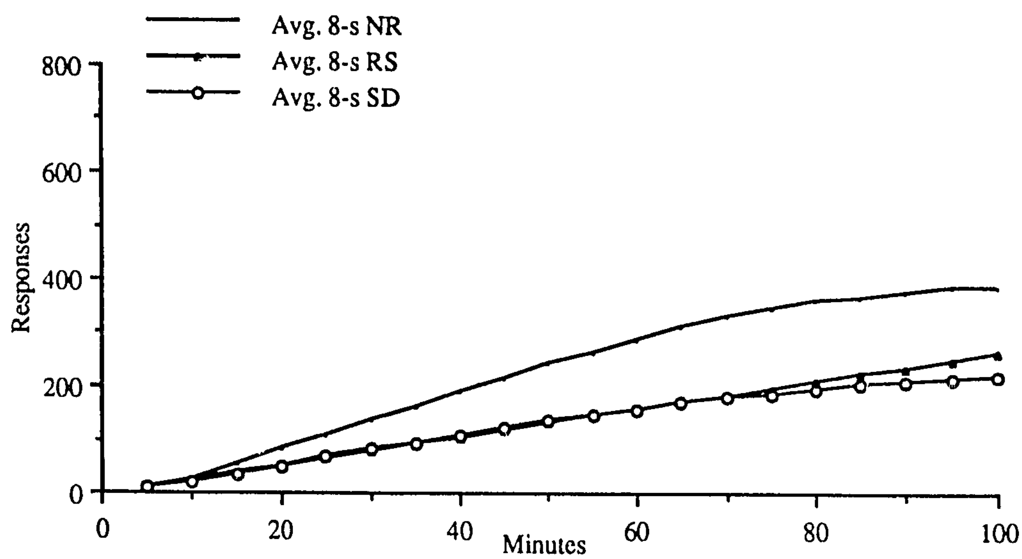
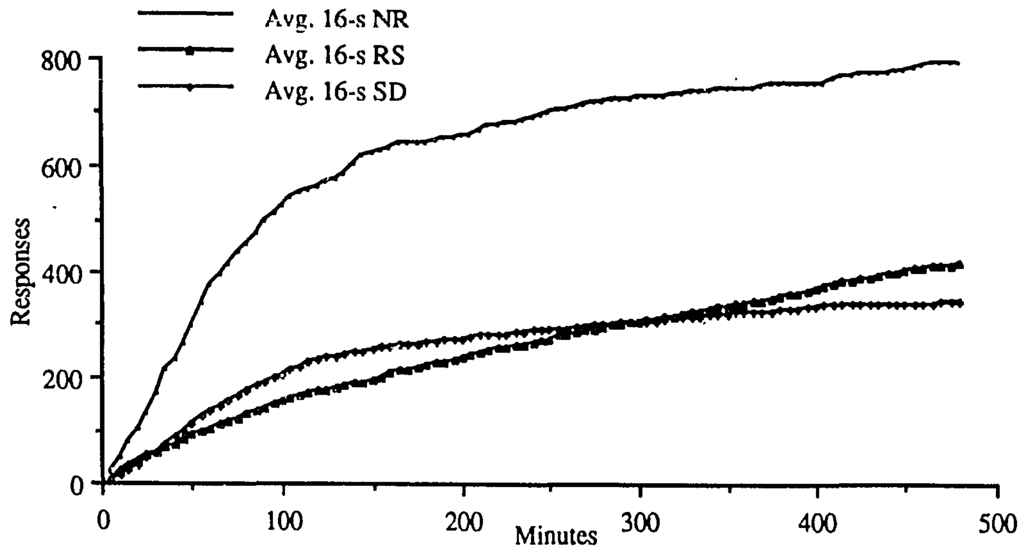


Figure 14. Comparisons Among Average Response Patterns for Subjects Tested at 8-second Delays in Each Delay Procedure.



