4-1979

A Parametric Study of Geometric Progressive Ratio Performance

Ali Uzunoz
Western Michigan University

A PARAMETRIC STUDY OF
GEOMETRIC PROGRESSIVE RATIO PERFORMANCE

by

Ali Uzunoz

A Dissertation
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Doctor of Philosophy

Western Michigan University
Kalamazoo, Michigan
April 1979

ACKNOWLEDGEMENTS

I am indebted to many people. First of all, I would like to thank my advisor, Dr. Arthur Snapper, who spent three years shaping my behaviors. I would also like to thank Dr. Jack Michael. His teachings have been my inspiration in the experimental analysis of behavior. I would like to extend my thanks to my dissertation committee members, Dr. David O. Lyon, Dr. Paul Mountjoy, and Dr. Daniel P. Hendrikson. I appreciated the friendship and help of the graduate students working in Dr. Snapper's laboratory. I would like to thank my friend, Dr. Hilary Jo Karp, whose encouragement and help sustained me during the course of my dissertation. I would also like to thank my aunt, Ayse Gulec, and my parents. They have made the sacrifices which made my education possible.

Ali Uzunoz

7913019

UZUNOZ, ALI

A PARAMETRIC STUDY OF GEOMETRIC PROGRESSIVE RATIO PERFORMANCE.

WESTERN MICHIGAN UNIVERSITY, PH.D., 1979

University Microfilms International 300 N. ZEEB ROAD, ANN ARBOR, MI 48106

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

INTRODUCTION

It has been recently recognized that behavior is lawful. For ages, behavior, under the label of voluntary action, was considered to be a function of the capriciousness of free will. It was Thorndike (1911) who released behavior from the whim of capricious free will and brought it under the authority of the law of effect. The traditional law of effect stated that:

> Of several responses made to the same situation, those which are accompanied or closely followed by satisfaction to the animal will, other things being equal, be more firmly connected with the situation, so that, when it recurs, they will be more likely to recur...The greater the satisfaction....the greater the strengthening...of the bond. (p. 244)

Although the traditional law of effect described an important relationship between behavior and environmental variables, it was only an approximation to the principle of reinforcement. In the traditional law of effect, it was assumed that there are three different types of events in nature which have inherent and absolute properties termed "satisfying", "annoying", and "neutral". These properties were considered irreversible properties of the events themselves. Thus, the traditional law of effect described a static relationship between behavior and the environment.

Skinner (1938, 1961, 1969) pointed out that an adequate formulation of the interaction between an organism and its environment must always specify three important variables: (1) the occasion upon which behavior occurs, (2) the behavior itself, and (3) the consequences of that behavior. He referred to the interrelationship among these three variables as the contingencies of reinforcement. In Skinner's reinforcement theory, the reinforcing property of an event in a situation was considered to be a function of the contingencies of reinforcement prevailing in that situation, rather than an inherent property of the event itself. This was an important departure from the traditional thought about the reinforcement process. For Skinner, the term reinforcement referred to a process in which the future probability of a behavior is increased as a function of the consequences produced by that behavior. This increase was commonly referred to as "strengthening" of the behavior. Skinner thus suggested that rate of responding (number of responses per unit time) was the most appropriate measure for quantifying this strengthening effect of reinforcement.

Since the early 1960s there has been a continuous debate about the adequacy of response rate as a measure of reinforcement value. Response rate has been criticized on four different grounds. First, in single manipulandum situations, such as used by Catania (1963) and Kennedy and Baldwin (1972), the response rate has been found to be relatively insensitive to manipulations of the parameters of reinforcement. Second, as noted by Nevin (1974, 1977), there is a frequent lack of correlation between response rate and resistance to extinction, although both measures would be expected to correlate with reinforcement value. Third, as noted by Hodos and Kalman (1963) and Hodos and Valenstein (1962), response rate, since it is dependent on time, can be easily affected by operations which affect motor performance, such as brain stimulation, drugs, and other physiological manipulations. Finally, response rate itself is a conditionable property of behavior (Nevin, 1974, 1977). For example, variable interval (VI) reinforcement schedules maintain a moderate response rate, because in VI schedules, the rate of reinforcement is relatively independent of the response rate. Thus, VI schedules selectively reinforce longer interresponse times (IRTs). Variable ratio (VR) schedules, on the other hand, maintain a high rate of responding, because in VR schedules, the rate of reinforcement is directly dependent upon response rate. Thus, ratio schedules selectively reinforce shorter IRTs. This phenomenon is called the shaping effect of reinforcement. For a better measure of reinforcement value, the strengthening effect of reinforcement needs to be disentangled from its shaping effect.

Thus, while response rate appeared to be the appropriate measure of reinforcement value by the definition of reinforcement, questions have been raised regarding its use, and alternate procedures and measures have been proposed. Basically, three different procedures have been developed to measure reinforcement value, each suggesting its own measure. These procedures are the resistance to change procedures, concurrent reinforcement schedules and progressive ratio reinforcement schedules. Two different types of resistance to change procedures are proposed. These procedures are the Columbia Obstruction Procedure and Nevin's "resistance to change" procedure (1974).

Historically, reinforcement value was studied with the Columbia Obstruction Procedure developed by Warden and Jenkins (1931). This procedure consists of interposing an electrified grill between a rat and a reinforcing stimulus. In this procedure, the experimenter usually varied the parameters of reinforcement and the intensity of the shock received in crossing the shock grill. It was assumed that the greatest intensity of shock which was tolerated by an animal could provide a sensitive measure for assessing reinforcement value under various motivational conditions. However, the results of the studies using this procedure indicated that variations in the intensity of the shock did not produce orderly relationships with the parameters of reinforcement, because of the problems involved with the repeated administration of the shock. In later studies with this procedure, the experimenters kept the intensity of the shock constant, used the number of crosses as the dependent variable and found more orderly relationship with the parameters of reinforcement.

Since Skinner (1938, 1961, 1969) frequently discussed reinforcement as the "strengthening" of a behavior, Nevin's (1974, 1977) proposal of "resistance to change" as a measure of response strength should be considered as an alternative measure of reinforcement value. Nevin (1974) pointed out that "the strength of an operant can be defined in relation to a second operant, by its higher rate of occurrence, relative to its baseline rate, when a single response weakening operation is applied to both operants to reduce their rate of occurrences." (p. 403). He demonstrated that response rate in components of multiple schedules correlated with the higher frequencies, larger magnitudes and shorter delays of reinforcement was more resistant to change than the response rate in components correlated with the lower frequencies, smaller magnitudes, and longer delays of reinforcement. He concluded that response strength, as defined by resistance to change, was a positive function of reinforcement value. The resistance to change procedure may be an appropriate procedure to study reinforcement value. However, Nevin's study (1974) is the only study using this procedure. It thus needs to be replicated in a variety of situations to determine its generality and its validity. In addition, in Nevin's study, the reinforcement value was still measured as a function of response rate. The relative change in response rate may not be the most reliable indicator of reinforcement value due to the problems involved with response rate mentioned previously.

A second procedure to assess reinforcement value involved concurrent reinforcement schedules. A typical concurrent reinforcement schedule consists of two or more schedules functioning simultaneously, each controlling a separate operant. Responding on each operanda produces reinforcement according to its own schedule. To avoid superstitiously reinforcing switching behavior, if a reinforcement opportunity is set up on one operandum, while the animal is responding on the other operandum, that reinforcement can only be obtained after the animal meets a change-over delay (COD) requirement. The COD requirement specifies the minimum time interval which must elapse between a switching response and a subsequent reinforced response.

Using concurrent VI schedules, Herrnstein (1961) demonstrated a quantitative relationship between the relative response rate and the relative reinforcement rate. The proportion of responses on one operandum was a linear function of the proportion of reinforcement on that operandum. He referred to this relationship as the matching law and proposed that relative rate of responding is the most appropriate measure of reinforcement value. Further investigations (Catania, 1963, 1966; Chung and Herrnstein, 1967; Herrnstein, 1970, 1971) extended the generality of the matching law to other parameters of reinforcement, such as amount, immediacy, and quality.

Baum (1973) and Baum and Rachlin (1969), on the other hand, argued that pigeons tend to peck with a constant rate when they respond, with the majority of the IRTs falling between 0.03 seconds and 0.05 seconds. Thus, the overall rate of responding may be a function of the duration of pauses between "bursts" of responding at a constant rate. They suggested that, in concurrent VI schedules, the time allocation to each alternative is more general than response allocation, and thus proposed time allocation as the most appropriate measure of reinforcement value.

However, as pointed out by de Villiers (1977), the relative response rate or relative time allocation is not an unambiguous measure of reinforcement value. The matching relationship does not hold in any other concurrent schedules except for concurrent VI schedules. Also, the matching relationship only holds in concurrent VI schedules when there is a change-over delay requirement. The strict dependence of the matching relationship on a short duration of a change-over delay contingency severely limits the generality of the relative rate of responding or relative time allocation as a measure of reinforcement value.

Also, the matching relationship may be an artifact of the adventitiously reinforced switching responses. In concurrent VI schedules, responding on one schedule may come partially under the control of reinforcement from the other schedule (de Villiers, 1977). The probability of reinforcement on one schedule increases as a function of the time spent responding on the other schedule. In concurrent schedules, the change-over delay contingency can minimize the development of superstitious chaining, but it does not totally eliminate it from the experimental situation. Thus, the matching relationship may be confounded by the way in which the timers of the schedules are arranged, as was found by Boivin (1978), De la Garza (1978), and Deluty and Church (1978). Therefore, concurrent schedules and their proposed measures, relative response rate or time allocation, do not appear to be most appropriate for the measurement of reinforcement value.

A third procedure to assess reinforcement value, the progressive ratio (PR) schedules, were suggested by Hodos (1961) to overcome the shortcomings of the historical Columbia Obstruction method. In a progressive ratio procedure, in order to obtain reinforcement, a subject has to emit an increasing number of responses after each reinforcement. Thus, Hodos used "work" in the progressive ratio procedure as an analogue to shock in the Columbia Obstruction Procedure. He suggested that the final completed ratio in a progressive ratio schedule would be a sensitive index for measuring reinforcement value under various motivational conditions.

Several investigators (Hodos, 1961; Hodos and Kalman, 1963;

Hodos and Trumbule, 1967; Kennedy and Baldwin, 1972) found a systematic relationship between the final completed ratio and the parameters of reinforcement. Further investigators (Dardano, 1968, 1973, 1974; Dardano and Sauerbrunn, 1964; Hurwitz and Harzem, 1968) found a similar relationship when they provided a reset option on a second operandum, by which the animals could control the work requirement. A response on the reset operandum would set the response requirement back to its initial value.

All of these experiments were done using arithmetic progressive ratio schedules. In an arithmetic progressive ratio, as the response requirement increases, the proportion of increase declines. At high values, this schedule increasingly approximates a fixed ratio schedule in which a constant number of responses is required to obtain reinforcement. While almost all progressive ratio studies have used the arithmetic progressive ratio, the increment in a schedule could also be a constant multiplier, as in a geometric progressive ratio. In a geometric progressive ratio schedule, the response requirement increases exponentially and the proportion of increase thus remains constant (Stewart, 1975).

