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THE FIXED-INTERVAL PRESENTATION  
OF A SMALL FIXED RATIO

by

Larry Allen Alferink

A thesis submitted in partial fulfillment  
of the requirements for the degree

of

MASTER OF SCIENCE

in

Psychology

Utah State University  
Logan, Utah

1973

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*Larry Allen Alferink*  
Larry Allen Alferink



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## ABSTRACT

## The Fixed-Interval Presentation of a Small Fixed Ratio

by

Larry Allen Alferink

Utah State University, 1973

Major Professor: Dr. Edward K. Crossman  
Department: Psychology

In mixed fixed-ratio schedules, reinforcement is delivered according to two or more fixed-ratio components, which may be programmed in simple alternation or according to a random sequence. If the components simply alternate, the behavior is similar to that obtained in a multiple schedule. Pauses are long before long fixed ratios and short before short fixed ratios. If a random sequence is used, responding is characterized by short pauses after reinforcement independent of the size of the ratio and primes occur at the beginning of many of the fixed ratios. The purpose of the present study was to investigate the possibility of other patterns of responding being controlled by component sequences other than simple or random alternation in mixed fixed-ratio schedules.

Two pigeons were trained to key peck on a fixed-ratio 100 (FR 100) schedule. Following this training, the schedule was based on a superimposed fixed-interval contingency which specified that an FR 10 would occur after the completion of the first FR 100 following a fixed period, timed from the last FR 10. Thus, the schedule was a mixed FR 100 FR 10 with FR 10 frequency controlled by the superimposed fixed-interval contingency. The value of the FI was varied for both birds. To control



for the possibility that the pattern of responding was related to priming, two additional pigeons were trained to respond on comparable multiple schedules in which primes were absent.

The mixed schedule shortened the pre-FR 100 pause. Analysis of the sequence of pauses following an FR 10 showed that the pause following an FR 10 was long relative to other pauses in the sequence which were short and approximately equal to the pre-FR 10 pause. Primes, a run of approximately ten responses at the beginning of a ratio followed by a pause, were relatively infrequent in the first FR 100 after an FR 10, but were more frequent in other positions in the sequence. In the multiple schedule, all pre-FR 100 pauses were long and approximately equal in length, but the pre-FR 10 pauses were short.

These results demonstrate that the pattern of responding obtained in the mixed schedule was related to priming. First, short pauses preceded FR 100s which contained primes in the mixed schedule. Primes did not occur in the multiple schedule, and the pre-FR 100 pauses were long. Second, primes were frequent only in those ordinal positions in the mixed schedule which were preceded by short pauses. Third, short pauses and primes developed simultaneously.

These three effects suggest a new account of priming as a unit of behavior. This unit consists of a short pause followed by a run of ten responses. This run of ten responses is intermittently reinforced by food delivery when the FR 10 occurs. The pause after this run, which occurs if the schedule is FR 100, is caused by the S-delta condition produced by the information that the schedule is not FR 10.

The pattern of responding in the mixed schedule was also related to the sequential nature of the schedule. Since FR 100s always followed FR

10s, FR 10s were followed by long pauses and few primes. FR 100s, on the other hand, were occasionally followed by FR 10s. Thus, the completion of an FR 100 was a discriminative stimulus for "FR 10-like behavior".

(96 pages)



## INTRODUCTION

Traditionally, the definition of a unit of behavior has been a problem in psychology. Findley (1962, p. 114) has noted that "... traits, feelings, perceptions, habits, acts, responses and reflexes ..." have all been tried as the unit of study and have been abandoned when better units were found.

Operant conditioners generally use the "lever-press" or the "key-peck" as units of behavior even though much of both everyday human and animal behavior is of interest at the macroscopic level. In everyday life, the units are functionally much larger than a single lever-press. We generally do not reinforce artists for a single brush stroke, but for an entire painting. Likewise, a politician is reinforced with election to office, not for a single handshake, but for a large class of topographically different behaviors generally referred to as "campaigning".

Based on analogy with other sciences, it is clear that a microscopic analysis of the universe provides a sound foundation of basic principles. However, to restrict a science to a microscopic analysis may limit the scope of that science. For example, biology may be said to have a molecular or cellular basis. Many important discoveries have been made by the biochemist and the cellular biologist, but other important phenomenon emerge only at a higher level of analysis.

If we jump from cellular biology to population ecology, for example, events which are not obvious at the cellular level begin to emerge. Species density and reproductive rate are closely related. When a population is very dense, the number of offspring produced each year will tend to be



small for many species (Odum, 1971). This interaction between reproductive rates and population density is not readily apparent when one gets outside of an organism and considers the interactions between organisms.

The importance of different levels of analysis does not preclude the possibility that events from one level may be reduced to principles derived at a lower level. It simply points out that each level has its own set of procedures; thus, a biochemist is not likely to discover the relationship between population density and reproductive rate. Even though such an observation may possibly be explained by biochemical principles, the observation itself may be overlooked by someone using the biochemical paradigm.

The possible importance of synthesis does not detract from the value of analysis. However, it is not enough simply to analyze existing phenomenon. Knowledge gleaned from microscopic analysis should be used to produce new behavioral phenomenon. Synthesis complements rather than competes with analysis; what is synthesized may subsequently be analyzed and elucidate "simple" phenomenon which currently are not well understood.

#### Enlarging the behavioral unit

The enlarging of the behavioral unit began with Skinner's (1938) observation that a fixed-ratio schedule tends to produce a unit which acts like a single response. This observation, later known as the response-unit hypothesis (Mowrer and Jones, 1945), was supported by experiments which showed that behavior maintained on an intermittent schedule was more resistant to extinction than behavior which was continuously reinforced (Humphreys, 1939a; 1939b; 1940).

The response-unit hypothesis set the occasion for the use of larger behavioral units in schedules of reinforcement. Most notable among these



are chained (Findley, 1962) and second-order schedules (Kelleher, 1966a; 1966b). In a chained schedule, completion of each unit is accompanied by a change in the stimulus conditions. In second-order schedules, a brief, rather than a lasting, stimulus change occurs after each unit. In both procedures, completion of the unit which satisfies the schedule requirement is followed by a reinforcer.

Both chains and second-order schedules have led to an increase in the amount of behavior which can be controlled (Findley, 1962; Findley and Brady, 1965). Generally, however, both techniques have been used to investigate conditioned reinforcement rather than to investigate scheduling with larger units of behavior.

#### Superimposed contingencies in mixed and multiple schedules

In a different approach to building more complex samples of behavior, the completion of one schedule, e.g., FR 100, is followed by the delivery of an unconditioned reinforcer. In addition, the subject is given the opportunity to emit a different schedule, e.g., FR 10, following the completion of a superimposed contingency. For example, Crossman and Silverman (in press) explored the use of a superimposed contingency by presenting an FR 10 contingent on the completion of a fixed number of FR 100s. This fixed number was varied systematically from 99 to 1.