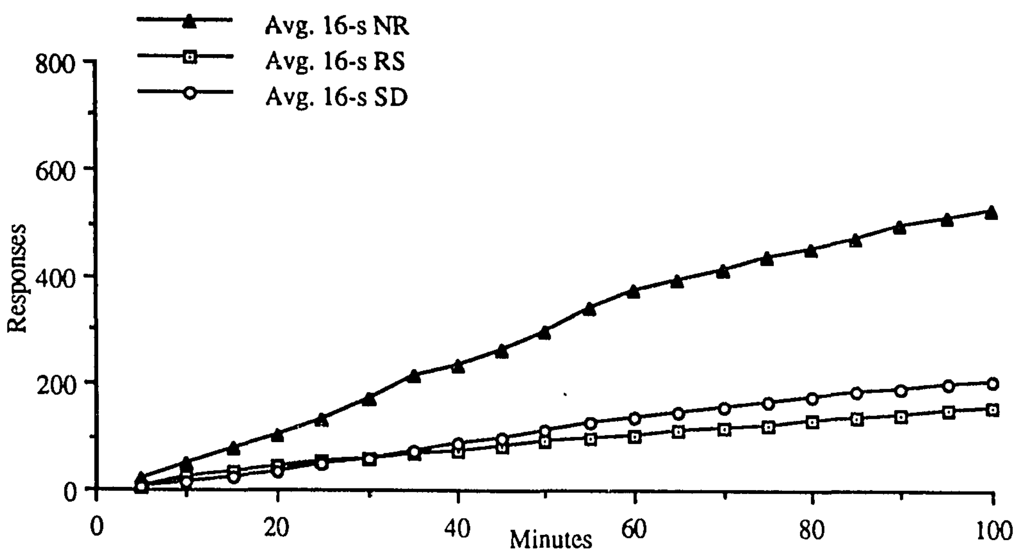


Figure 15. Comparisons Among Average Response Patterns for Subjects Tested at 16-second Delays in Each Delay Procedure.

first 100 minutes of the session. Figure 14 illustrates the same comparisons for the three procedures with the 8-second delays, and Figure 15, the 16-second delays.

CHAPTER III

DISCUSSION AND CONCLUSIONS

Discussion

In all three delay procedures lever presses on the active lever occurred by the end of the first five minutes of the session (the first data point), suggesting that the topographies involved in depression of the lever were part of the subjects' repertoires prior to experimentation. Persistence of the response, however, only occurred when lever-pressing was followed by food presentation, even though food was delayed (i.e., responding was virtually nonexistent in the extinction group). In two of the procedures (the nonresetting and stacked arrangements) programmed delays of up to 16 seconds established and maintained responding on the active lever (mean = 1.41 and .79 responses per minute, respectively, over the entire session), but it should be remembered that it was possible for responses that occurred during the delay interval to be followed by food delivery after a shorter period of time than that specified by the programmed delay. In the resetting delay arrangement, lever-pressing was developed when food was presented no sooner than 32 seconds following responses (average responding = .34 responses per minute compared to .07 for subjects that received no reinforcement) despite the arrangement whereby interim responding postponed food delivery until the programmed delay interval had elapsed. These results support the findings of the Lattal and Gleeson (1990) experiments, which suggested that a discrete operant response could be established in the absence of either shaping or immediate reinforcement.

As mentioned previously, two of the procedures employed in the present study allowed the possibility for responses to occur during the delay interval and therefore be followed by food delivery in a time shorter than the specified delay. In the nonresetting delay, the first response and each subsequent first response following food presentation programmed food delivery after a specified period. The first response could not be followed by immediate reinforcement (within a second or so), but the next response ostensibly could. Likewise in the stacked delay arrangement, food delivery could occur immediately following a lever-press. With the opportunity for at least intermittent immediate reinforcement in these two procedures, acquisition of the response would be predicted; however the various programmed delays generated different patterns of responding.