The purpose of this study was to determine if the final completed ratio would be an appropriate measure of reinforcement value using a geometric progressive ratio procedure. To do this, the constant multiplier of the geometric progressive ratio schedule (or increment value) was parametrically manipulated. In addition, the effect of a reset option, allowing the animals to control the response requirement was examined as a function of the duration of response contingent timeout on the reset lever.

LITERATURE REVIEW: PROGRESSIVE RATIO AND PROGRESSIVE INTERVAL SCHEDULES

A schedule of reinforcement refers to a rule which determines the conditions to be met for the delivery of reinforcement (Morse and Kelleher, 1977). In progressive schedules, the delivery of reinforcement can be based on either a response requirement or a continually increasing temporal requirement. When based on a response requirement (a progressive ratio schedule), the number of responses necessary for the delivery of reinforcement is specified. When based on a temporal requirement (a progressive interval schedule), reinforcement follows the first response after a specified period of time elapses. Unlike the simple ratio or interval schedules, the specified requirement for each reinforcement on a progressive schedule is a constantly increasing function of the preceeding requirement. This function can be based on either an arithmetic or a geometric progression, as well as harmonic progressions or a combination of arithmetic and geometric progressions.

In an arithmetic progressive schedule, the basis of the progression is the addition of a constant increment value to the previous requirement to obtain reinforcement. By convention, unless otherwise indicated, the initial value of an arithmetic progressive ratio schedule also specifies the increment value. For example, an arithmetic progressive ratio schedule of 5 (PR 5) requires 5 responses for the first reinforcement, 10 for the second, 15 for the third, 20 for the fourth, and continues in this manner, adding 5 responses for each subsequent reinforcement. In a geometric progressive schedule, the progression is based on a constant multiplier. For example, using a geometric progressive ratio of 2 with an initial value of 5, for the first reinforcement, the animal is required to emit 5 responses. For the second reinforcement, he must emit 10, for the third 20, for the fourth 40, and the response requirement continues to increase as a multiple of 2.

The major purpose of using progressive ratio schedules has been to quantify reinforcement value. In addition, they have been used to examine the effects of drugs and other physiological manipulations on behavior. Progressive interval schedules have been used to examine time discrimination. These studies will be briefly summarized.

Reinforcement Value Using Progressive Ratio Schedules

Findley (1958) was the first researcher who used progressive ratio schedules. He studied pigeons' "switching" responses under concurrent progressive ratio reinforcement contingencies. He used a change-over key concurrent schedule. A typical change-over key concurrent schedule involves two keys. On one of the keys (main key), two different reinforcement schedules are programmed, each correlated with a different discriminative stimulus. The pigeon switches the reinforcement schedule on the main key by responding on the other key (change-over key).

Findley programmed two equivalent arithmetic progressive ratio schedules on the main key, PR 100, PR 100. A single peck on the change-over key (switching response) produced the alternate progressive ratio schedule, with its discriminative stimulus, and reduced the response requirement to its initial value. Thus, a pigeon could change the reinforcement schedule and control the response requirement on the main key by making a single response on the change-over key.

With prolonged training in this procedure, Findley found a similar response pattern under both schedules. Pigeons typically obtained several reinforcements on one component, and then switched to the other component. Most of the switching responses occurred during the post reinforcement pauses (PRPs).

In further experiments, he programmed two non-equivalent arithmetic progressive ratio schedules on the main key, and increased the switching response requirement. When he used non-equivalent progressive ratio schedules on the main key, he found that switching responses occurred usually after the ratio requirement in the smaller PR component exceeded the initial PR value in the larger PR component. Increasing the response requirement to switch the components reduced the switching response rate. He thus suggested that switching response rate could be used as an index for the pigeon's schedule "preference" on concurrent arithmetic progressive ratio schedules.

Hodos (1961) modified the progressive ratio procedure employed by Findley (1958) and used it to measure reinforcement value under various motivational conditions. He removed the change-over key from Findley's procedure and added a "breaking point" feature. The breaking point was defined as the number of responses in the last ratio completed before the rat failed to respond for a 15 minute period of time.

He reinforced the rats' responding on an arithmetic progressive ratio 2 with sweetened milk. He systematically manipulated the concentration of sweetened milk, body weights of the rats and amount of reinforcement in three consecutive experiments. He found a systematic relationship between the median number of responses in the final completed ratio and the above variables. The median final completed ratio increased as a function of the increases in the concentration and volume of the sweetened milk and the deprivation level of the animals. He suggested that, because the number of responses in the final completed ratio was systematically correlated with the parameters of reinforcement and deprivation levels, it could be used as a reliable index for reinforcement value.

Hodos and Kalman (1963), using this index, studied the effect of increment values and of the amount of reinforcement on arithmetic progressive ratio schedules. The rats were reinforced with food on arithmetic progressive ratio schedules of 2, 5, 10, 20, and 40. Hodos and Kalman found that the median number of responses in the final completed ratio increased as a function of the increment values. However, the number of reinforcements obtained during a session sharply decreased as a function of the increment value.

The effect of the volume of reinforcement interacted with increment value. With large ratio increments, the median number of responses in the final completed ratio declined with the larger volumes of milk, suggesting a satiation effect. The total number of responses, the overall response rate, and the running rate did not systematically correlate with the manipulations of the independent variables.

Hodos and Kalman thus also suggested that the number of responses in the final completed ratio could be a reliable index to measure the relative value of reinforcement without reference to rate of responding. They further discussed the utility of the progressive ratio procedure for measuring reinforcement value when an organism's ability to respond at a high rate is impaired. A brain-injured or drugged organism could show a response rate decrement which could be due to an impaired motor system rather than due to a motivational change. However, the measurement of the final completed ratio is relatively independent of temporal variables affecting rate, and thus may be less affected by such impairments.

To further establish the utility of the final completed ratio, Kennedy and Baldwin (1972) with pigs studied the effect of sugar concentration on VI 30 sec. and arithmetic PR 10 reinforcement schedules. In both reinforcement schedules, they systematically manipulated the sugar concentration levels. They found that on VI 30 sec. reinforcement schedules, the rate of responding was not systematically related to sugar concentration. On arithmetic PR 10 schedules, however, the mean final completed ratio increased as a function of the increases in the sugar concentration. Their results suggested that the final completed ratio of arithmetic PR reinforcement schedules is a more sensitive measure for the relative reinforcement value than response rate in VI reinforcement schedules.

Hawkins, Schrott, Githens, and Everett (1972) used the final completed ratio to compare the relative reinforcing value of 90 mg. portions of liquid diet with 45 mg. pellets. They found that the rats consistently completed longer ratio runs for the liquid diet than for the pellets. The differences were most extreme for the initial comparisons; as the conditions were repeatedly reversed, the differences tended to diminish. They concluded that 90 mg. portions of liquid diet were at least as effective as 45 mg. pellets in sustaining progressive ratio performance.

Steiner (1967, 1970), with monkeys, demonstrated that the progressive ratio procedure could also be used to measure the conditioned reinforcement value of a discriminative stimulus in an observing response paradigm. In his procedure, the food and no-food trials alternated randomly. The monkey's responses on the food lever were reinforced on a VI 60 sec. reinforcement schedule if the trial was a food trial, and not reinforced if the trial was a no-food trial. On an arithmetic PR 2 schedule, the monkey's observing responses produced the stimuli signalling the outcome of the trials. He systematically manipulated the probability of the food trials from 0.1 to 0.9. He found that the monkeys made the observing responses more frequently when the probability of food trials was smaller. To produce the stimuli signalling the outcome of the trials, the monkeys responded on the observing lever until the response requirement on the progressive ratio reached a maximum of 50. Beyond that value, they quit responding on the observing lever. These results suggested that the progressive ratio procedure could also be very useful in measuring the conditioned reinforcement value of discriminative stimuli.

Progressive Ratio Schedules with the Reset Option

Hodos and Trumbule (1967), in a choice situation with chimpanzees, studied the relative reinforcing value of two mutually exclusive reinforcement schedules, a fixed ratio (FR), and an arithmetic progressive ratio 20. The chimpanzees were confronted with two "schedule selection" switches, each illuminated with a different color light correlated with one of the schedules. A response on one of the "schedule selection" switches turned off these lights, illuminated a response switch with the same color light, and instituted its corresponding reinforcement schedule on the response switch. After each reinforcement, the "schedule selection" switches were illuminated again, and the chimpanzees could "choose" to respond either on the FR or the arithmetic PR schedule. Each selection of the fixed ratio reinforcement schedule reset the response requirement in the progressive ratio schedule to its minimum value. Once a schedule was selected, it remained in effect until the animal obtained reinforcement. Additional responses on the "schedule selection" switches had no effect after the schedule was selected.

Hodos and Trumbule systematically varied the FR values from 40 to 1000. They used the number of completed ratios (runs) per block on the progressive ratio schedule as a measurement of reinforcement value. A block was defined as a sequence of consecutive progressive ratio runs terminated by a fixed ratio run. They found that the mean number of runs per block increased as a function of the increases in the fixed ratio values. By comparing their data to theoretical curves, generated by different models, they suggested that chimpanzee schedule selection could be based on a reinforcement cost minimization strategy rather than a simple matching of the response requirement on the progressive ratio to the fixed ratio.

Hurwitz and Harzem (1968) also studied the relative reinforcement value on progressive ratio schedules when the rats were given a reset option. The rats' responses on the reinforcement lever were reinforced on arithmetic PR schedules of 5, 10, 20, and 30. A response on the reset lever reset the progressive ratio to its minimum value.

They found an inverse relationship between the distribution of reset responses and the number of reinforcements before a reset response occurred. The smallest percentage of reset responses occurred after the largest number of uninterrupted ratio runs under any one schedule. This relationship was itself related to the increment value of the progressive ratio schedule in operation; the higher the increment value of the schedule, the fewer the reset responses following more than one reinforcement. That is, with the higher progressive ratio schedules, the animals most often reset the ratio after the first reinforcement, suggesting that responding on progressive ratio schedules is determined by the strategy of reinforcement cost minimization proposed by Hodos (1967).

Dardano and Sauerbrunn (1964), with pigeons, studied the effects of selective punishment on a change-over key concurrent reinforcement schedule. They programmed two equivalent arithmetic progressive ratio reinforcement schedules (PR 50, PR 50) on the main key. Under one component, each response produced a shock, while under the other component, no responses were shocked. A response on the change-over key (switching key) changed the components and reset the progressive ratio to its minimum value, provided that at least one ratio run had been completed. They systematically manipulated the shock intensity.

The results indicated that the animals completed longer ratios of the progressive ratio under the non-shock component. However, even when the severity of the shock suppressed responding in the shock component, the pigeons continued to switch to that component after completing a number of ratios in the non-shock component, thus resetting the ratio to its minimum value. Even under high intensities of shock, the pigeons made switching responses to the shock component. Dardano and Sauerbrunn interpreted their results as suggesting that the stimulus correlated with the non-shock component, when the ratio requirement reached a certain level, appeared to be as aversive as the stimuli associated with the response-produced shock component.