In one part of their experiment, Crossman and Silverman found that the pause preceding the first FR 100 which followed an FR 10 was long, while the other pre-FR 100 pauses were shorter and approximately equal in length. In some ways, this pattern of responding resembles that obtained in a simple fixed-ratio schedule. In a simple FR, the delivery of a reinforcer is followed by a long pause and then a high rate of responding, i.e.,



the pauses (IRTs) between responses are short (Ferster and Skinner, 1951; Felton and Lyon, 1966; Powell, 1968).

Although a reinforcer is generally defined in terms of its effects on the frequency of responding, the pattern of responding has also been used as an indicator of a reinforcer. For example, Skinner and Morse (1958) presented a stimulus on a fixed-interval schedule. Although this contingency actually decreased the frequency of wheel running, they held that the stimulus was a reinforcer since a typical fixed-interval scallop was obtained. The pattern of responding obtained when units in a second-order schedule are followed by a brief stimulus change was also one of the criteria which Kelleher (1966b) and deLorge (1967) have used to indicate that the brief stimulus change is a conditioned reinforcer. Thus, the pattern of responding obtained in Crossman and Silverman's study suggests that the FR 10 functioned as a reinforcer for performance on the FR 100.

On the other hand, this pattern could have resulted from the manner in which the components were alternated. Frequently, the components in mixed and multiple schedules either simply alternate, or alternate on a random basis. In mixed fixed-ratio schedules with simple alternation, pauses are longer before the long FR than before the short FR (Crossman, 1971). This same pattern is obtained in a multiple FR schedule. In mixed FR schedules in which the components randomly alternate, pauses are short before all ratios (Ferster and Skinner, 1957). Thus, patterns of responding are a function of the method of alternation. Crossman and Silverman used a third method of alternation in which fixed numbers of FR 100s were followed by a single FR 10. Thus, the sequence of components produced by their method could have resulted in different pause relationships. The order of the FR components could have produced a long pause following an FR 10, perhaps due to contrast.



The only types of superimposed contingencies which have been investigated are those in which the occurrence of one component is contingent on the completion of a fixed number of a second component (Crossman and Silverman, in press; Silverman, 1970), or on the length of the pause before the second component (Findley, 1962; Kelleher, Fry and Cook, 1964). Superimposed interval contingencies have been neglected as a means of programming components in mixed and multiple schedules. The purpose of the present study was to investigate the effects of using a superimposed fixed-interval contingency in mixed and multiple FR schedules. More specifically, the present study attempted to determine, first, whether the pattern of responding obtained by Crossman and Silverman was due to the contingency according to which an FR 10 occurred or to the sequence of components generated by the method of alternation, and second, by using a multiple schedule comparison, to determine if priming was related to this pattern.

#### Contingency versus sequence

The use of a fixed interval as the superimposed contingency is more sensitive for detecting whether or not the pattern is controlled by the component sequence than is a fixed-number contingency. An FR 10 may produce a long pause after it. Since this would be the same pattern as is observed in a simple fixed-ratio schedule, a fixed-number contingency would not distinguish control by sequence from control by the superimposed contingency. With an FI contingency, this problem is avoided. Since an FI contingency would also produce a sequence of FR 100s followed by a single FR 10, the order of the components would approximate the sequence obtained by Crossman and Silverman. However, in addition to a long pause following the FR 10, the superimposed FI contingency, if effective, should



produce a gradual shortening of all pauses as the FR 10 is approached. Failure to obtain such a pattern would suggest that the order or sequence of components was affecting the behavior rather than the superimposed contingency.

Typically, a fixed-interval schedule produces a "scallop" in which the rate of responding gradually increases to a high terminal rate near the end of the interval (Ferster and Skinner, 1957). On the other hand, Schneider (1969) has suggested that the FI has two states: a pause and a high terminal rate. Schneider presented an averaged cumulative record for FIs ranging from 16 to 512 sec. In the shorter intervals, the performance was "break and run", but with longer intervals, scalloping occurred. This suggests that FI performance belongs on a continuum from the "break and run" produced by the short FI to the "scallop" produced by the long FI.

The existence of several "typical" fixed-interval patterns produces a problem if the pattern of responding is to be taken as an indicator of the reinforcing function of the small FR. If "break and run" performance occurred, it could indicate that the FR 10 was functioning as a reinforcer. On the other hand, it could also indicate that the sequence of schedules is the important factor in determining the pattern of responding and that the superimposed contingency has importance only to the extent that it requires such a sequence to occur.

To avoid this problem, several FI values were used. A long FI should produce a scallop if the opportunity to emit the FR 10 is a reinforcer. This would demonstrate the importance of the contingency in controlling response patterns. "Break and run" performance would show that component sequencing produced the response pattern.



### Contingency versus primes

Finally, since mixed FR schedules produce primes (a run of response at the beginning of the FR followed by a pause) as well as short pauses, the pattern of responding could be related to priming. To control for this possibility in the present experiment, a comparable multiple schedule was used to eliminate priming. Thus, the occurrence of similar patterns of pausing in both the mixed and multiple schedule would demonstrate the importance of the contingency. On the other hand, long pre-FR 100 pauses in the multiple schedule would show that primes and short pauses are related and that the pattern of responding in the mixed schedule was related to these primes rather than to the contingency.

## SURVEY OF RELEVANT LITERATURE

### Behavioral units

The need for an appropriate unit for the analysis of behavior was recognized early (Skinner, 1938). Although the response might at first seem to be an adequate unit, this is not the case. Responses under the control of the same events are likely to have different topographies, although in many cases this difference may be slight.

In 1938, Skinner set forth two general types of response classes: respondents and operants. The respondent is elicited; its control lies in the occurrence of an antecedent stimulus. The operant, on the other hand, occurs with a given frequency without the necessity of an antecedent stimulus. Although stimuli may set the stage for its occurrence, emission of the operant is controlled by the consequences which follow. In selecting these units, Skinner sacrificed the ability to produce exactly the same response topography for smooth curves. The units had an early pragmatic basis; the test of their goodness was the ability to generate functional relationships.

Skinner also realized the importance of the size of the units. In the initial research with schedules of reinforcement, the behavior generated by the fixed ratio occurred at a high rate due to "temporal discrimination" based on the relationship between response rate and reinforcement frequency. This high rate was subsequently maintained by stimuli arising from each press, with the food pellet occasionally accompanying these stimuli (Skinner, 1938). Thus, each bar-press on a fixed-ratio schedule is functionally controlled by the same event, the food pellet at the end of the ratio. This led Skinner (1938, p. 300) to suggest that, "As a



rather general statement it may be said that when a reinforcement depends upon the completion of a number of similar acts, the whole group tends to acquire the status of a single response".