In the stacked delay procedure, development of the eventual pattern of responding was related to the length of the programmed delay. The 4-second stacked delays produced the highest average response rate and the most overall responding throughout the 8-hour sessions. Although the 8- and 16-second delays developed lower rates than the 4-second, the average patterns of responding established with these two values differed only slightly from one another.

The patterns of responding established with the nonresetting delay procedure are somewhat difficult to account for in terms of the programmed contingencies involved in the present experiment. In the stacked and resetting delay procedures, shorter delays (not surprisingly) generated, on average, faster learning and higher rates of responding. The opposite was the case with the nonresetting delays. The highest rates of responding were seen with the longest delay value (mean response rate for the first 100 minutes in the 16-second condition = 4.47 responses per minute and 1.41 over the entire session). Average response rates in the first 100 minutes for the 8- and 4-second groups were 3.85 and 3.15 responses per minute, respectively.

Average response rate calculated over the entire session for the 8-second group was 1.23 per minute and was .91 per minute for the 4-second group.

Given conventional wisdom regarding the relative importance of contiguity of reinforcement for learning, one possible interpretation of these results might be that the average acquisition curve of the 16-second group was artificially inflated due to the influence of one or two anomalous response patterns. It is the case that several of the subjects in the 16-second nonresetting group showed inordinately high rates of responding in the first 100 minutes of the session (see Table 1), but even excluding the contribution of the two subjects with the highest rates (16-1-0 NR and 16-2-0 NR), the average response rate for this group would be 3.38 responses per minute which would still be comparable to that of the 8-second group (3.85 responses per minute) and higher than that of the 4-second group (3.15 responses per minute). It is therefore uncertain whether it would be appropriate to consider these two subjects outliers. It may be the case that such a procedure simply generates more than one common pattern of performance similarly to the way in which both break and run and scalloped response patterns are seen under fixed interval schedules. The possibility that some of the 4-second subjects may have been extraordinary in some way which contributed to inordinately slow learning is also unsupported by the data. Figure 13 shows the average response rates of the 4-second subjects run under all three procedures. The average responding of the nonresetting delay group does not differ remarkably from that of the 4-second subjects in the other two conditions.

Ferster (1953) suggested that the patterns of performance he observed in pigeons responding under 60-second signaled delays imposed on a VI 1-minute schedule were likely the result of accidentally conditioned behaviors that developed during the delay. One could speculate that something along these lines was responsible for the patterns of responding seen with the nonresetting delay procedure in the present

study. It may be the case that the high rates of responding that developed in some of the 16-second nonresetting delay subjects arose adventitiously as a result of the distribution of reinforcers throughout the session. Since food was consistently delivered 16 seconds after the first depression of the active lever following the last reinforcer, responses that occurred during the delay would also have been subject to the strengthening effect of reinforcement. In addition, the response-produced stimuli arising from these interim behaviors would presumably have acquired conditioned reinforcing properties which would have further functioned to strengthen earlier responses in an accidentally developed chain.

If this superstitious chaining phenomenon occurred at the 16-second delays, why then would it not be seen in the shorter nonresetting delays or in the 16-second stacked delay procedure? Possibly the 4-second delays were short enough for reinforcement to have a direct strengthening effect on lever-pressing. Figure 1 illustrates that the average curves for the zero-delay and 4-second nonresetting delay subjects were nearly identical. Perhaps it takes a longer interval between the first response (the response that initiates the delay) and the delivery of food for superstitious behavior to develop, and perhaps 4 seconds is not long enough but 8 seconds is. Table 1 shows that five of the nine subjects in the 8-second group responded at a rate of over 4 responses per minute during the first 100 minutes of the session in contrast to a mean of 3.15 for the 4-second subjects. In regard to the stacked delay group, the 16-second stacked delay subjects received a reinforcer for every response. Although each reinforcer came 16 seconds from the lever-press that programmed its delivery, the frequency of reinforcement in this arrangement could be much higher and interreinforcer intervals much lower. In the stacked arrangement, there would not be as many 16-second intervals between those responses that initiated the delay and food deliveries. If a lever-press occurred in this condition and was