Dardano (1968), with pigeons, further studied the role of the reset responses in a slightly different procedure. The primary schedule of reinforement was an arithmetic PR 50. A response on the reset key produced shock and reset the progressive ratio to its minimum value. He manipulated the intensity of the shock. Before the shock was introduced, the pigeons typically reset the ratio almost after each reinforcement. Thus, the number of responses to produce reinforcement and the inter-reinforcement interval were minimized. Even though the frequency of the reset responses thereafter decreased as a function of increasing shock intensities on the reset lever, the animals continued to reset the progressive ratio to its minimum value. These results again suggested that the stimuli, in whose presence a higher rate of responding to obtain reinforcement is required, may acquire aversive properties.

Dardano (1973), although he did not use a reset option in this study, further examined the aversive properties of the progressive ratio schedules as a function of self-imposed timeouts (TO). In a three key pigeon chamber, responses on the first key produced reinforcement on an arithmetic PR 50 schedule. Responses on the second key produced a period of timeout. Responses on the third key were inconsequential. He manipulated the durations of timeout from 5 seconds to 9 minutes. Pigeons pecked the timeout key regardless of whether the timeouts were brief or lengthy. The frequency of the self-imposed timeouts was directly related to the number of responses required for reinforcement, increasing as the pigeons entered longer progressive ratio steps. Infrequent and sporadic responding on the inconsequential key occurred, but to a lesser degree than on the key with the timeout consequence, suggesting that the timeout functioned as a reinforcer. Dardano interpreted his results suggesting that responding to produce timeouts was maintained because it allowed escape from the aversive stimuli generated by the progressive ratio reinforcement schedule.

Using a similar procedure, with the addition of a reset option with response-contingent shock, Dardano (1974) further examined the role of the self-imposed timeouts. Pigeons' responding on the reinforcement key produced grain on an arithmetic PR 50. A response on the timeout key produced a 3 minute timeout period. A response on the reset key reset the PR schedule to its initial value, but also produced a shock. Dardano manipulated the intensity of the shock. Under low and intermediate shock intensities, timeouts were not produced, but reset responses were made. Under high shock levels, no reset responses were emitted, but timeouts were produced regularly. Both reset responses and timeout responses occurred most frequently during the larger ratio requirements and usually occurred during the post reinforcement pauses. Thus, these results suggested that the occurrence of a self-imposed timeout option could be altered as a function of the shock intensities on a simultaneously available reset option. However, it should be noted that the increased response requirement was the main variable which controlled the optional reset and timeout behaviors.

Drug Effects Using Progressive Ratio Schedules

Progressive ratio schedules have been commonly used to assess the effects of tranquilizers on behavior. Thompson (1972), with pigeons, studied the effect of chlordiazepoxide and phenobarbital (minor tranquilizers) on progressive ratio performance. The pigeons' responses were reinforced with food on an arithmetic PR 8. Four doses of each drug, ranging from 5 to 80 mg./kg., were tested, and drug was administered 30 minutes before the session started.

He found that both drugs increased the final completed ratio.

The dose-effect curves were inverted U-shaped curves with the maximum enhancement of performance occurring at 20 mg./kg. for chlordiazepoxide and at 40 mg./kg. for phenobarbital. The most marked effect the drugs had on behavior was to decrease the post reinforcement pauses associated with larger ratios. Generally, the high running rates were not disrupted by the drugs, except under the largest drug dose when the pigeons appeared to have difficulty in standing. Thompson suggested that increases in the final completed ratio and shortening of the post reinforcement pauses could be taken as evidence that both of the drugs reduced the aversiveness of the progressive ratio schedule.

Dantzer (1976), with pigs, studied the effect of diazepam (tranquilizer) on progressive ratio performance. Pigs' responses on a panel were reinforced on an arithmetic PR 2 schedule. The 1 mg./kg. diazepam was injected 30 minutes before the session started. The pigs completed greater final ratios with the drug than without the drug. The lengthening of the post reinforcement pauses with the larger ratio was not affected by the drug administration. Dantzer suggested that the increases in the final completed ratios induced by diazepam could be interpreted as a result of nonspecific response releasing properties of the drug, or an increase in the pigs' motivation to work for food.

Stewart, Blampied, and Highes (1974), with rats, studied the effect of scopolamine (tranquilizer) on a geometric progressive ratio performance. The response requirements for the first five reinforcements were 1, 4, 6, 10, and 12. Thereafter, each ratio was 1.25 times the preceeding one. The scopolamine, in doses ranging from

0.05 to 2.0 mg./kg., was administered 30 minutes before the session started. Increasing doses of scopolamine typically produced first increases, then decreases in the final completed ratios. Thus, the inverted-U dose-response curve found with scopolamine on a geometric progressive ratio schedule was similar to those found by Thompson (1972) with the chlordiazepoxide and phenobarbital on arithmetic progressive ratio schedules.

Other Physiological Manipulations Using Progressive Schedules

Some other physiological manipulations which have been examined using progressive ratio schedules include intracranial stimulation (ICS) and atmospheric pressure. Hodos and Valenstein (1962) pointed out that response rate is not a satisfactory measure of the reinforcement value of intracranial stimulation (ICS). Stimulations in the different areas of the brain produce their own characteristic response patterns and rates. For example, ICS in the posterior hypothalamus produces high and uniform response rates. ICS in the septal area of the brain produces low and irregular response rates. Also response rate is not a reliable index of reinforcement value for high intensities of ICS due to the disruption of the response rate by tremors, seizures, and forced movements generated at those levels.

To measure the reinforcement value of ICS, they suggested that the final completed ratio would be relatively less affected by the side effects of ICS, since it was not dependent on time. Thus, Hodos (1965) studied the effect of the duration of ICS on arithmetic progressive ratio schedules. He systematically manipulated the duration of ICS in different areas of the brain. He found that the final completed ratio increased as a function of the increases in the duration of ICS in the amygdola, and in the preoptic and tegmental areas of the brain.

Keesey and Goldstein (1968) also suggested that the final completed ratio could be a more reliable index of the reinforcement value of ICS. They studied the effect of ICS in the septal and hypothalamic areas of the brain, systematically manipulating the intensity of the ICS. Their results indicated that the final completed ratio on arithmetic progressive ratio schedules increased as a function of increases in the intensity of ICS. These results suggest that the intensity of ICS was functionally similar to the duration of ICS.

Thomas (1974) studied the effects of the relationship between increment values and atmospheric pressure on arithmetic progressive ratio schedules. The rats were reinforced with food on schedules of arithmetic PR 2, 5, and 20. Thomas systematically manipulated the air pressures in the animal chambers from 3.1 $kg./cm.^2$ to 9.4 $kg./cm.^2$ The mean final completed ratio increased as a function of the increases in the increment values. However, increased air pressure generally produced decreases in the mean final completed ratio. He discussed the possibility that air under pressure could function as a central nervous system depressant which might increase the aversive properties of the increased response requirement on progressive ratio schedules.

Progressive Interval Schedules

The progressive interval schedules, a variation of progressive ratio schedules, have also been shown to be important procedures for the experimental analysis of behavior. They are considered useful to determine if the organism can adjust to temporally based changes in the reinforcement contingencies. In a progressive interval (PI) reinforcement schedule, like in a fixed interval schedule, a response is reinforced only if a specified interval has elapsed since the previous reinforcement. Unlike the FI schedule, however, the durations of the successive intervals between reinforcements of a progressive interval schedule are increased according to an arithmetic or geometric progression.

Findley (1958) was again the first researcher who used progressive interval reinforcement schedules. He studied the effect of increment values on the switching response rate on a change-over concurrent reinforcement schedule. On the main key, he programmed two identical arithmetic progressive interval schedules. A switching response changed the schedules and reset the interval to its minimum value. He systematically manipulated the increment value from 1 minute to 8 minutes. The switching response rate increased as a function of the increases in the increment value. These results suggested, that for the progressive interval schedules as well, the responding on the switching key was a function of the contingencies of reinforcement on the main key.

Harzem (1969), with rats, studied time discrimination, comparing behavior under arithmetic and geometric progressive interval schedules.

He used an arithmetic PI 60 sec. and a geometric PI 60 sec. which increased as a multiple of 1.25. He found that, as the session progressed, the post reinforcement pauses in both schedules increased in a manner similar to the progression on each schedule. On the arithmetic PI schedule, the post reinforcement pauses increased linearly. On the geometric PI schedule, the post reinforcement pauses increased exponentially.

He also found that the number of responses per interval remained stable in both schedules. However, on the geometric PI schedule, the smaller variability in the responses per interval suggested that rats discriminated changes in the reinforcement contingencies on the geometric PI schedule more easily than on the srithmetic PI schedule. Thus, Harzem suggested that in time discrimination, the relative magnitude of temporal change was more important in the control of behavior than the absolute values of the intervals involved in such a change. Accordingly, it could be concluded that progressive interval schedules could be important tools in analyzing the effect of temporal variables on behavior.

Statement of the Problem

As it can be seen from the reviewed studies, although there are relatively few studies using the progressive procedures in general, there are almost none using the geometric progressive schedules. The only studies using geometric progressive schedules were those by Stewart et al. (1974) and by Harzem (1969). Stewart et al. (1974) studied the effect of the drug scopolamine on geometric progressive ratio performance. Harzem (1969) compared the performance of rats under arithmetic and geometric progressive interval schedules.

All of the studies examining reinforcement value have used arithmetic progressive ratio schedules. As can be seen in Harzem's (1969) study, performance under geometric progressive schedules may exhibit different functional relationships than that under arithmetic progressive schedules. Thus, there is a need for further specification of the essential parameters of the geometric progressive ratio schedules. This study will parametrically examine the effect of increment values on the final completed ratio on geometric progressive ratio schedules.

METHOD

Overview

With two groups of five rats, the effects of some parameters on the final completed ratio was examined, using a discrete-trial geometric progressive ratio procedure. The primary variables which were parametrically manipulated were increment value and the duration of timeout contingent on responses on the non-reinforcement lever. Since no systematic relationship was obtained, and responding declined, additional manipulations were carried out to maintain responding and to isolate the critical variables. The variables manipulated in these additional procedures included initial value of the progressive ratio schedule, the type of procedure (geometric or arithmetic), and the simplification of the basic procedure. Once responding was restored, using the simplified basic procedure, the effect of increment value on the final completed ratio was again examined.

Subjects

Ten male albino rats served as subjects. The animals were donated by the Upjohn Company of Kalamazoo, Michigan, and were about 90 days old when they were first obtained. They were individually housed and kept at approximately 80% of their free-feeding weight, by limiting their daily access to water. The animals were given free access to water seven to ten minutes after each daily experimental session, and multi-vitamins were mixed in their water to maintain optimal health conditions. Purina laboratory chow was always available in each rat's home cage during the course of the experiment.

Apparatus

Five identical chambers were used. The interior dimensions of each chamber were 20 cm. long, 13 cm. wide, and 15 cm. deep. The ceiling and walls were made of plexiglas, and the interior surface of the walls was covered with aluminum sheets. The floor of each chamber consisted of a grid of four tubular rods, 1.9 cm. in diameter.