#### Chained and second-order schedules

Recently, there has been a great deal of concern with the size of the units. Findley, (1962), in particular, has suggested that we must begin developing the degree of behavioral control necessary to produce more complex samples of behavior. Findley began his investigation using the chain as the basic unit and a philosophy that the answers to questions were less important than techniques leading to greater behavioral control.

In the initial experiments, Findley used a heterogeneous two-link chain in which pulling a chain in darkness produced a light on a VI 4 min schedule. In the presence of the light, bar-pressing was reinforced with food, also on a VI 4 min schedule. An important implication of studies such as this is the prospect that chains can sustain a great deal of behavioral output.

In an attempt to increase output, Findley (1962) expanded the chain to five operants with an FI 15 sec associated with each of five different colors. The subjects readily acquired this chain with an orderly increase in behavioral output in the progression from the first to the last link. However, with continued exposure, the behavior in the early portion of the chain began to deteriorate until the chain could no longer be maintained. The problem of chain length could thus place definite limitations on the complexity of the behavioral samples to be built. A solution to this problem was essential if work with the chain were to continue. By making a chain of variable length, Findley was able to maintain a five operant chain.



When food reinforcement occurred on a random basis after each of the five operants, the behavior in the initial links was maintained even when the FI was increased.

Futher attempts along the same line led to similar failures and interesting solutions. Using a three-operant chain, Findley manipulated the FR value associated with each link and found that the behavior seldom occurred when the fixed ratio associated with each link was raised to FR 80, thus, requiring a total output of 240 pecks. An interesting attempt to produce greater behavioral output led to a precursor of what is now called the second-order schedule.

Consider the following experiment. Findley (1962) reduced the size of the ratio from FR 80 to FR 10 in each link of the three-component chain. However, rather than requiring simply a single completion of the chain for food reinforcement, he now required eight. Completion of each chain produced a four sec white light which was paired with food. Prior to this experiment, Findley had concerned himself with chain components as units. Now, a different unit appeared, the chain, with the completion of eight chains required to produce food reinforcement. This enlargement of the unit resulted in the maintenance of the 240 responses which could not be maintained when a simple three-link chain was used.

Findley and Brady (1965) also found it possible to maintain behavior on large fixed-ratio schedules by breaking the ratios into smaller units and presenting brief stimulus changes following the completion of these smaller units. With one subject an FR 120,000 was required to produce food, but a brief feeder light flash followed every 4000 responses. Not only were there long pauses after food delivery, but pausing also developed following the brief feeder light flashes. These experiments not only



demonstrate the ability to produce enormous behavioral outputs, but also demonstrate the importance of how response units are constructed.

Another development which preceded second-order procedures occurred in work with token reinforcement. For example, Kelleher (1957) reports a study in which chimpanzees were reinforced with tokens according to an FI 5 min schedule. The chimps were required to accumulate a number of tokens before exchanging them for other reinforcers. The number of tokens required for exchange was called the exchange ratio. Thus, the FI 5 min served as the basic unit reinforced according to an FR schedule. Kelleher (1958) maintained behavior on an FR 125 with an exchange ratio of 50 tokens. Treating the behavior maintained by an FR 125 as a unit reinforced according to an FR 50 is the defining feature of a second-order schedule.

Kelleher (1966a, 1966b) defined the second-order schedule as a "schedule of a schedule" in which the pattern of responding maintained by one schedule is treated as a unitary response which is reinforced according to a second schedule. We have seen how Findley (1962) maintained the behavior engendered by a chain FR 10 FR 10 FR 10 by treating this chain as a unit with food reinforcement following the completion of eight of these units. Subsequent work with second-order schedules has generally relied upon much briefer stimulus changes than the four sec white light used by Findley (1962).

To illustrate the standard second-order procedure, we shall look briefly at Kelleher's (1966a) original experiment. The unit Kelleher used was an FR 20. The completion of each FR 20 was followed by a .5 sec flash of a white light and completion of the first FR 20 after ten minutes was followed by the brief feeder light and food. Using Kelleher's notation, the schedule was thus a second-order FI 10 min (FR 20); the FR 20 was considered to be a unitary response which was reinforced according to the FI 10 min schedule. Presentation of the feeder light was followed by brief



pauses, with an abrupt change to a high response rate, much as occurs when fixed-ratio schedules are followed by food delivery. However, the pauses preceding each unit were longer at the beginning of the interval than in later portions producing an overall scalloped pattern which resembled that typically maintained by standard fixed-interval schedules. Thus, both the pattern within and across units resembled that which occurs in the analogous simple schedules of food reinforcement.

Even though second-order schedules are of interest for the investigation of behavioral units, their importance has primarily been as a technique for investigating conditioned reinforcement. Standard conditioned reinforcement procedures require pairing of a stimulus with a reinforcer such as food. However, several investigators have produced patterns appropriate to the schedule on which an unpaired stimulus is presented. For example, Neuringer and Chung (1967) reinforced a response-initiated FI 5 sec according to a VI 1 min schedule. When blackouts followed some FIs and food others, appropriate pausing developed after blackouts. Using a variety of second-order schedules, Stubbs (1971) found no differences between the effects of brief stimuli which were paired with primary reinforcers and those which were not. Both procedures produced patterns appropriate to the schedule on which the brief stimulus was presented. In studies with percentage reinforcement, Ferster and Skinner (1957) produced break and run patterns when some fixed ratios were followed by food and some by timeout. Zeiler (1972a) found a similar effect with percentage reinforcement of fixed intervals. Unpaired timeouts were followed by typical fixed-interval performance.

These experiments all have one thing in common; a unit of behavior is defined by regularly scheduling a stimulus change following completion of that unit. These results led Zeiler (1972a, p. 187) to conclude that



"what is necessary for fixed-interval behavior to operate as a unitary response is that the completion of each sequence be demarcated by an event that effectively terminates the sequence".

If the role of brief stimuli in second-order schedules is not behavior maintenance, but rather is the empirical definition of a response, a comparison should be drawn between these empirical units and conventional units. Davison (1969) has compared behavior generated by an FR 6 with that obtained using a second-order FR 6 (FR 6). Essentially, this can be conceptualized as a comparison between two second-order schedules: an FR 6 (FR 1) and an FR 6 (FR 6). Pauses (IRTs) between units on the FR 6 (FR 1) schedule were longest following a reinforcement, but remained fairly uniform between other responses in the ratio. Inter-response times with units on the FR 6 (FR 6) schedule followed a similar pattern, but pauses preceding emission of each unit tended to decrease from the first to the sixth unit.