followed by another one 5 seconds later, the two reinforcers would be delivered 5 seconds apart (i.e., 16 and 21 seconds later). With the delay in the nonresetting condition always being a consistent 16 seconds, there would be a greater opportunity for a relatively uniform chain of behaviors to develop during the interval. In the stacked delay, however, more frequent food deliveries would interrupt the development of a repetitive chain. High rates would not be expected in the 16-second resetting condition since the occurrence of interim lever-presses had the effect of further postponing reinforcement. Whether or not this superstitious behavior hypothesis accounts for the present findings cannot be ascertained from the data at hand, but the contingencies involved in the nonresetting delay procedure merit further analysis with respect to this question.

Of the three procedures studied, the results of the resetting delay procedure show the most convincing evidence in support of the notions that (a) responding can be established with delayed reinforcement in the absence of additional training, and (b) the rate of learning is inversely related to the length of the delay to reinforcement. As explained previously, the resetting delay procedure precluded responses from being followed by reinforcement by a time shorter than the programmed delay value. As in the other procedures, 4-, 8-, and 16-second delays resulted in the acquisition of the response. Since the resetting delay arrangement afforded the lowest chance for temporal contiguity between responses and reinforcer deliveries, this procedure would be the one least likely to result in response acquisition if contiguity were indeed critical. The fact that responding emerged with 32-second delays lends even further support to the conclusion that responding can be developed in the absence of immediate reinforcement. These results suggest that a contingency between responding and reinforcement is enough to establish responding and that contiguity, although relevant, may be only of secondary importance.

The notion of relative contiguity described by Lattal and Gleeson (1990) may be applicable to the present case. These authors explain that "a delay of 10 seconds in the context of a long session may not function as an equivalent delay duration does in the context of a shorter session" (p. 38). In the present experiments, sessions lasted 8 hours. The environment of the experimental chamber provided relatively few exteroceptive stimulus changes over the course of 8 hours, the delivery of food constituting the most conspicuous. Over the course of a long session the appearance of food in a relatively impoverished environment some time after the occurrence of a discrete response might have a different effect on the repertoire of a food-deprived animal than the appearance of food after a period of the same duration in a less static environment. A 32-second delay in such an environment may function like a much shorter delay would under other conditions. It may be the case that contiguity is relevant, as Lattal and Gleeson point out, relative to its temporal context. The importance of absolute contiguity would be supported, though, by the fact that higher rates of responding developed and developed earlier in the session with shorter delays. To what degree the resetting contingency for interim responding in this condition contributed to the longer delays establishing lower response rates, however, is not clear. The fact that higher response rates occurred on the inoperative lever with the longer delays in the resetting arrangement would also suggest the importance of contiguity over contingency. For a more thorough account of evidence from studies of delayed reinforcement that support the notion of contiguity, see Lattal and Gleeson (1990).

The fact that the first response emerged so quickly for all subjects in the present report can also be attributed, in part, to the physical design of the experimental environment. Lattal and Gleeson (1990) used (in their experiments 4 and 5) chambers that were 20.5 cm wide by 19.5 cm high by 23.5 cm long, and they

reported that responding first appeared after various times for their subjects (from a minimum of 4 minutes into the first session for one subject to a maximum of 236 minutes for another subject). The chambers used in the present study were substantially smaller (12 cm wide by 15 cm high by 20 cm long). For all subjects in the present study responding was occurring by the end of the first 5-minute bin. For many subjects, exploration of the chambers was informally observed to result in depression of the levers before the experimental programming equipment could be turned on to begin the session. Subjects had but to stand on their hind legs and lean forward in these chambers to contact the levers. This exploratory behavior may have been evoked by the presence of olfactory stimuli in proximity to the levers produced by other rats who had pressed the levers in earlier sessions, as Lattal and Gleeson (1990) have suggested. Furthermore, the fact that all subjects were moderately food deprived (kept at 80% of their ad libitum weights) seemed to be enough to generate levels of activity sufficient to bring them into contact with the levers and eventually result in lever-pressing. Exactly what factors accounted for the first lever-press in these experiments, however, have not been identified conclusively.