On the front wall, a stationary standard response bar was mounted, 3 cm. from the left edge of the front wall and 11 cm. above the floor of the chamber. This response bar was deactivated, and never used throughout the experiment. On the right side of the front wall, 2 cm. above the floor of the chamber, there was a circular opening, 2.5 cm. in diameter. This circular opening provided occasional access to a dipper which normally rested in a reservoir containing milk. When the dipper was raised, it provided access to a drop of milk.

Two circular openings, each 2.5 cm. in diameter, were located on the back wall, 9 cm. above the chamber floor, and 3.5 cm. from the left and right edges of the wall respectively. Each opening could be illuminated by a light from behind. These lights were called the lever lights. Directly underneath the two lever lights, two standard omni-directional response levers were located 5 cm. above the floor. These omni-directional response levers were tubular shaped, 0.5 cm. in diameter, and were designed to close a microswitch when a force of 25 gms. was applied to them from any direction.

On the "side" wall, facing the door of the chamber, a circular opening, 2.5 cm. in diameter, was located, 9 cm. above the floor, and equidistant from the left and right edges of the side wall. This circular opening could be illuminated with a red light which was called the "inter-trial interval light." Also on the side wall, a tone generator (Sonalert Model SC 628) was mounted.

Each experimental chamber was enclosed in a sound-attenuated cabinet. The cabinet contained a house-light and a fan. Extraneous sounds were masked by white noise presented through a speaker connected to a Grason-Stadler (Model 901B) white noise generator.

A PDP8/E computer controlled the programming of the experimental conditions and the recording of the data. The controlling software, SUPER SKED (Snapper and Inglis, 1979), allowed for programming and data analysis while the experiments were running. The computer was located in an adjacent room. The experimental chambers were connected to the computer through an interface provided by State Systems, Inc., Kalamazoo, Michigan.

Preliminary Training

Shaping lever pressing

The rats were trained to approach the dipper and drink milk at the sound of the dipper mechanism. They were then hand-shaped to press the right omni-directional lever on the back wall for milk. The light over the right lever was continuously illuminated, except during dipper presentation. During the hand-shaping of the right lever press, the left lever was removed from the experimental chamber. The lever pressing was considered established when the rats had obtained 50 milk presentations during a 15 minute period. Thereafter, training on the right lever was continued for three additional daily sessions of 50 milk presentations.

This was followed by training for the left lever press. During the left lever training, the right lever was removed from the experimental chamber, and the light over the left lever was illuminated. The rats acquired the left lever press without requiring additional hand-shaping. Once they obtained 50 milk presentations during a 15 minute period, the rats were given 3 more daily sessions with only the left lever present in the experimental chamber.

Training for pressing reinforcement lever

With both levers present in the experimental chamber, the rats were exposed to a discrete trial procedure in which they would receive milk only for pressing the lever over which the light was illuminated. A session began with the illumination of the house light and the red inter-trial interval (ITI) light. At the end of the 60 second ITI, the red light was turned off and a tone was turned on. Simultaneous with the tone presentation, one of the lever lights on the back wall was randomly illuminated with a 0.5 probability. The lever under that light was designated as the reinforcement lever. The first response on the reinforcement lever produced a sequence of six three-second presentations of milk. In each presentation of milk, the dipper arm containing the milk was raised for 3 seconds and dropped down for 0.5 seconds to refill the dipper. The milk used was diluted to a concentration of 1 cup of dried milk powder to 2 quarts of water. During milk presentation, the lever light and the tone were turned off. After milk presentation, the 60 second ITI was initiated. After the ITI, the next trial began. Responses during the ITI had no effect. During the trial, responses on the lever without the light turned off the lever light and initiated the ITI. A daily session lasted for 50 trials.

The rats were trained in this procedure until the mean percentage of correct responding (responding on the lever over which the light was illuminated) during the last 5 sessions was above 90%. This took a minimum of 30 sessions. Following the training for pressing the reinforcement lever, the rats were arbitrarily divided into two groups. Each group of five rats was used in one experiment. The procedures for each group will be discussed separately.

Procedures

Basic procedure: Two-lever discrete-trial geometric progressive ratio

The essential features of the basic procedure are illustrated by the state diagram in Figure 1. The sessions began with a one second ITI period, during which the red light was illuminated. At the end of the ITI period, the red light was turned off, the tone was presented, and one of the lever lights was randomly illuminated with a 0.5 probability. Simultaneous with the lever light illumination, the computer determined the number of responses required for milk

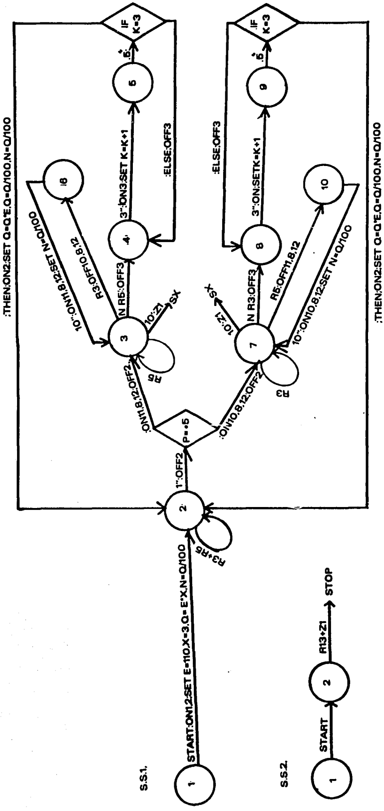
S.S.1.
1
START:ON12:SET E=110,X=3,Q=E*X,N=Q/100
2
R3+R5
1":OFF2
P=.5
:ON11,8,12:OFF2
:ON10,8,12:OFF2
3
7
R5
R3
10":Z1
SX
N R5:OFF3
N R3:OFF3
10":ON11,8,12:SET N=Q/100
10":ON10,8,12:SET N=Q/100
R3:OFF10,8,12
R5:OFF11,8,12
18
10
4
8
3":ON3:SET K=K+1
3":ON:SETK=K+1
:ELSE:OFF3
:ELSE:OFF3
5
9
.5"
.5"
IF K=3
IF K=3
:THEN:ON2:SET Q=Q*E,Q=Q/100,N=Q/100
:THEN:ON2:SET Q=Q*E,Q=Q/100,N=Q/100
S.S.2.
1
START
2
R13+Z1
STOP

FIGURE 1

presentation based on a geometric progression. Completion of the response requirement (ratio) by responding on the reinforcement lever produced a sequence of three milk presentations in the same manner as during the initial training. During milk presentation, the lever light and the tone were turned off, and after a one second ITI, a new trial was initiated, and the position of the reinforcement lever was redetermined.

The first response on the lever without the light (non-reinforcement lever) produced a 10 second timeout period during which the lever light and the tone were turned off. After the timeout period, the lever light on the same lever was illuminated, and the response requirement for the milk presentation remained at the same level. The rat was not given any credit for the responses which had already been emitted on the reinforcement lever before the response on the non-reinforcement lever. Thus, for milk presentation, the rat was required to make the determined number of responses on the reinforcement lever, uninterrupted by a response on the non-reinforcement lever.

Each session continued until the rat did not make any responses for a ten-minute period. Sessions were generally conducted seven days a week, at approximately the same time each day.

Geometric and arithmetic progressions

The geometric progression was determined in the following manner. The initial value was set at an arbitrarily determined figure. For each subsequent trial, the ratio value of the previous trial was multiplied by a constant value (increment value), and the product was rounded to the nearest integer. This value specified the number of responses required for each reinforcement. The arithmetic progression was determined in the same manner, except that a constant value was added to the previous response requirement. Sample values for the first 25 trials for the various progressions used in these experiments are presented in Table I.

Stability criterion

The stability criterion was based on the final completed ratio, inspected after each session. The behavior of the rats was considered stable when no trend, increasing or decreasing, was observed in the final completed ratio for three consecutive sessions. Unless otherwise indicated, the rats were not introduced to a new procedure until they reached the stability criterion.

TABLE I

GEOMETRIC AND ARITHMETIC PROGRESSIONS

	Geometric							Arithmetic	
	Init. Val.= 3						Init. Val.= 10	Init. Val.= 2	
	Inc. Val.= 1.05	Inc. Val.= 1.07	Inc. Val.= 1.09	Inc. Val.= 1.10	Inc. Val.= 1.11	Inc. Val.= 1.12	Inc. Val. = 1.12	Inc. Val.= 1	Inc. Val.= 2
1-	3	3	3	3	3	3	10	2	2
2-	3	3	4	4	4	4	11	3	4
3-	3	4	4	4	4	4	13	4	6
4-	4	4	4	4	5	5	14	5	8
5-	4	4	5	5	5	5	16	6	10
6-	4	5	5	5	6	6	18	7	12
7-	4	5	5	6	6	7	20	8	14
8-	4	5	6	6	7	7	22	9	16
9-	5	6	7	7	8	8	25	10	18
10-	5	6	7	8	9	9	28	11	20
11-	5	6	8	9	9	10	31	12	22
12-	5	7	8	9	10	12	35	13	24
13-	6	7	9	10	12	13	40	14	26
14-	6	8	10	11	13	15	44	15	28
15-	6	8	11	13	14	16	49	16	30
16-	7	9	12	14	16	18	55	17	32
17-	7	9	13	15	18	21	61	18	34
18-	7	10	14	17	20	23	69	19	36
19-	8	11	15	18	22	26	77	20	38
20-	8	12	17	20	24	29	86	21	40
21-	8	12	18	22	27	32	96	22	42
22-	9	13	20	24	30	36	108	23	44
23-	9	14	22	27	33	41	121	24	46
24-	10	15	24	30	37	46	136	25	48
25-	10	16	26	33	41	51	152	26	50

EXPERIMENT 1 : THE EFFECT OF INCREMENT VALUES

Procedures

The purpose of this experiment was to determine the effect of increment values on the final completed ratio. Four groups of manipulations were made. Each group will be discussed separately, in the same order in which they were carried out.

I. Parameter manipulation of increment value

The rats were exposed to the basic two-lever discrete-trial geometric progressive ratio procedure described above. The initial value of the progressive ratio was set to three. The increment value was set at 1.10, 1.11, and 1.12 in three conditions.

II. Effect of higher initial value

As can be seen in Table I, the response requirement to obtain the first 20 or so milk presentations was not drastically different across increment values of 1.10, 1.11, and 1.12, when the initial value was set to 3. Accordingly, rats could obtain a minimum number of milk presentations and yet differences in the final completed ratio would not be observed. Thus, the same basic procedure was used, but the initial response requirement was set to 10. The increment value was kept at 1.12.

Also, in the basic procedure, if the rat responded on the nonreinforcement lever before completing a ratio, he did not receive credit for the already emitted responses, and the ratio count for that trial was started from the beginning. This feature of the procedure could function as a hurdle preventing the rat from receiving milk, in spite of his continuous responding. Since the problem could become particularly acute with the higher response requirement when the initial value was increased, the effect of the higher increment value was further examined when responding on the non-reinforcement lever was inconsequential. That is, the 10-second timeout was removed and the rat was given credit for each response on the reinforcement lever, irrespective of responses on the non-reinforcement lever.