In a similar study, Shull, Guilkey and Witty (1972) changed the unit in second-order fixed-interval schedules from FR 1 to FR 10. The length of the FI ranged from 3 min to 12 min. Except for a lengthening of the postreinforcement pause when the unit was FR 10, little other difference was observed between the two units.

The second-order schedule may, therefore, have more importance in the study of basic units than in elucidating conditioned reinforcement phenomenon. By building and studying more complex samples of behavior, perhaps we can better understand the so-called simple schedules of reinforcement.

#### Fixed ratios as units

Since the unit chosen for study in the present experiment is the behavior maintained by fixed-ratio schedules, it is appropriate that we



should examine fixed-ratio schedules and their properties, particularly those properties which suggest behavioral unity. By suggesting unity, several things are intended. First, individual responses should have cohesiveness. That is, individual responses should produce subsequent responses and the probability of short IRTs should be high. Secondly, the unit should potentially have the properties of an operant. When reinforcers are applied contingent on the unit, certain properties of that unit should be strengthened and maintained. For our purposes, this defines behavioral unity.

Ferster and Skinner (1957) have characterized the FR as a chain with each response serving as a stimulus for a subsequent response with the last response being discriminative for reinforcement. We have already seen how Findley (1962) used chains as a potential unit of behavior.

The pattern of behavior maintained by fixed-ratio schedules suggests that FRs are cohesive units. The behavior on a fixed ratio is characterized by a pause after reinforcement followed by an instantaneous change to a high terminal rate of response (Ferster and Skinner, 1957). After an initial pause, the response requirement is rapidly completed. These responses tend to hold together even when the reinforcement schedule is changed from FR to extinction. Extinction following FR is characterized by runs of responding at a high rate with long pauses separating these runs. As extinction progresses, the pauses increase in length and the runs shorten (Ferster and Skinner, 1957). Thus, FR behavior could be characterized as having two states; pauses follow reinforcement, but once the first response in the ratio occurs, the rest follow in rapid succession, even in extinction. As Mowrer and Jones (1945) suggested, the fixed-ratio behaves as a unitary response.



### Evidence for a two-state analysis

Studies manipulating a variety of different variables have generally supported this two-state analysis. In an early experiment studying the effects of deprivation on fixed-ratio responding, Sidman and Stebbins (1954) found differential effects for each state on an FR 25 schedule. In this study, partial satiation was accomplished by using long sessions or by prefeeding the subjects before each session. Examination of cumulative records showed that pause length increased in satiated animals while response rate remained relatively constant. Malott (1966) also found that the postreinforcement pause was a direct function of prefeeding. In addition, the response rate increased over successive quarters of the FR 64.

Instead of investigating the effects of deprivation by prefeeding subjects, Ferster and Skinner (1957) varied the body weights of their subjects. Examination of cumulative records showed that pauses increased with increased body weight while little effect on terminal rate was evident. Powell (1969a) varied the number of hours of food deprivation at 85% and at 70% ad lib weight. Although response rate did not show consistent effects, the postreinforcement pause decreased with increases in deprivation.

Pause length also varies systematically with reinforcement magnitude. Powell (1969b) varied the duration pigeons had access to a food hopper after completion of a fixed-ratio response requirement. Under several different response requirements, the 4 sec access time produced shorter pauses than did the 2.5 sec access time. Changes in response rate were inconsistent. Likewise, Inman and Cheney (in press) varied the amount of water presented following the FR 30 component in a mult FR 30 FR 10. By increasing the magnitude of reinforcement after the FR 30, they found that



they could reverse the length of the pauses such that the pause preceding the FR 30 became shorter than the pause preceding the FR 10.

Azrin, (1959) has shown that the postreinforcement pause varies as a function of shock intensity when responses are punished. In this study, pigeons were trained to respond on either FR 10 or FR 50. Shock was delivered through pubis electrodes following each response. As shock intensity increased, pause length increased. At higher intensities, breaks at the beginning of the ratio also occurred. Except for these breaks, local response rate did not change.

#### Effects of size of the fixed-ratio unit

Pause length increases as a function of the force requirement (Birch, 1964; Notterman and Mintz, 1965). Similarly, increases in ratio size produce increases in the length of the pause. A number of studies have investigated the effects of the size of the ratio requirement on pause length and response rate. In one of the earliest studies, Skinner (1938) measured pause lengths from cumulative records obtained with rats on different fixed-ratio schedules. He found that pause length increased with increases in fixed-ratio size. Using pigeons, Ferster and Skinner (1957) also observed increases in pause length with increases in the response requirement. However, little or no change in local rate was evident from the cumulative records.

Similar effects have been found in studies with fixed-ratio escape. Kaplan (1956) investigated the effects of ratio size on escape from a bright light with rats. When the response requirement was varied from 1 to 31, the latencies increased. Terminal rate also increased with increases in the response requirement. Winograd (1965) also found that the median latency tended to increase with increases in the response requirement for



shock escape. Changes in response rate were inconsistent, but rate tended to decrease with increases in ratio size. Examination of cumulative records showed breaks in the ratio runs at higher ratios. Winograd suggested that the decrease in rate was due to these breaks in the run.

Most of these investigators have relied on examination of cumulative records. Other studies have made more systematic measurements of rate and pause length. For example, Thompson (1964) trained rats to respond on an FR 25. He then increased the response requirement in steps of 25. He found progressive lengthening of the postreinforcement pause with increases in ratio size. As FR size increased, the frequency of pauses longer than 50 sec increased.

Felton and Lyon (1966) varied the response requirement from FR 25 to FR 150. In addition several points were recovered. As the fixed-ratio requirement increased, so did the postreinforcement pause. As the ratio requirement increased, local response rate tended to decrease, although this was not as consistent. Examination of cumulative records showed that terminal rate remained relatively constant, but that multiple pausing tended to occur in larger fixed ratios. Powell (1968) used small sequential increases in the response requirement of an FR to investigate changes in pause length. He found that postreinforcement pause distributions became more variable and that the frequency of longer pauses tended to increase as the ratio requirement was raised. As Felton and Lyon found, Powell showed that the response rate tended to decrease with increases in the response requirement.

Powell (1970) showed that the postreinforcement pause consistently increased with increases in ratio size but, again, changes in response



rate were inconsistent. The decreases in rate which did occur appeared to be due to breaks in the run. Analysis of these breaks showed that at least 70% occurred in the first 20% of the ratio.

Although most of these studies indicate that little or no change in terminal rate occurs with increases in the response requirement, most have not made a detailed analysis of response rate. Barofsky and Hurwitz (1968) obtained IRT distributions under different fixed-ratio schedules. They found shifts in the IRT distributions with changes in fixed-ratio size. However, since IRT distributions were not presented, it is difficult to determine whether or not these changes were due to increases in the frequency of multiple pausing reported by other investigators (Felton and Lyon, 1966; Powell, 1970).