At all delay values in the nonresetting and stacked delay procedures responding persisted on the operative lever but occurred only sporadically on the inoperative one. This result attests to the role of response-reinforcer dependency in accounting for the second and subsequent responses in these procedures. To the degree that a response on either lever had an equal chance of being followed by food in these procedures once a response on the active lever had occurred, significantly greater responding on the lever actually involved in the contingency would suggest that response-reinforcer dependency played an important role, even though reinforcement was delayed. The difference in rates of responding on the two levers also demonstrates (though

somewhat crudely) that the contingency, not the food delivery per se, was responsible for establishing the response of interest.

The development of higher rates of responding on the inactive lever in the 8-, the 16-, and the 32-second delays in the resetting condition can be attributed to the difference between the contingencies for pressing one lever as opposed to the other in this arrangement. For these groups, pressing the active lever during the delay functioned to postpone food delivery. Presses of the inactive lever had no such effect and could potentially be followed by food after a shorter (or even no) delay. Despite the postponement contingency associated with the active lever, however, responding on this lever was developed with up to 32-second delays, which suggests that the effect of delayed reinforcement in establishing discrete behavior is robust.

In examining the importance of delay of reinforcement as an independent variable in relation to the acquisition of new behavior, the methodology used in investigating this phenomenon must be critically evaluated. Each of the three procedures examined in the present report contain features that make it less than optimal for studying the effects of delayed consequences. None of the procedures allows examination of the relationship of a response to a delayed consequence without the inclusion of some other variables that confound that pure relationship. It may simply be the case that it is impossible to study learning with delayed consequences because it is impossible to arrange for behavior to occur without some immediate consequence (intrinsic or otherwise). As Lattal (1987) has suggested, it may be ill-advised to look at reinforcement delay as an independent variable. He notes the possibility that variability in temporal contiguity may better be viewed as a dependent variable which results from other environmental arrangements such as changes in frequency and distribution of reinforcers. Consequently, it may not be possible to separate contiguity from the aggregations of other variables that give rise to it. The

contingencies built into the procedures examined herein may be better thought of as involving other, more basic principles rather than delayed reinforcement. In any event, further refinement of the research methodology used to study the functional relationships involved in delay of reinforcement procedures will be necessary to determine how the phenomenon would be most aptly conceptualized.

Conclusions

The results of the present experiments demonstrate, in three different procedures for arranging delayed reinforcer delivery, that a new response can be developed in the absence of either explicit training or immediate reinforcement. Furthermore, the length of the delay to reinforcement and the type of procedure used to arrange reinforcement delays are variables that determine the patterns of responding that develop over the course of 8-hour sessions.

With the exception of one investigation (i.e., Lattal and Gleeson, 1990), studies of the effects of delayed reinforcement on learning have failed to eliminate sources of immediate conditioned reinforcement from the procedures used or have studied the effect of delayed reinforcement on the maintenance of behavior previously established with immediate reinforcement. The present study supports the results of the Lattal and Gleeson (1990) experiments indicating that immediate reinforcement is not necessary for the acquisition of a novel response and extends these findings by systematically examining different delay values under three different procedures for arranging delays.

At all delay values in all the procedures studied, responding emerged early on, suggesting that the topographies involved in the lever-press response were at a baseline level greater than zero prior to experimentation. However the response only persisted when it was followed by reinforcement. Subjects whose responding had no

programmed consequences did not persist in pressing the lever. In two of the procedures (resetting and stacked delays) rate of responding was inversely related to length of the delay to reinforcement, and in the other procedure (nonresetting delays), longer delays were associated with greater responding, possibly due to the development of superstitious behavior generated by the contingencies inherent in the longer nonresetting delays.