III. Arithmetic progressive ratio

The purpose of this group of manipulations was to restore the rats' responding so that further manipulations could be made. The rats were exposed to the same procedure as in the last condition, but using an arithmetic progressive ratio with an initial value of 2 and an increment value of 1. In addition, in a second condition, the left lever was removed from the experimental chamber. Thus, the rats were not given the opportunity to respond on the non-reinforcement lever.

IV. Parametric manipulation of increment value using a simplified procedure

The increment value was again parametrically manipulated to determine the effect on the final completed ratio, uncontaminated by discrimination problems. Thus, the single-lever procedure described above was used, but with a geometric progressive ratio. The initial value was again set to 3, and increment values of 1.05, 1.07, and 1.09 were examined. The lower increment values were chosen so that the response requirements would be on the same order of magnitude as in the arithmetic progressive ratio used above.

Results

The number of sessions in each condition for each set of manipulations is shown in Table II. The results will be discussed under three headings: (1) Final completed ratio and obtained reinforcement, (2) Responses on each lever and percentage of responses on the non-reinforcement lever, and (3) Response rate.

Final completed ratio and obtained reinforcement

The presentation of milk contingent on the completion of an increasing number of responses functioned as reinforcement, depending on the size of the response requirement. When the response requirement became excessive, the rats stopped pressing the lever. The number of responses required, at which the rats stopped performing, varied for the individual rats. This number is presented as the final completed ratio. The final completed ratio is the number of responses required in the last ratio that the animal completed and for which he received reinforcement. Each sequence of milk presentations, as described in the basic procedure, was counted as a single obtained reinforcement. Figure 2 presents the mean final completed ratios (various figures with solid lines), and the mean number of obtained reinforcements (open circles with broken lines) for each

TABLE II

NUMBER OF SESSIONS IN EACH CONDITION FOR EACH SET OF MANIPULATIONS

	Geometric					Arithmetic		Geometric		
	Initial Value = 3			Initial Value = 10		Initial Value = 2		One Lever		
	Increment Values =			With	Without	Two	One	Increment Values =		
	1.10	1.11	1.12	T.O.	T.O.	Lever	Lever	1.05	1.07	1.09
Rat	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
356	21	25	21	5	5	14	10	5	5	5
359	21	25	21	5	5	14	10	5	5	5
360	21	25	21	5	5	14	10	5	5	5
361	21	25	21	5	5	14	10	5	5	5
364	21	25	21	5	5	14	10	5	5	5

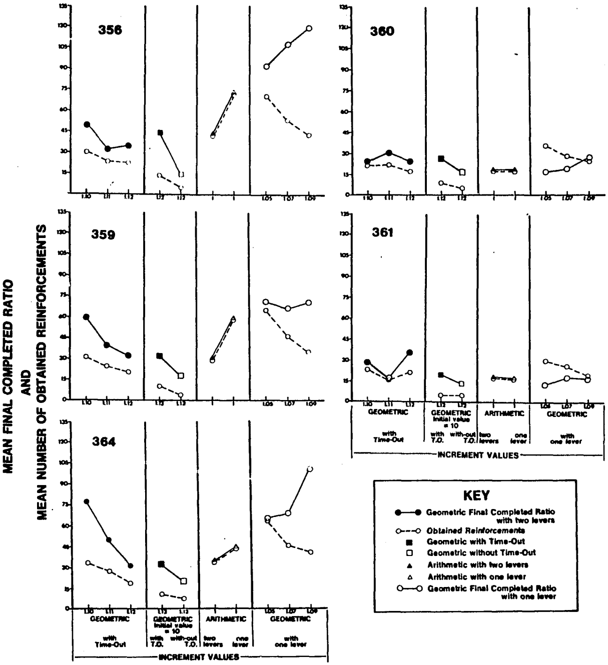
MEAN FINAL COMPLETED RATIO
AND
MEAN NUMBER OF OBTAINED REINFORCEMENTS
356
360
359
361
364
GEOMETRIC
with Time-Out
GEOMETRIC
Initial value = 10
with T.O.
with-out T.O.
ARITHMETIC
two levers
one lever
GEOMETRIC
with one lever
INCREMENT VALUES
KEY
Geometric Final Completed Ratio with two levers
Obtained Reinforcements
Geometric with Time-Out
Geometric without Time-Out
Arithmetic with two levers
Arithmetic with one lever
Geometric Final Completed Ratio with one lever

FIGURE 2

group of experimental manipulations. Each data point in Figure 2 represents the mean of the last three sessions in each experimental condition. The results from each group of experimental manipulations are discussed separately.

I. Parametric manipulation of increment value. In the first panel of Figure 2, the mean final completed ratio, and the mean number of obtained reinforcements are shown as a function of increment values. The mean final completed ratio is indicated by closed circles. For the two rats, 359 and 364, the mean final completed ratio and the mean number of obtained reinforcements declined as a function of the increases in the increment value. For the other rats, 356, 360, and 361, the mean final completed ratio and the mean number of obtained reinforcements did not systematically relate to the increases in the increment values. These results are clearly in conflict with the results of Hodos (1967) and Hodos and Kalman (1963). These researchers found an increasing function relating the final completed ratio and the increment values.

II. The effect of the higher initial value. The mean final completed ratio and the mean number of obtained reinforcements for this group of manipulations are shown in the second panel of Figure 2. The mean final completed ratio is shown as closed and open squares for the first and second conditions respectively. In the first condition (in which the responding on the non-reinforcement lever was consequential), the higher initial value did not produce greater final completed ratios. For all of the rats, the mean final completed ratio remained at approximately the same level as in the last condition of the previous set of manipulations. The higher initial value, however, reduced the obtained number of reinforcements for all of the rats.

The daily inspection of the data showed a declining trend in both mean final completed ratio and mean number of obtained reinforcements. It was assumed that with prolonged training in this procedure, responding would continue to deteriorate. Thus, the effect of the higher initial value was examined in the second condition, in which the responding on the non-reinforcement lever was inconsequential. The mean final completed ratio and mean number of obtained reinforcements, however, continued declining, suggesting that with prolonged training in this procedure, the responding would be totally lost. In summary, the effect of the higher initial value was a reduction both in final completed ratio and obtained reinforcement, whether the responses on the non-reinforcement lever were consequential or not.

III. Arithmetic progressive ratio. The mean final completed ratio and mean number of obtained reinforcements for this group of manipulations are shown in the third panel of Figure 2. The mean final completed ratio is shown as closed and open triangles, for the two conditions, respectively. For rats 356, 359, and 364, when the arithmetic progressive ratio procedure was introduced, the mean final completed ratio, and the mean number of obtained reinforcements slightly increased over the previous condition. For rats 360 and 361, the mean final completed ratio and mean number of obtained reinforcements did not significantly change. The small magnitude of changes in the data could be due to the responses on the non-reinforcement lever.

When the rats were not given the opportunity to respond on the non-reinforcement lever, in the second condition, the mean final completed ratio, and mean number of obtained reinforcements for Rats 356, 359, and 364 increased to a much greater extent. However, the performances of Rats 360 and 361 again were not significantly changed. Thus, for three of the rats, the arithmetic ratio schedule, particularly with the single-lever procedure, generated greater final completed ratios, and thus an increase in obtained reinforcement.

IV. Parametric manipulation of increment values using a simplified procedure. In the last panel of Figure 2, the mean final completed ratio and mean number of obtained reinforcements were again shown as a function of the increment values. The mean final completed ratio is shown by open circles connected by solid lines. The mean final completed ratio increased as a function of increment value increases for Rats 356, 360, and 364. However, it remained relatively unchanged for Rats 359 and 361. At the same time, the mean number of obtained reinforcements monotonically decreased as a function of the increases in the increment value for all rats. Thus, three of the rats produced final completed ratios showing a similar functional relationship to increment value as that found by previous researchers (Hodos, 1967; Hodos and Kalman, 1963) with the arithmetic progressive ratio schedules.

Responses on each lever and percentage of responses on the non-reinforcement lever

Table III shows the mean number of responses on the reinforcement and non-reinforcement levers and the mean percentage of responses on the non-reinforcement lever for each condition in which two levers were present in the experimental chamber. This includes the three initial conditions in which increment values were manipulated, the two conditions with the higher initial value, and the first condition using the arithmetic progressive ratio procedure. Each number represents the mean of the last three sessions in that condition for each rat. The mean percentage of responses on the non-reinforcement lever was calculated by dividing the mean number of responses on the non-reinforcement lever by the mean total number of responses and multiplying the result by 100. The data from each group of experimental manipulations is again discussed separately.

I. Parametric manipulation of increment value. As can be seen in Table III, the mean number of responses on the reinforcement lever during these conditions (1-3), for all of the rats, was quite variable, ranging from 137 to 846. As would be expected, this mean shows the same functional relationships to increment value as the final completed ratio did. That is, for Rats 359 and 364, the mean number of responses on the reinforcement lever decreased as the increment values increased; the mean for the other rats showed no systematic relationship.

The mean number of responses on the non-reinforcement lever during these conditions (1-3) was very small, ranging from 0 to 4.6, and showed no significant changes across conditions. The percentage

TABLE III

RESPONSES ON BOTH LEVERS

	Geometric					Arith-metic
	Init. Val. = 3			Init. Val. = 10		
Rat	Inc. Val. =1.10 (1)	Inc. Val. =1.11 (2)	Inc. Val. =1.12 (3)	With T.O. (4)	With-out T.O. (5)	Two Lever (6)
Mean Responses on Reinforcement Lever						
356	527	298	305	318	129	967
359	611	365	273	207	57	476
360	231	287	192	161	70	217
361	287	137	306	106	104	216
364	846	491	271	221	130	623
Mean Responses on Non-Reinforcement Lever						
356	0.3	0.3	3.6	0.6	33.6	315.3
359	0.3	0.3	0	0	0.3	34.0
360	4.0	2.6	1.0	0.3	26.0	1.6
361	4.6	0.3	2.0	2.3	2.6	26.3
364	3.3	0.6	0	0.6	21.3	102.0
Percentage of Responses on the Non-Reinforcement Lever						
356	0.0%	0.1%	1.1%	0.1%	20.6%	24.5%
359	0.0%	0.0%	0.0%	0.0%	0.5%	6.6%
360	1.7%	0.8%	0.5%	0.2%	27.0%	0.7%
361	1.5%	0.2%	0.6%	2.1%	2.4%	10.8%
364	0.3%	0.1%	0.0%	0.2%	14.0%	14.0%

of responses on the non-reinforcement lever ranged from 0 to 1.7%. Since the rats made very few responses on the non-reinforcement lever, the contradiction between these results and those of previous researchers (Hodos, 1967; Hodos and Kalman, 1963) cannot be explained by poor discrimination of the reinforcement lever.

II. The effect of the higher initial value. The decline in responding with the higher initial value can also be seen by examining Table III. The mean responses on the reinforcement lever declined for four of the five rats when the initial value was increased (Condition 4). In addition, when responding on the non-reinforcement lever was inconsequential (Condition 5), the responding on the reinforcement lever further declined.