#### Problems with a two-state analysis

So far, studies which demonstrate the unity of the FR have been noted. Although Ferster and Skinner (1957) characterized fixed-ratio performance as a pause after reinforcement with an instantaneous change to a high terminal rate, this is not quite accurate. As previously noted, Powell (1970) found an increase of breaks in the first 20% of the ratio as the ratio size was increased. This suggests that control is weaker early in the ratio. Likewise, Mintz (1962) has shown that response force increases over the unreinforced responses in the ratio. Nevin, Cumming and Berryman (1963) have shown that errors increased in a matching-to-sample procedure with increases in the fixed-ratio requirement although these increases did not occur in a comparable variable ratio. Errors were most likely immediately following reinforcement with accuracy increasing as the ratio progressed. Mintz, Mourer and Weinberg (1966) later confirmed these observations using a probe in which reinforcement was



occasionally followed by stimulus conditions appropriate for the end of the ratio. Error rates were low after reinforcement in the probe condition, but high in the presence of stimuli associated with the beginning of the ratio. Likewise, Stubbs (1968) has shown that accuracy is lower early in fixed ratio reinforcement of a discrimination of stimulus duration and Birch (1964) has shown that error rates were highest early in the ratio. Errors were defined as either responses with a force or a displacement outside of the reinforced range.

Lyon (1964), using an Estes-Skinner conditioned suppression procedure varied the location of the warning stimulus in an FR 150. If the warning stimulus occurred before the first twenty responses, complete suppression occurred. If it occurred in the middle of the ratio it sometimes resulted in complete suppression and sometimes in continued responding. If the warning stimulus occurred near the end of the ratio, the subjects continued responding. Hutchinson, Azrin and Hunt (1968) showed that barbiting aggression in squirrel monkeys induced by fixed-ratio schedules is most probable during the postreinforcement pause and early in the ratio. Similar observations were made by Gentry (1968) and Cherek and Pickens (1970). Thus, control is weaker early in the ratio. This questions the appropriateness of a two-state analysis. Although the pause and the terminal rate seem to be separate phenomenon, a third state representing the transition between the pause and the high terminal rate may be appropriate. The change to a high terminal rate may not be as instantaneous as Ferster and Skinner (1957) suggested.

#### Modifications of the two-state analysis

The fact that control is weaker at the beginning of the ratio does not, however, rule out the possibility that the FR is controlled by two sets of variables.



Killeen (1969) showed that this is the case. Four pigeons were trained to respond on various fixed-ratio schedules. Four birds were subsequently yoked to these FR birds such that the yoked birds were reinforced following the first response after the FR bird had completed its response requirement. Thus, the yoked birds were on an interval schedule which approximated an FI since reinforcement depended on the time taken by the FR bird to complete the FR. Pauses tended to be longer at larger fixed ratios for both the FR birds and the yoked birds. Killeen takes this as evidence for the control of pause length by the interreinforcement interval. The response requirement was then modified for the yoked birds by adding a fixed ratio in tandem with the interval. Increasing the tandem fixed-ratio requirement had no effect on pause length, but terminal response rate increased. Neuringer and Schneider (1968) confirmed the finding that the pause is controlled by the interreinforcement interval. They held the interreinforcement interval constant on an FI while controlling the number of responses. In a fixed-ratio they held the number of responses constant and varied the interreinforcement interval. This was accomplished by imposing a short blackout after each response and varying the length of this blackout. The longer the blackout, the fewer the number of responses which can occur in a fixed-ratio. Using this technique, they found that pause length did not vary as a function of number of responses in a fixed interval, but did increase in the fixed-ratio as the interreinforcement interval increased. Based on this evidence they concluded that the postreinforcement pause was a function of the interreinforcement interval, but not of the number of responses.

The fact that response rate is controlled by the ratio requirement



has also been confirmed. Zuriff (1970) compared variable ratios and variable intervals in a multiple schedule in which the interreinforcement intervals were equivalent. Response rate on the variable ratio was approximately twice that obtained on the variable interval. Blough (1963) studied the transition from VI to FR. The number of long IRTs decreased. A serial analysis of IRTs in the FR showed that the first IRT was long while the other IRTs were shorter and approximately equal in length.

Thus, the pattern in a fixed ratio demonstrates the cohesiveness of the FR as a unit. These studies illustrate that the terminal rate tends to be high and uniform. Blough's (1963) study, in particular, demonstrates this. Changing the schedule from VI to FR tended to eliminate long IRTs. Blough's data indicated that responses generate or control other responses.

#### Fixed ratios as operants

Studies with the explicit use of the fixed-ratio unit began with the study of adjusting schedules. Kelleher, Fry and Cook (1964) delivered a reinforcer after the completion of a fixed ratio only if the pre-ratio pause had exceeded the specified length. Using this procedure, they found that they could, in fact, vary the length of the postreinforcement pause. Expanding on this procedure, Zeiler (1970) imposed time limits on FRs to determine if pause and run varied as a unit. Reinforcement occurred only if the time to complete the ratio exceeded the specified value. He found that the time taken to complete the ratio varied as a function of the time limit imposed. In addition, analysis of pausing or the run individually did not produce orderly relationships. The orderly relationship occurred only when both the pausing and the run



were considered. Likewise, Zeiler (1972b) imposed time limits in a multiple schedule. In one component the time to complete the ratio had to exceed the time limit while in the other component, the time to complete the ratio had to be less than the time limit for reinforcement to occur. The time to complete the ratio varied as a function of the contingencies in effect. The time was short in the component associated with the maximum time limit and long in the component associated with the minimum time limit. These studies not only illustrate the unity of the FR, but also demonstrate that the FR is an operant, and as such, is susceptible to contingencies imposed on the unit. Thus, based on its cohesive nature and its ability to serve as an operant, the fixed ratio would seem to deserve further consideration as a unit of behavior.

#### Multiple fixed-ratio schedules

In multiple schedules, each schedule is associated with a different exteroceptive stimulus. Multiple schedules generally produce response patterns which would have occurred if the schedules had been programmed in isolation. Using a multiple schedule which closely approximated this situation, Ferster and Skinner (1957) studied a mult FR 60 FR 200 schedule in which each component remained in effect for a single session. Postreinforcement pauses were short in the FR 60 component and long in the FR 200 component. This effect also occurs if the components are alternated. Multiple FI 10 min FR 20 produced high rates on the FR schedule and lower rates and some "scalloping" in the FI component when these schedules simply alternated (Ferster and Skinner, 1957). Similar results are obtained when more than two components are used. A mult FI 2 min FI 11 FR 50 FR 250 produced characteristic FI behavior with pauses which varied with



the length of the interval and FR behavior with longer pauses before the larger ratio (Ferster and Skinner, 1957).