The procedures used to study the effects of delayed reinforcement in the acquisition of new behavior in the absence of immediate consequences are in need of further methodological refinement. Each procedure studied in the present report had its own idiosyncratic shortcomings. In each case there is a question as to what features of the patterns of responding generated by the procedure are attributable to delayed reinforcement as opposed to other, unanalyzed, complex contingencies. The question was raised as to whether it is even possible to isolate a phenomenon called delayed reinforcement from the other variables with which this phenomenon is intertwined.

Appendix A

Institutional Animal Care and Use Committee Protocol

RECEIVED
JAN 26 1989
RSP

Date of Receipt 1-23-89
Date of Approval 1-23-89
Date of Third Year Review 1-23-92
Approved IACUC Number 0021

WESTERN MICHIGAN UNIVERSITY INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE

Application to Use Vertebrate Animals for Research or Teaching

IACUC Review for (check one):

- A. [ ] New sponsored grant/contract proposal
- B. [ ] Continuation grant/contract proposal (present IACUC Number ________________)
- C. [x] Department funded or unfunded research
- D. [ ] Teaching or demonstration exercise
- E. [ ] Revision of ongoing animal research protocol (present IACUC Number ________________)

Title of Project: Acquisition of lever-pressing in rats by delayed reinforcement of successive approximations.

Principal Investigator: Jayson Wilkenfield (Faculty Advisor: Alan Poling)

Mailing Address: WMU Dept. of Psychology

Phone: 387-4484

Potential grantor/contractor: ________________

Please answer the following applicable requests (please type):

1. [illegible] appropriate spaces in this table)

Procedure Category		Age	Number Male	Number Female
A		6 mos.	150	
B				
C				

*Defined on pages 1 and 2 in *General Information and Instructions*.

2. **Provide an abstract or summarize the aims and objectives of this animal research, testing, or instructional project. (Use nontechnical language that a layperson can understand).**

Traditionally, teaching organisms to engage in specified behavior has been accomplished by presenting a reward immediately upon the occurrence of the designated response. The immediacy of the reward presentation has been emphasized as the most critical feature of this arrangement for optimum acquisition of the desired behavior; however literature regarding other than immediate reward presentation (i.e. delayed reinforcement) is not extensive. Those studies which have addressed delayed reward presentation have been primarily concerned with the maintenance of behavior that was acquired at some earlier time. The present study will compare various reinforcement delays in training subjects to approximate and ultimately engage in a specified response (lever-pressing) and thus will focus on the efficacy of delayed reward presentation in the acquisition rather than the maintenance of behavior.

3. **Judicious use of animals (explain in language that a layperson can understand).**

   a) **What are the probable benefits of this work to human or animal health, the advancement of knowledge, or the good of society?**

Although conventional wisdom in the experimental analysis of behavior suggests that the immediacy with which a reward is presented is critical in establishing and maintaining behavior, a careful analysis of the delay parameter in the acquisition of a new response has not been undertaken. The proposed study will docum[illegible] degree to which reinforcement can effectively be used [illegible]ish a new response when the reward occurs at various [illegible] after approximations to the targeted response.

b) Explain why computer simulation, *in vitro* biological ~~systems or audiovisual demonstration~~ are not acceptable alternatives to the use of animals in this project.

At present there is no way to simulate the acquisition of animal behavior through the reinforcement of successive approximations to a targeted behavior.

c) Justify use of the animal species listed in Item #1. Describe the biological characteristics of the animal that are essential to the proposed study. Include evidence of experience with the proposed animal model and manipulation.

Rats have been used traditionally in experiments like the one proposed here for several reasons. They are inexpensive, relatively tame, fairly resistant to disease and infection, easy to house, feed, and care for, and they readily learn to press levers in experimental chambers.

d) Justify use of the *number* of animals listed in Item #1. Specifically address why fewer animals cannot be used?