When the responding on the non-reinforcement lever was consequential (Condition 4), both the mean number of responses, and the mean percentage of responses on the non-reinforcement lever remained at approximately the same level as when the initial value was lower (Conditions 1-3). However, when the responding on the non-reinforcement lever was inconsequential (Condition 5), the mean responses and mean percentage of responses on the non-reinforcement lever increased markedly. Thus with a high initial value, when there were no consequences for responding on the non-reinforcement lever, the rats tended to respond more frequently on that lever, and less frequently on the reinforcement lever.

III. Arithmetic progressive ratio. As can be seen in Table III, when the two-lever arithmetic progressive ratio procedure was used (Condition 6), the mean responses on the reinforcement lever for all rats increased substantially in the same way as the final completed ratio did. For Rats 356, 359, 361, and 364, mean responses and mean percentage of responses on the non-reinforcement lever also increased substantially. Three of these rats, 356, 359, and 364, were the same rats whose final completed ratio was most affected by the arithmetic progressive ratio procedure. For Rat 360, the mean responses and the mean percentage of responses on the non-reinforcement lever decreased. These results suggest that responding on both levers increased with the arithmetic progressive ratio procedure, and stimulus control further declined for four of the five rats.

Response rate

In Figure 3, the mean response rate and mean number of responses on the reinforcement lever are shown for the first and last part of Experiment 1; that is, for those sets of manipulations involving the increment values. The response rate was calculated as the total number of responses on the reinforcement lever in a session, divided by the duration of that session (with ITIs and reinforcement durations subtracted). The mean response rate for the last three sessions of each condition is indicated with closed circles in Figure 3. The mean number of responses on the reinforcement lever for the last three sessions of each condition is indicated with open circles in Figure 3.

I. Parametric manipulation of increment value. The data in the first panel of Figure 3 were obtained with the two-lever basic

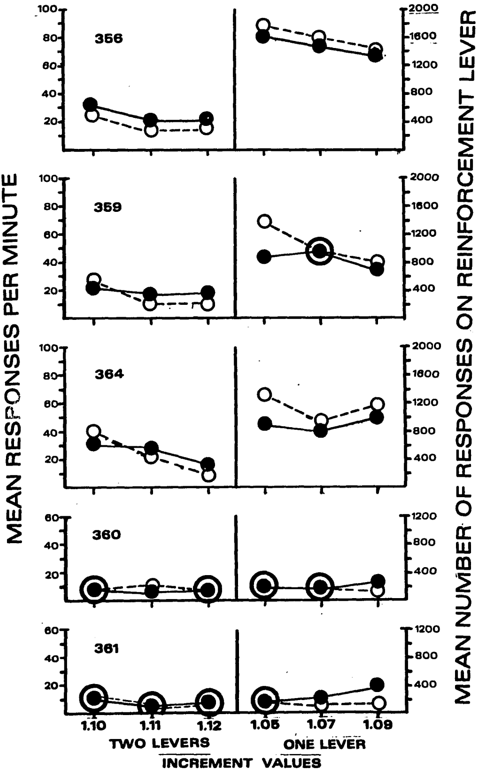
356
359
364
360
361
MEAN RESPONSES PER MINUTE
MEAN NUMBER OF RESPONSES ON REINFORCEMENT LEVER
1.10
1.11
1.12
1.05
1.07
1.09
TWO LEVERS
ONE LEVER
INCREMENT VALUES

FIGURE 3

geometric progressive ratio procedure used in the first part of the experiment. For Rat 364, the mean response rate and mean number of responses on the reinforcement lever decreased very slightly as a function of the increases in the increment values. For the other rats, the mean response rate and mean responses on the reinforcement lever were not systematically related to the increment values.

IV. Parametric manipulation of increment value using a simplified procedure. The data in the second panel of Figure 3 were obtained with the simplified one-lever geometric progressive ratio procedure used in the last set of manipulations in Experiment 1. For Rat 356, the mean response rate decreased as a function of increment value, and for Rat 361, it increased. For the other rats, no systematic relationship appeared. For Rats 360, 361, and 364, the mean number of responses on the reinforcement lever also was not systematically related to the increment values. For Rats 356 and 359, the mean number of responses on the reinforcement lever decreased as a function of increases in the increment values. In summary, the response rate was less senstitive to the manipulations of the increment value than was the final completed ratio.

Conclusion

The final completed ratio was not systematically related to increment values ranging from 1.10 to 1.12, using the two-lever basic geometric progressive ratio procedure, despite a high degree of discrimination of the reinforcement lever. However, using lower increment values, ranging from 1.05 to 1.09, and a simplified one-lever procedure, the final completed ratio systematically increased when the increment value increased for three of the five rats. It appeared that the behavior of the other two rats remained relatively unchanged irrespective of the experimental manipulations. At the same time, the mean number of obtained reinforcements monotonically decreased as a function of the increases in the increment value for all rats, but especially for those rats whose final completed ratios increased.

In addition, when responses on the non-reinforcement lever were followed by a timeout period and the loss of credit for already emitted responses on the reinforcement lever, the rats consistently responded on the reinforcement lever, suggesting a high degree of stimulus control. When responses on the non-reinforcement lever were not followed by these consequences, the rats tended to respond on both levers, suggesting a weakening of the stimulus control. The occurrences of responses on the non-reinforcement lever were not located during a certain portion of the session. They occurred during the post reinforcement pauses and in the middle of a ratio run. Also, it appeared that response rate and the number of responses on the reinforcement lever were relatively insensitive to the experimental manipulations.

EXPERIMENT 2 : THE EFFECT OF TIMEOUT DURATIONS AND REPLICATIONS OF EXPERIMENT 1

Procedures

The purpose of this experiment was to explore the relative reinforcement value of a reduction in the response requirement of a geometric progressive ratio schedule. The maximum completed ratio was examined as a function of the parametric manipulations of timeout durations preceding the reduction in the response requirement. In addition, the results of Experiment 1 were systematically and directly replicated. In this experiment also, four different sets of manipulations were carried out. They will each be discussed separately in the order in which they were presented.

I. Parametric manipulations of timeout durations. The same basic two-lever discrete-trial geometric progressive ratio procedure as used in Experiment 1 was used, with the following exceptions: a) When a light was illuminated over a lever, the occurrence of a response on the lever without the light (reset lever) produced a timeout period and reset the response requirement for milk presentation to its minimum value; and b) The session ended either after the rats obtained 50 milk presentations or when the rat stopped responding for a 10 minute period. The duration of the response-contingent timeout period was parametrically manipulated, and timeout durations of 10 seconds, 20 seconds, and 40 seconds were used during three different conditions. In each condition, the geometric progression had an initial value of 3 and an increment value of 1.10.

II. Removal of the reset option. The purpose of this manipulation was to examine the rats' behavior when the responses on the reset lever no longer reset the response requirement to its minimu value. It was assumed that if the responses on the reset lever occasionally occurred due to a failure to discriminate the reinforcement lever, rather than due to an excessive response requirement on that lever, the rats would complete greater ratios when the reset lever no longer functioned. The rats were thus exposed to the same procedure as in the first part of the experiment except that responses on the non-reinforcement lever did not produce a timeout period and did not reset the response requirement to its minimum value.

III. Arithmetic progressive ratio: A systematic replication. In the third part of Experiment 1, an arithmetic progressive ratio with an initial value of 2 and an increment value of 1 was used to restore responding. It could be argued that the increment value of 1 was too small to produce larger final completed ratios before the rats would be satiated. The procedures of that experiment were systematically replicated using an increment value of 2. The rats were initially exposed to a two-lever arithmetic progressive ratio procedure, as in the third part of Experiment 1, except with the higher increment value. Later, the same arithmetic progressive ratio procedure was used, but the left lever was removed from the experimental chamber, precluding the opportunity to respond on the non-reinforcement lever.

IV. Parametric manipulation of increment value using a simplified procedure: A direct replication. The purpose of this set of manipulations was to replicate the results of the last part of Experiment 1, and to extend their generality to this group of rats. The same one-lever geometric progressive ratio procedure with the same initial and increment values was used as in Part 4 of Experiment 1. The initial value was 3 and the increment values were 1.05, 1.07, and 1.09.

Results

The number of sessions in each condition for each set of manipulations is shown in Table IV. The results will be discussed under two headings: 1) Final completed ratio and obtained reinforcement, and 2) Responses on each lever, and percentage of responses on the non-reinforcement lever.

Final completed ratio and obtained reinforcement

Figure 4 presents the mean final completed ratio (various figures with solid lines), and the mean number of obtained reinforcements (open circles with broken lines) for each group of experimental sessions. Each data point in Figure 4 represents the mean of the last three sessions in each experimental condition.

I. Parametric manipulation of timeout durations. The data of this group of manipulations are shown in the first panel of Figure 4. Since the rats could reset the ratio to its minimum value at any time during a session, the final completed ratio, as defined in

TABLE IV

NUMBER OF SESSIONS IN EACH CONDITION FOR EACH SET OF MANIPULATIONS

	Geometric				Arithmetic		Geometric		
	Timeout Durations With Reset			No T.O. No Reset	Two Lever	One Lever	Increment Values		
							1.05	1.07	1.09
	10"	20"	40"						
Rat	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
350	21	25	21	10	14	10	5	5	5
351	19	25	21	10	14	10	5	5	5
352	20	25	21	10	12	10	5	5	5
353	21	25	21	10	12	10	5	5	5
354	21	25	19	10	14	10	5	5	5

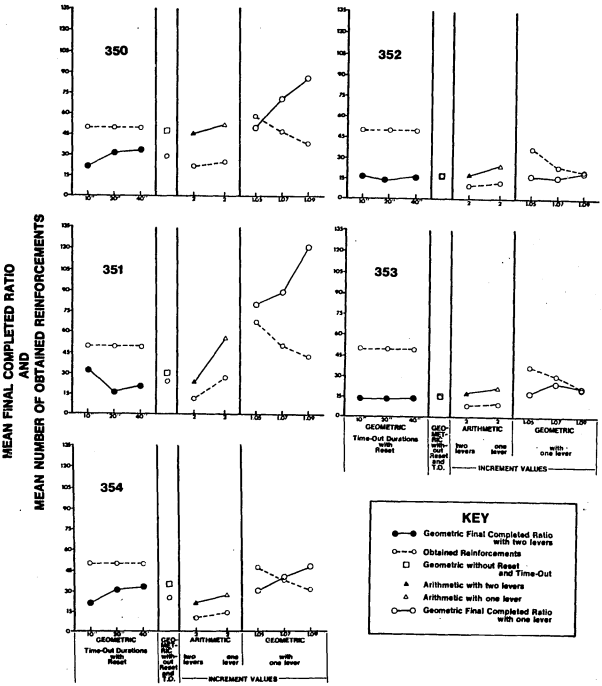
MEAN FINAL COMPLETED RATIO
AND
MEAN NUMBER OF OBTAINED REINFORCEMENTS
350
352
351
353
354
GEOMETRIC
Time-Out Durations with Reset
GEO-MET-RIC with-out Reset and T.O.
ARITHMETIC
two levers
one lever
GEOMETRIC
with one lever
INCREMENT VALUES
KEY
Geometric Final Completed Ratio with two levers
Obtained Reinforcements
Geometric without Reset and Time-Out
Arithmetic with two levers
Arithmetic with one lever
Geometric Final Completed Ratio with one lever

FIGURE 4

Experiment 1, was not a useful measure. Instead the maximum ratio size which was achieved by an animal before he reset the ratio was taken as a measure of reinforcement value. Accordingly, only for this group of manipulations, the mean of the maximum completed ratio is called mean final completed ratio, and is indicated with closed circles in Figure 4. In the first panel, both measures are presented as a function of the timeout durations.