Since multiple schedules produce responding which resembles that of the components programmed in isolation, they have considerable promise as a means of comparing schedules within the same session. Schuster (1959) compared the effects of ratio size in a mult FR FR schedule. As the ratio requirement of one component was increased from FR 10 to FR 80, the pause in front of this component increased while the pause in front of the constant FR 20 component decreased. This increase in the pause for one component with an accompanying decrease in the pause for the other component was called contrast. Crossman (1971) also manipulated the size of the ratio in one component while holding the other constant. Using a mult FR L FR 10 in which the components simply alternated, Crossman found that as the FR L increased from FR 15 to FR 55, the pause before that component increased; the pause before the FR 10 component decreased. This confirms the contrast obtained in Schuster's (1959) study.

A second implication of Schuster's (1959) experiment is terminological in nature. The term "postreinforcement pause" implies that the pause is controlled by the ratio it follows (Griffiths and Thompson, 1972). Schuster's (1959) study suggests that the pause is controlled by the upcoming ratio and, thus, should be called a pre-ratio pause. The concept of a pre-ratio pause is supported in a series of experiments by Findley (1962). In one of these experiments, in the presence of a green light the subject was reinforced for responding on three different ratios. These ratios progressively increased from FR 33 to FR 132 to FR 528. In the presence of a red light, these same ratios occurred in decreasing order. Pause length increased in the green sequence and decreased in the



red sequence. Thus, pause length is a function of the size of the next ratio. A second experiment by Findley (1962) showed similar results. In the presence of a red light, the animal completed a sequence of ratios consisting of FR 37, FR 132 and FR 528. In the presence of a green light, the subject completed three FR 132s. Pauses following the FR 132 in the green light were uniform in length, but were longer following the FR 132 (preceding the FR 528) in the presence of the red light. Again, this shows pause length is a function of the next rather than the last ratio. Davison and Over (1966), Crossman (1968) and Griffiths and Thompson (1972) have also shown that pauses are long preceding long ratios and short preceding short ratios.

#### Mixed schedules with simple alternation

In mixed schedules, a change in the schedule is not accompanied by a change in the stimuli. In the simplest type of mixed schedule, the components simply alternate. Under these conditions, the pattern of responding is similar to that obtained in a multiple schedule. Crossman (1971) found similar effects in mixed and multiple schedules with fixed-ratio components when the size of one component was varied. However, larger changes in the mixed schedule were necessary to produce similar changes in behavior. Patrikou and Keehn (1964) found longer pauses preceding the FR 45 component of mix FR 15 FR 45.

Apparently, in a mixed schedule in which the components simply alternate, the subject relies on cues arising from the ratio just completed to govern its behavior. It has been shown that animals can respond on the basis of stimuli which are no longer present. Ferster and Skinner (1957) presented evidence of this work with mult FR 50 primed FI 10 min. No differential stimuli were associated with either schedule except during



the beginning of the FI. During this period, a stimulus associated with the FI was briefly presented, but the subject continued to produce an FI pattern after the differential stimulus was removed. Mabry (1965) also presented differential stimuli briefly at the beginning of fixed ratios and fixed intervals and found that appropriate performance was maintained when these differential stimuli were no longer present. Likewise, Kendall (1969) presented a stimulus associated with either an FR 10 or an FR 100 for thirty sec. After this thirty sec, this cue was turned off and the response key was illuminated with the same stimulus for both FRs. Pauses were short before the FR 10 and long before the FR 100. Thus, trace stimuli arising from the ratio just completed may explain why alternating mixed schedules are so similar to multiple schedules.

An even more striking example of this occurred in a four component mix FR 15 FR 45 FR 15 FR 135 (Keehn, 1965). Pauses were longer before the FR 135 than before the FR 45 even though both of these schedules followed an FR 15. Since no differential cues were provided by the experimenter, the subjects apparently were discriminating an FR 15 following an FR 135 from one following an FR 45. If this was the case, it would indicate that rats can rely on cues arising from two components back to govern their current behavior.

#### Mixed schedules with random alternation

If random alternation is used to program the components in mixed schedules, primes or priming runs generally result. A priming run is a run of responses approximately equal to that of the schedule with the shortest interreinforcement interval. This priming run is followed by a pause. In mix FR FR, for example, the priming run would be equal to the shortest ratio.



Ferster and Skinner (1957) investigated mixed schedules using primarily random alternation. A comparison of mix FR 50 FR 300 and mult FR 50 FR 300 schedules with random alternation revealed that the multiple performance was more difficult to maintain. According to Ferster and Skinner (1957), a mix FR FR schedule has the effect of averaging the two ratios to produce a mean ratio. The multiple schedule does not have this effect. Thus, a long ratio in a multiple schedule may produce an extremely long pause while such long pauses do not occur in a mixed schedule. Presumably, this mean ratio rather than the separate component ratios controls pause length in a mixed schedule in which primes occur.

Frequently, primes in mixed FR FR schedules are preceded by short pauses typical of the shorter ratio. Ferster and Skinner (1957) investigated a number of mixed schedules using random alternation. In a mix FR 190 FR 30, both ratios were preceded by short pausing. The long ratio contained frequent priming runs in which the subjects emitted about thirty responses followed by a pause appropriate to the longer ratio. In a mix FI 10 min FR 125, both the FR and the FI component began with a pause and a high rate of responding appropriate to the FR. The ratio pattern (priming) in the FI component was followed by a gradual scallop after about 125 responses.

Priming also occurs when one component of the mixed schedule is extinction. In a mix FR 50 EXT 20 min in which each component was separated by a ten sec timeout, a priming run occurred at the beginning of extinction (Ferster and Skinner, 1957).

Priming can be brought under stimulus control. Ferster and Skinner (1957) found that a multiple schedule in which one component was a simple FR 160 and the other a mix FR 20 FR 160 produced appropriate component



performances. The FR component contained long pauses and no priming while the mix FR FR component produced short pauses and frequent primes.

Thompson (1964) has shown that animals are likely to place themselves in a timeout condition during the postreinforcement pause in a simple fixed ratio. In a second experiment (Thompson, 1964), animals were provided with the opportunity to enter a timeout condition in a mix FR 25 FR 225. Pauses were typical of a simple FR 25 and timeouts occurred only after primes of twenty-five responses in the FR 225.