Ten subjects will be trained at each of five values of reinforcement delay. In addition to the ten experimental subjects at each delay value ten subjects (one for each of the ten expermental subjects) will receive reinforcement at the same time as their "yoked" counterparts so. Ten more subjects will serve as control subjects at each value of the delay. These control subjects [illegible] any reward during experimental sessions. The [illegible] groups at each delay value are necessary to demonstr[illegible] the effects on the experiemental subjects are due to th[illegible] procedure and not simply the exposure to the experim[illegible]ers.

4. Describe any form of required (a) prolonged animal restraint, (b) painful or aversive stimulation.

N/A

5. Where applicable to counteract pain, discomfort ~~or distress give name of drugs,~~ approximate dosage and route of administration. (Procedures such as injection, tattooing and blood sampling normally do not require pain relieving drugs.)

N/A

6. If pain is likely to occur and pain relieving drugs will not be used, give specific details as to why. (Use continuation sheets if necessary.)

N/A

7. Describe any surgical procedures

N/A

8. How [illegible]ed?

If the [illegible] used for subsequent research they will be exposed to carbon dioxide.

It is anticipated, however, that all subjects will be used in follow-up research in the area of conditioning and learning.

9. ~~Describe special handling and care such as diet, litter, lighting or post-operative care~~ that will be required from the animal facility:

Subjects will be maintained at 80% of their free-feeding weights on standard rat chow and housed communally in a room that is fluorescently illuminated 24 hrs/day. Litter is changed 7 days per week.

10. Identify any biohazardous materials such as radioisotopes, pathogens, toxins and carcinogens. What arrangements have been made to house the animals and to protect personnel?

N/A

11. If the study involves survival surgery, specify the surgical suite location; what are the post-operative care needs and who will provide the care?

N/A

12. If the [illegible] outside a designated Western Michigan University animal facility, speci[illegible] number. These locations are subject to IACUC compliance insp[illegible]

N/A

INVESTIGATOR CERTIFICATION

Title of Project: Acquisition of lever-pressing in rats by delayed reinforcement of successive approximations.

If any of the above procedures are changed, I will submit a new protocol.

I understand that any failure to comply with the *Animal Welfare Act*, the provisions of the *DPHS Guide for the Care and Use of Laboratory Animals* and requirements set down by the IACUC may result in the suspension of my animal studies.

Signature: Principal Investigator	Psychology Department	1-16-89 Date

Signature Faculty Advisor: ______

REVIEW BY THE INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE

______ Disapproved   X Approved   ______ Approved with the provisions listed below

Provisions: or Explanation

______

IACUC ______   1-23-89 Date

Research...

Signature: Principal Investigator   1-16-89 Date

IACUC Chairperson Final Approval   Date

Approved IACUC Number 0027

Revised June, 1988

BIBLIOGRAPHY

Azzi, R., Fix, D. S. R., Keller, F. S., & Rocha e Silva, M. I. (1964). Exteroceptive control of response under delayed reinforcement. Journal of the Experimental Analysis of Behavior, 7, 159-162.

Brown, P. L. & Jenkins, H. M. (1968). Auto-shaping of the pigeons' key peck. Journal of the Experimental Analysis of Behavior, 11, 1-8.

Catania, A. C., (1984). Learning (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall.

Communidad Los Horcones (1987). The concept of consequences in the analysis of behavior. The Behavior Analyst, 10, 291-294.

Cooper, J. O., Heron, T. E., & Heward, W. L. (1987). Applied Behavior Analysis. Columbus, OH: Merrill.

Dews, P. B. (1960). Free-operant behavior under conditions of delayed reinforcement: I. CRF-type schedules. Journal of the Experimental Analysis of Behavior, 3, 221-234.