For Rats 351, 352, and 353, the mean maximum completed ratio was not systematically related to the timeout durations. For Rats 350 and 354, the mean maximum completed ratio appears to be increasing as a function of increasing timeout durations. All of the rats invariably obtained the full 50 reinforcements in a session, suggesting that satiation was not a major variable determining the rats' performance.

II. Removal of the reset option. Since the reset option was removed in this condition, the final completed ratio, as defined in Experiment 1, was again used as the measure of reinforcement value. Mean final completed ratio is represented by an open square in the second panel of Figure 4. Removing the reset option from the procedure did not produce significant changes in the mean final completed ratio for four of the rats, 351,352, 353, and 354. However, it did lead to an increase in the mean final completed ratio for one rat, 350. In addition, the mean number of obtained reinforcements decreased substantially from the previous level for all of the rats as a result of removing the reset option. The rats always terminated the session by pausing for ten minutes before they had obtained

50 reinforcements. These results suggest that when the response requirement increased on the reinforcement lever, most of the rats did not increase their responding when they could not reset the ratio, in spite of thus obtaining fewer reinforcements than in the previous conditions. This suggests that the increased response requirement was a more critical variable determining the final completed ratio than the rats' occasional failure to discriminate the reinforcement lever.

III. Arithmetic progressive ratio: A systematic replication. When these rats were exposed to the same arithmetic progressive ratio procedures as the rats in Experiment 1, but with a higher increment value, the results showed similar functions to those found in that experiment. The mean final completed ratio is represented in the third panel of Figure 4 by closed and open triangles for the two conditions (two-lever and one-lever) respectively.

When the arithmetic progressive ratio 2 with an increment value of 2 was introduced, the mean final completed ratio did not significantly change for any of the rats. However, the mean number of obtained reinforcements slightly decreased for all of the rats. When the rats were not given an opportunity to respond on the non-reinforcement lever, the mean final completed ratio increased for all rats, although the increase was very slight for Rats 352 and 353. At the same time, the number of obtained reinforcements also increased, but the rate of increase was generally lower than that of the final completed ratio.

IV. Parametric manipulation of increment value using a simplified procedure: A direct replication. The mean final completed ratio (open circles with solid lines), and the mean number of obtained reinforcements (open circles with broken lines) are shown as a function of the increment values, 1.05, 1.07, and 1.09, in the fourth panel of Figure 4. For Rats 350, 351, and 354, the mean final completed ratio increased while the mean number of obtained reinforcements decreased as a function of the increases in the increment values. For the other two rats, 352 and 353, while the obtained reinforcements also decreased as a function of increases in increment value, the mean final completed ratio showed no relationship. These results supported those found in the last conditions of Experiment 1, and increased their generality to these rats.

Responses on each lever and percentage of responses on the non-reinforcement lever

In Table V, the mean number of responses on the reinforcement and non-reinforcement levers and the percentage of responses on the non-reinforcement lever are shown for each condition in which two levers were present in the experimental chamber. These include the three initial conditions in which timeout duration on the reset lever was manipulated, the condition in which the reset lever was made inconsequential, and the two-lever arithmetic progressive ratio condition. Each number represents the mean of the last three sessions in each condition for each rat. The data from each group of manipulations are again discussed separately.

I. Parametric manipulations of timeout durations. As can be

TABLE V

RESPONSES ON BOTH LEVERS

	Geometric			Arithmetic	
	Timeout Duration With Reset			No T.O. No Reset	Two-Lever
Rat	10" (1)	20" (2)	40" (3)	(4)	(5)
Mean Responses on Reinforcement Lever					
350	444	477	385	490	526
351	513	314	369	319	166
352	356	311	304	175	111
353	321	311	313	150	95
354	394	498	408	358	122
Mean Responses on Non-Reinforcement Lever					
350	2.3	3.6	3.3	178.6	233.6
351	3.0	5.0	2.6	39.3	53.6
352	4.6	4.3	5.3	31.6	26.3
353	6.3	3.6	3.6	8.6	3.6
354	3.3	2.3	3.0	5.0	2.0
Percentage of Responses on the Non-Reinforcement Lever					
350	0.5%	0.7%	0.8%	26.7%	30.7%
351	0.5%	1.5%	0.6%	10.9%	24.4%
352	1.2%	1.3%	1.7%	15.3%	19.1%
353	1.9%	1.1%	1.1%	5.4%	3.6%
354	0.8%	0.4%	0.7%	1.3%	1.6%

seen in Table V, the mean number of responses on the reinforcement lever during these conditions (1-3) varied for each rat, and ranged from 304 to 513. These responses were relatively unaffected by changes in timeout duration, as they did not systematically vary across conditions. The mean number of responses on the non-reinforcement lever (reset lever) was quite small, ranging from 2.3 to 6.3, but consistantly occurred in each session. The percentage of responses on the non-reinforcement lever, ranging from 0.4% to 1.9%, also was small suggesting a high degree of discrimination of the reinforcement lever. Both of these measures were also relatively unchanged across the conditions. These results indicated that the rats did not reset the ratio to its minimum value after each reinforcement, but instead, they increased the ratio and obtained several reinforcements before resetting the ratio requirement to its minimum value.

II. Removal of the reset option. As can be seen in Table V, when the reset and timeout consequences were no longer presented contingent on responses on the non-reinforcement lever (Condition 4), the rats tended to distribute their responses on both levers. Four of the rats, 351, 352, 353, and 354, responded less frequently on the reinforcement lever, and more frequently on the non-reinforcement lever, leading to an increased percentage of responses on the non-reinforcement lever. Rat 350, however, increased his responding on both levers, but to a greater extent on the non-reinforcement lever, also leading to an increased percentage of responding on the non-reinforcement lever. It should be noted that Rat 350 was also the only rat whose mean final completed ratio increased in this condition.

III. Arithmetic progressive ratio: A systematic replication. When the response requirement was determiend by an arithmetic progression, the mean number of responses on the reinforcement lever continued to change in the same direction as in the previous condition; Rat 350 further increased, and the other four rats further decreased their responses on the reinforcement lever. Rat 350 also continued increasing his responses on the non-reinforcement lever. Of the other four rats, three, 352,353, and 354 decreased their responses on the non-reinforcement lever, but one, 351, continued to increasingly respond on that lever. The variability in the distribution of the rats' responses on both levers is reflected in the percentage of responses on the non-reinforcement lever, which ranged from 1.6% to 30.7%. These results suggest that the introduction of the arithmetic progressive ratio procedure did not produce significant changes in responding, and thus, the rats obtained fewer reinforcements than in previous conditions.

Conclusion

The maximum completed ratio appeared to be generally relatively insensitive to the parametric manipulations of timeout duration contingent on responses on the reset lever, ranging from 10 seconds to 40 seconds. However, two rats showed a tendency toward an increasing maximum completed ratio with increasing timeout duration. All of the rats terminated the session by obtaining 50 reinforcements, indicating that satiation was not a major variable determining responding.

When the reset option was available, all of the rats responded on the reset lever, but infrequently. When the reset option was no longer available, the final completed ratio remained relatively unchanged although the rats thus obtained a smaller number of reinforcements. In addition, when the responses on the non-reinforcement lever were inconsequential, those responses increased. Thus, it appears that the responses on the non-reinforcement lever were not only a function of the consequences on that lever, but also a function of the consequences on the reinforcement lever.

The systematic replication of the arithmetic progressive ratio procedure, using an increment value of 2, generally did not produce a greater final completed ratio than in the previous condition. However, when the non-reinforcement lever was removed from the experimental chamber, two rats produced greater ratios. All of the rats obtained fewer reinforcements in this condition.

The direct replication of the parametric manipulation of increment value showed a similar functional relationship between final completed ratio, obtained reinforcement, and increment value as was found in Experiment 1. Three of the five rats showed increases in final completed ratio while the obtained reinforcements decreased as a function of the increases in increment value. The performance of the other two rats remained relatively unchanged irrespective of the experimental conditions.

DISCUSSION

The results of this study suggest that there may be some limitations on the use of the final completed ratio as a measure of reinforcement value. The systematic relationship between final completed ratio and increment values found in previous studies using arithmetic progressive ratio procedures was found with a geometric progressive ratio procedure only under limited conditions. The lack of relationship between final completed ratio and the higher increment values (1.10 to 1.12) with a two-lever procedure could be due to several factors. The most likely explanations involve the differences between arithmetic and geometric progressions.

In an arithmetic progressive ratio procedure, the proportion of increases in the response requirement declines after each reinforcement. Thus, as the progression increases, the schedule increasingly approximates a fixed ratio schedule in which reinforcement is delivered after a fixed number of responses. However, in a geometric progressive ratio procedure, the proportion of increases in the response requirement remains constant throughout the session, producing relatively high response requirements for later reinforcements.

In addition, the arithmetic and geometric progressive ratio schedules differ in their response requirements for the initial reinforcements. In the early stages, the response requirements in an arithmetic progressive ratio schedule increases rapidly in comparison to that of a geometric progressive ratio schedule. The multipliers typically used in geometric progressive ratio schedules are relatively low, to avoid immediate ratio strain. Thus, the response requirement increases very slowly initially, and requires larger ratios only later in the session. The increases in response requirements for arithmetic progressive ratio schedules are just the reverse; initially, the response requirement rises rapidly, but later slowly.

One factor contributing to the lack of relationship between final completed ratio and the increases in the higher increment values could be deprivation. Presumably, in the earlier part of the session, the animal is more deprived than in the later part. With a geometric progression, the response requirement during that earlier part of the session is relatively low, enabling the animal to obtain a number of reinforcements for a relatively low number of responses. In later parts of the session, when the response requirement is increasing rapidly, the animal may be relatively satiated. Thus, with higher increment values, and particularly with higher initial values, the animals are likely to quit earlier after obtaining some minimum number of reinforcements due to the interaction of the deprivation level within the session and the response requirement.

Hodos and Kalman's (1963) findings also support this explanation. In their experiments, as the increment value became larger, the rat would only respond as much as was necessary to obtain some minimum number of reinforcements, and then would quit. They still obtained increased final completed ratios, but this most likely was due to the nature of the response requirements of arithmetic progressive ratio procedures during the earlier part of the progression.

Another factor which may have affected the results of this experiment may be related to the response pattern established in the early part of the session. In an arithmetic progressive ratio procedure, to obtain the initial reinforcements, the animal has to complete relatively greater ratios because of the rapid early increase in response requirement. This may establish a pattern of responding which would not be disrupted by the smaller increases in the latter part of the session. In a geometric progressive ratio procedure, on the other hand, to obtain the initial reinforcements, the animal has to complete relatively small ratios. This may establish a response pattern which may be disrupted by the significantly greater increases in the response requirement in the latter part of the session. This aspect of the progression may be more pronounced with the higher increment values.