#### Mixed and multiple schedules with other means of alternation

The pattern of responding obtained in mixed schedules is a function of the manner in which the components are sequenced. If the components occur in simple alternation, the pattern is similar to a multiple schedule (Crossman, 1971). If random alternation is used, pauses are short and primes are frequent (Ferster and Skinner, 1957). Simple and random alternation are clearly not the only means of determining the occurrence of components in mixed and multiple schedules. Findley (1962) was among the first to recognize this and made the occurrence of one component contingent on performance in another. Findley reinforced animals according to an FR 100 in the presence of a red light and an FI 2 min in the presence of a blue light. A pause of six sec before the ratio in red resulted in the presentation of the blue component. The frequency of entry into the blue component depended on the FI requirement. When an FR requirement was added in tandem to the FI requirement in blue, pauses in red shortened and entry into blue became less frequent.

A similar effect occurs when an adjusting FR schedule is used (Kelleher, Fry and Cook, 1964). Essentially an adjusting schedule is simply a mixed



schedule with an unspecified number of FR values. A ratio shorter than the current one is contingent on a long pause while a longer ratio is contingent upon a short pause. Like Findley's (1962) experiment the schedule in effect is a function of the animal's behavior.

Unfortunately, both Findley's (1962) procedure and the adjusting schedule have something in common with random alternation. None of these procedures allows the experimenter to specify the sequence of components. Simple alternation allows the experimenter to specify the sequence but, in the case of the mixed schedule, eliminates priming. An obvious solution to this problem is to extend the sequence length such that one schedule is repeated several times before the next schedule occurs. Thus, Dews (1958) examined a mix FR 50 FI 15 min schedule in which the schedules occurred according to the following fixed sequence: RRRIRIRRRRRRRRIIR (in which R equals FR 50 and I equals FI 15 min). FI components began with a short pause and a high rate typical of the FR 50. After the completion of about fifty responses, this pattern was followed by a gradual scallop typical of the FI.

Likewise, Weissman (1960) turned a light on for the last thirty sec of the extinction component in a mix FR 24 EXT 10 min. The sequence used in this study consisted of nine FR 24s followed by a single extinction period. The beginning of the extinction component was characterized by a priming run followed by a long pause. Occasionally the subjects emitted runs of less than 24 responses followed by a pause in the FR component. Similar results were obtained when twenty FR 10s were followed by extinction for sixty min in a mixed schedule (Bullock, 1960).

Mintz, Mourer and Gofseyeff (1967) used a mult FR 50 FR 50 FR 20 FR 20. They found that this means of programming the components produced



sequential effects. Pauses preceding both FR 20s were short. However, the pause between an FR 20 and an FR 50 was longer than the inter-FR 50 pause. This sequential effect was apparently due to contrast.

Silverman (1970), compared a mix FR 75 FR 75 FR 75 FR 10 to a multiple schedule with the same sequence. On both the mixed and the multiple schedules, the pause following the FR 10 was the longest. Moreover, this pause was longer on the multiple schedule than on the mixed schedule. The pre-FR 10 pause was the shortest pause in the multiple schedule with the inter-FR 75 pauses being of intermediate length. On the mixed schedule, the inter-FR 75 and the pre-FR 10 pauses were extremely short and approximately equal. The post-FR 10 pause in the multiple schedule was interpreted as a sequential effect due to contrast.

Crossman and Silverman (in press) investigated a mixed schedule in which a fixed sequence of FR 100s were followed by a single FR 10. They varied the proportion of FR 100s to FR 10s from 99:1 to 1:1. As FR 10s became more frequent, the post-FR 100 pause shortened and the frequency of primes at the beginning of the FR 100 increased. When the proportion of FR 100s to FR 10s was reduced to about 4:1, priming became relatively infrequent on the first FR 100 after an FR 10 and more frequent in other ordinal positions.

#### Priming in mixed schedules

In mixed schedules with simple alternation, animals rely on cues arising from their own behavior to determine which schedule is in effect. According to Ferster and Skinner (1957), primes have a similar function in mixed schedules with random alternation. Apparently the bird's own behavior functions as a stimulus in a similar manner to the exteroceptive stimuli in a multiple schedule or in a mixed schedule with simple



alternation. The priming run provides information about which schedule is in effect.

This information can be provided in other ways. Hendry (1969) provided pigeons with the opportunity to make an observing response on an observing key. The observing response had the effect of changing a mix FR 20 FR 100 to a mult FR 20 FR 100 on the food key. Thus, the observing response had essentially the same function as a prime. However, the observing can occur anywhere in a ratio while the prime provides information only after the number of responses in the short FR have been completed. Following observing responses, Hendry found a short pause prior to the FR 20 and a longer and more variable pause before the FR 100. If no observing response occurred, the pause was short before both ratios. Observing responses were most likely following reinforcement, but were also probable after sixteen to forty responses in the FR 100 had occurred. Since this is approximately the length of the short ratio, observing responses are apparently replacing the priming run. However, completion of about twenty responses on the food key already provides information as to which schedule is in effect. Any information provided by an observing response is thus redundant and should not maintain the prime (Egger and Miller, 1963). Assuming the information theory of priming is correct, a possible explanation is that red and green lights are more reliable predictors of the schedule in effect than a priming run.

Based on their data, Crossman and Silverman (in press) question the information hypothesis of priming. A prime provides the same amount of information independent of FR 10 frequency. To counter the information hypothesis they claim the prime is essentially a large unit of behavior. This unit of behavior is intermittently reinforced by food delivery on



the FR 10 schedule. The prime is thus dependent on FR 10 frequency and would be maintained when the FR 10 occurs frequently enough.

## METHODS AND RESULTS

The purpose of the present study was to examine the effect of a superimposed FI contingency on mixed and multiple FR schedules. More specifically, the FI contingency was used to determine if the pattern of responding obtained by Crossman and Silverman (in press) was due to their superimposed fixed-number contingency or to the order in which the components occurred. The multiple schedule was included to control for a possible relationship between pausing and priming.

Experiment I - mixed schedule

Subjects. One White Carneaux pigeon (MT-1) and one homing pigeon (MT-4) served as the experimental subjects. The age and sex of each bird were unknown. Mt-1 had previous experience on concurrent schedules. MT-4 was experimentally naive.

Apparatus. Sessions were conducted in a standard three-key pigeon chamber (Ferster and Skinner, 1957). The reinforcer consisted of 3 sec access to a hopper containing Purina Pigeon Chow. The left response key, located directly above this food hopper, was transilluminated by a colored light. The remaining two keys were not used and remained dark. The chamber was illuminated by two clear 24 vdc bulbs located near the top of the intelligence panel on which the response keys were mounted. White noise was present at all times to mask extraneous sounds. The experiment was controlled and data recorded by electromechanical equipment housed in an adjacent room. Pause lengths were recorded in sixtieths of a sec by an on-line PDP-5 digital computer (Digital Equipment Corporation).