Ferster, C. B. (1953). Sustained behavior under delayed reinforcement. Journal of Experimental Psychology, 45, 218-224.

Ferster, C. B. & Skinner, B. F. (1957). Schedules of reinforcement. New York: Appleton-Century-Crofts.

Grice, G. R. (1948). The relation of secondary reinforcement to delayed reward in visual discrimination learning. Journal of Experimental Psychology, 38, 1-16.

Guthrie, E. R. (1935). The psychology of learning. New York: Harper.

Hamilton, E. L. (1929). The effects of delayed incentive on the hunger drive in the white rat. Genetic Psychology Monographs, 5 (2), 131-209.

Harker, G. S. (1956). Delay of reward and performance of an instrumental response. Journal of Experimental Psychology, 51, 303-310.

Hull, C. L. (1932). The goal gradient hypothesis and maze learning. Psychological Review, 39, 25-43.

Hull, C. L. (1943). Principles of behavior: An introduction to behavior theory. New York: Appleton-Century-Crofts.

Hull, C. L. (1952). A behavior system. New Haven: Yale University Press.

Keller, F. S. & Schoenfeld, W. N. (1950). Principles of psychology. New York: Appleton-Century-Crofts.

Lattal, K. A. (1987). The effect of delay and of intervening events on reinforcement value. In M. L. Commons, J. E. Mazur, J. A. Nevin, & H. Rachlin (Eds.), Quantitative analyses of behavior: Vol. 5. (pp. 107-123). Hillsdale, NJ: Lawrence Erlbaum Associates.

Lattal, K. A. & Gleeson, S. (1990). Response acquisition with delayed reinforcement. Journal of Experimental Psychology: Animal Behavior Processes, 16 (1), 27-39.

Logan, F. A. (1952). The role of delayed reinforcement in determining reaction potential. Journal of Experimental Psychology, 43, 393-399.

Martin, G. & Pear, J. (1988). Behavior modification: What it is and how to do it (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Michael, J. (1989). Concepts and principles of behavior analysis. Unpublished manuscript, Western Michigan University, Kalamazoo.

Mowrer, O. H. (1960). Learning theory and behavior. New York: Wiley.

Neuringer, A. & Neuringer, M. (1974). Learning by following a food source. Science, 184, 1005-1008.

Perin, C. T. (1943). The effect of delayed reinforcement upon differentiation of bar responses in white rats. Journal of Experimental Psychology, 32, 95-109.

Perkins, C. C. (1947). The relation of secondary rewards to gradients of reinforcement. Journal of Experimental Psychology, 37, 377-392.

Renner, K. E. (1964). Delay of reinforcement: A historical review. Psychological Bulletin, 61, 341-361.

Sidman, M. (1960). Tactics of scientific research. New York: Basic Books.

Skinner, B. F. (1938). The behavior of organisms. New York: Appleton-Century-Crofts.

Skinner, B. F. (1953). Science and human behavior. New York: Macmillan.

Skinner, B. F. (1969). Contingencies of reinforcement: A theoretical analysis. New York: Appleton-Century-Crofts.

Spence, K. W. (1947). The role of secondary reinforcement in delayed reward learning. Psychological Review, 54, 1-8.

Spence, K. W. (1956). Behavior theory and conditioning. New Haven, CT: Yale University Press.

Vargas, E. A. (1984). A new term and some old advice. The Behavior Analyst, 7, 67-69.

Warden, C. J. & Haas, E. L. (1927). The effect of short intervals of delay in feeding upon speed of maze learning. Journal of Comparative Psychology, 7, 107-115.

Watson, J. B. (1917). The effect of delayed feeding upon reaction. Psychobiology, 1, 51-60.

Williams, B. A. (1976). The effects of unsignalled delayed reinforcement. Journal of the Experimental Analysis of Behavior, 26, 441-449.

Wolfe, J. B. (1934). The effect of delayed reward upon learning in the white rat. Journal of Comparative Psychology, 17, 1-21.