This factor may have been the reason that the Stewart et al. (1974) study modified the geometric progressive ratio procedure so that the earliest response requirements more closely approximated those of an arithmetic progressive ratio procedure. They used a geometric progressive ratio procedure with an initial value of 1 and an increment value of 1.25. However, for the first five reinforcements, the response requirement was set to 1, 4, 6, 10, and 12, and only thereafter increased as a multiple of 1.25. In a typical geometric progressive ratio procedure with an initial value of 1 and an increment value of 1.25, the response requirement for the first five reinforcements would be 1, 1, 2, 2, and 2. Unfortunately, they did not explain why this modification was made, so it is merely speculation that using the geometric progressive ratio procedure from the beginning might have precluded the level of responding needed to test the effects of the scopolamine in the study.

An additional factor which should be considered, especially in conjunction with the response pattern hypothesis, is the order effect. All of the animals in each experiment were presented with the conditions in the same order. Whether training in an earlier phase either facilitated or inhibited responding in a later phase remains unknown. The response pattern established in the early conditions with an initial value of 3 may have led to the sudden decline in responding when the initial value was set to 10. However, the similarity of the functional relationships found in the direct replication in Experiment 2, in which the initial conditions differed, suggest that the earlier conditions had less effect on the behavior than the experimental manipulations.

Another explanation of the difference in results under the early and late conditions of the experiment unfortunately was not ruled out. In the earlier procedure, with the higher increment values, a two-lever discrimination procedure was used. The animal was required to discriminate the reinforcement lever before responding, and was required to make no intermediate responses on the other, non-reinforcement, lever before obtaining reinforcement. In the later conditions, with the lower increment values, only one lever was present in the chamber, so the animal did not need to discriminate the reinforcement lever. It is possible that some aspect of the two-lever procedure precluded a positive relationship between the final completed ratio and the increment value. For example, the discrimination requirement itself may have functioned as an increased response requirement leading to earlier ratio strain. However, this seems to be a less probable explanation since the level of discrimination of the reinforcement lever under the initial two-lever conditions was extremely high.

Another factor which may have affected the results could be the criterion to end the daily sessions. In this study, a ten minute post reinforcement pause was used. This ten minute post reinforcement pause period was arbitrarily chosen. Presently, a reliable criterion to end the session in progressive ratio performance is unknown. It is possible that using a different measure based on inter-reinforcement intervals or the structures of responding to terminate the sessions could produce different results.

Additional factors which may explain the general low level of responding include the physical characteristics and placement of the response levers, and the reinforcement potency of the milk. As was stated earlier, omni-directional levers were used. These tubular levers, when compared with standard response bars, were significantly smaller. The difficulty in responding on these levers for the rats was reflected in the length of time needed to shape the lever response, and the unusual topographies the animals developed such as lever biting. It is possible that increased responding and more orderly relationships would have been obtained with standard response bars.

Also, the location of the levers on the wall opposite to the dipper may have increased the response requirement. The rats had to turn back to respond on the levers after each reinforcement. In most experiments using progressive ratio schedules, the dipper and response lever have been placed on the same wall. Thus, the physical arrangement of the levers could have also affected the level of responding and thus the relationships found.

The potency of the reinforcement could also have affected the results. Hodos (1961) found that sweetened condensed milk could function as reinforcement for rats even when they were not food deprived. The larger magnitudes of responding found in other studies using progressive ratio procedures may be explained by the use of sweetened condensed milk when the animals were also food deprived. It is possible that the lower level of responding in this study was at least partially a function of the use of non-sweetened milk, and that a more potent reinforcement would have led to different results.

This study can be seen as an exploratory study, since so few previous studies have used geometric progressive ratio procedures. It suggests that the use of the final completed ratio to assess reinforcement value with the geometric progressive ratio procedure may be limited by some characteristics of those procedures themselves. However, further work needs to be done to eliminate the confounding variables, such as the one- and two-lever procedures, the size and placement of the levers, and the potency of the reinforcement. Also, further experimentation would be necessary to determine if the establishment of a low level response pattern in early parts of a geometric progression, the within-session deprivation levels, or some combination of these explanations would account for the differences in the results of this study from previous studies. With these considerations in mind, the geometric progressive ratio procedure may still be a very useful tool to compare the reinforcement value of different parameters of reinforcement under various motivational conditions. However, it is clear that further work must be done to find the limiting conditions.

REFERENCES

Baum, W. M. Time allocation and negative reinforcement. Journal of the Experimental Analysis of Behavior, 1973, 20, 313-322.

Baum, W. M. and Rachlin, H. C. Choice as time allocation. Journal of the Experimental Analysis of Behavior, 1969, 12, 861-874.

Boivin, J. M. A comparison of choice procedures: Positive reinforcement. Unpublished Master's Thesis, Western Michigan University, 1978.

Catania, A. C. Concurrent performances: A baseline for the study of reinforcement magnitude. Journal of the Experimental Analysis of Behavior, 1963, 6, 299-300.

Catania, A. C. Concurrent operants. In W. K. Honig (Ed.), Operant Behavior: Areas of Research and Application. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1966.

Chung, S. H. and Herrnstein, R. J. Choice and delay of reinforcement. Journal of the Experimental Analysis of Behavior, 1967, 10, 67-70.

Dantzer, R. Brief communication: Effect of Diazepam on performance of pigs in a progressive ratio schedule. Physiology and Behavior, 1976, 17, 161-163.

Dardano, J. F. Reversal of performance under progressive ratio schedules by punishment. Journal of the Experimental Analysis of Behavior, 1968, 11, 133-146.

Dardano, J. F. Self-imposed timeouts under increasing response requirements. Journal of the Experimental Analysis of Behavior, 1973, 19, 269-292.

Dardano, J. F. Response-produced timeouts under a progressive ratio schedule with a punished reset option. Journal of the Experimental Analysis of Behavior, 1974, 22, 103-113.

Dardano, J. F. and Sauerbrunn, D. Selective punishment of concurrent progressive ratio behavior. Journal of the Experimental Analysis of Behavior, 1964, 7, 51-65.

De la Garza, R. R. A comparison of choice procedures: Negative reinforcement. Unpublished Master's Thesis, Western Michigan University, 1978.

Deluty, Z. M. and Church, M. R. Time allocation matching between punishing situations. Journal of the Experimental Analysis of Behavior, 1978, 29, 191-198.

de Villiers, P. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig and J. E. R. Staddon (Eds.), Handbook of Operant Behavior, Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1977.

Findley, J. D. Preference and switching under concurrent schedules. Journal of the Experimental Analysis of Behavior, 1958, 1, 123-144.

Harzem, P. Temporal discrimination. In R. M. Gilbert and N. S. Sutherland, Animal Discrimination Learning. London: Academic Press, 1969.

Hawkins, T. D., Schrott, J. F., Githens, S. H. and Everett, P. B. Schedule-induced polydipsia - An analysis of water and alcohol ingestion. In R. M. Gilbert and J. D. Keehn (Eds.), Schedule Effects, Drugs, Drinking and Aggression. Toronto: University of Toronto Press, 1972.

Herrnstein, R. J. Relative and absolute strength of responses as a function of frequency of reinforcement. Journal of the Experimental Analysis of Behavior, 1961, 4, 267-272.

Herrnstein, R. J. On the law of effect. Journal of the Experimental Analysis of Behavior, 1970, 13, 243-266.

Herrnstein, R. J. Quantitative hedonism. Journal of Psychiatric Research, 1971, 8, 399-412.

Hodos, W. Progressive ratio as a measure of reward strength. Science, 1961, 134, 943-944.

Hodos, W. Motivational properties of long duration of rewarding brain stimulation. Journal of Comparative and Physiological Psychology, 1965, 59, 219-224.

Hodos, W. and Kalman, G. Effects of increment size and reinforcer volume on progressive ratio performance. Journal of the Experimental Analysis of Behavior, 1963, 6, 387-392.

Hodos, W. and Trumbule, H. G. Strategies of schedule preference in chimpanzees. Journal of the Experimental Analysis of Behavior, 1967, 10, 503-514.

Hodos, W. and Valenstein, S. E. An evaluation of response rate as a measure of rewarding intracranial stimulation. Journal of Comparative and Physiological Psychology, 1962, 55, 80-84.

Hurwitz, H. M. B. and Harzem, P. Progressive ratio performance with reset option. The Psychological Record, 1968, 18, 553-558.

Keesey, E. R. and Goldstein, D. M. Use of progressive fixed ratio procedures in the assessment of intracranial reinforcement. Journal of the Experimental Analysis of Behavior, 1968, 11, 293-301.

Kennedy, J. M. and Baldwin, B. A. Taste preferences in pigs for nutritive and non-nutritive sweet solutions. Animal Behavior, 1972, 20, 706-718.

Morse, W. H. and Kelleher, R. T. Determinants of reinforcement and punishment. In W. K. Honig and J. E. R. Staddon (Eds.), Handbook of Operant Behavior. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1977.

Nevin, J. A. Response strength in multiple schedules. Journal of the Experimental Analysis of Behavior, 1974, 21, 389-408.

Nevin, J. A. Response strength and reinforcement value as resistance to change. Paper presented at the Midwestern Association for Behavior Analysis, Chicago, May, 1977.

Skinner, B. F. The Behavior of Organisms: An Experimental Analysis. New York: Appleton-Century-Crofts, 1938.

Skinner, B. F. Are theories of learning necessary? In B. F. Skinner (Ed.), Cumulative Record. New York: Appleton-Century-Crofts, 1961.

Skinner, B. F. Contingencies of Reinforcement: A Theoretical Analysis. New York: Appleton-Century-Crofts, 1969.

Snapper, A. G. and Inglis, J. The Super Sked Manual 3. Sked Users Group, Psychology Department, Western Michigan University, 1979.

Steiner, J. Observing responses and uncertainty reduction. Quarterly Journal of Experimental Psychology, 1967, 19, 18-29.

Steiner, J. Observing responses and uncertainty reduction II: The effect of varying the probability of reinforcement. Quarterly Journal of Experimental Psychology, 1970, 22, 592-599.

Stewart, J. W. Progressive reinforcement schedules: A review and evaluation. Australian Journal of Psychology, 1975, 27, 9-22.

Stewart, J. W., Blampied, N. M. and Hughes, R. N. The effects of scopolamine on performance on a geometric progressive ratio schedule. Psychopharmacologia, 1974, 38, 55-66.

Thomas, J. R. Changes in progressive ratio performance under increased pressures of air. Journal of the Experimental Analysis of Behavior, 1974, 21, 555-562.

Thompson, D. M. Enhancement of progressive ratio performance by chlordiazepoxide and phenobarbital. Journal of the Experimental Analysis of Behavior, 1972, 18, 287-293.

Thorndike, E. L. Animal Intelligence: Experimental Studies. New York: Macmillan, 1911.

Warden, J. C. and Jenkins, N. T. Obstruction technique. In J. C. Warden (Ed.), Animal Motivation: Experimental Studies on the Albino Rat. New York: Columbia University Press, 1931.