Procedure. Both subjects were maintained at approximately 80% ad lib weight and trained to peck a red key by reinforcing successive approximations of this response. The number of responses required for reinforcement was then gradually raised both within and across sessions until an FR 100 was established. Following this training, the session length was fixed at 90 min and the weight of the subjects was allowed to vary as a function of the food consumed during experimental sessions. Sessions were conducted six days a week. Subjects were fed maintenance rations on days in which sessions were not conducted. Water was available at all times in the home cage.

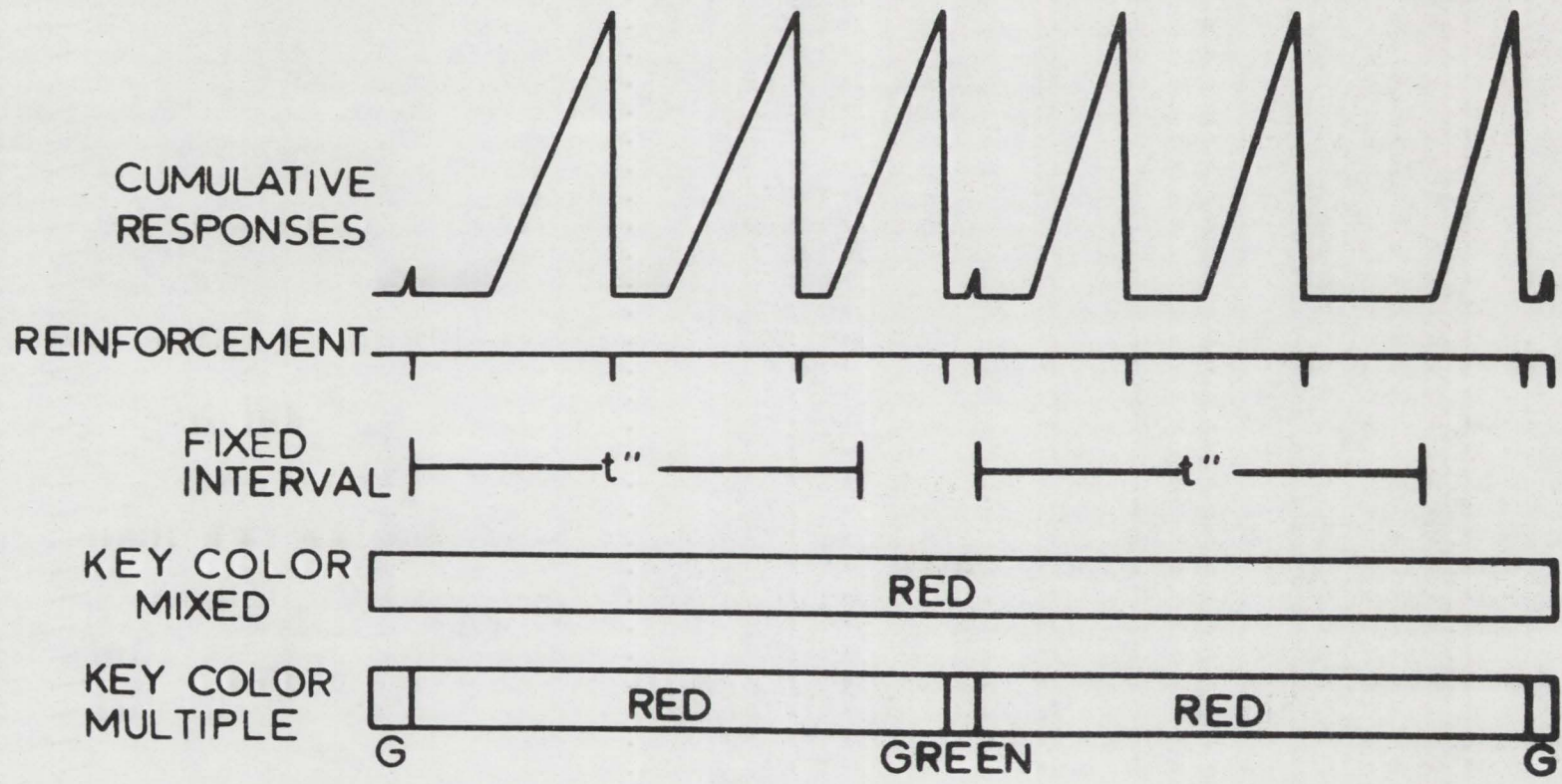
When no trend was evident in the median pre-FR 100 pause length, the mixed schedule was introduced and FR 10 components were presented according to a fixed-interval (FI) contingency. This contingency specified that an FR 10 would occur following the completion of the first FR 100 component after "t" min timed from either the end of the reinforcement cycle of the FR 10 or the beginning of the session, whichever occurred last. The key light remained red during both the FR 100 and the FR 10 components.

This procedure is diagrammed in Figure 1. The top line represents a stylized cumulative response record in which the pen reset with each reinforcement. The line immediately below this shows reinforcer delivery, indicated by a downward deflection. The next line shows the interval, "t" min, beginning with the end of the reinforcement cycle for the last FR 10. The first interval timed out in the middle of the FR 100 run and the subject was required to complete that FR 100 to produce an FR 10. The second interval timed out in the pre-FR 100 pause and an additional 100 responses were required before the FR 10 became available. The bottom two bars illustrate the key color(s) in effect during each component





Figure 1. A diagram of the schedule contingencies for the mix FR 100 FR 10. The top line represents a stylized cumulative response record. The pen is reset after the completion of an FR 100 or an FR 10 with food delivery indicated by a downward mark on the line immediately below. The third line indicates the timing cycle of the FI contingency. The fourth and fifth lines indicate the colors of the response key during the FR 100 and the FR 10 in the mixed and multiple schedules respectively.





of the mixed schedule (top bar) used in Experiment I and the multiple schedule (bottom bar) used in Experiment II.

The sequence of FI values was 10, 7, 4, 7 and 10 min for MT-1 and 4, 7, 10, 7 and 4 min for MT-4. Each FI value remained in effect for approximately 18 sessions and until no trend was evident in the median pre-FR 100 pause. Medians were used to minimize the effect of exceptionally long pauses which occasionally occurred. The sequences of FI values were preceded and followed by a simple FR 100 schedule (baseline condition) for both birds.

Results. The mixed schedule produced a pattern of responding in which the first pre-FR 100 pause after an FR 10 was long and contained few primes. (Primes were arbitrarily defined as a run of 9 to 18 responses at the beginning of an FR 100 followed by a pause of at least 9 sec). All other pre-FR 100 pauses were short and approximately equal to the pre-FR 10 pause. Primes were frequent in these other FR 100s.

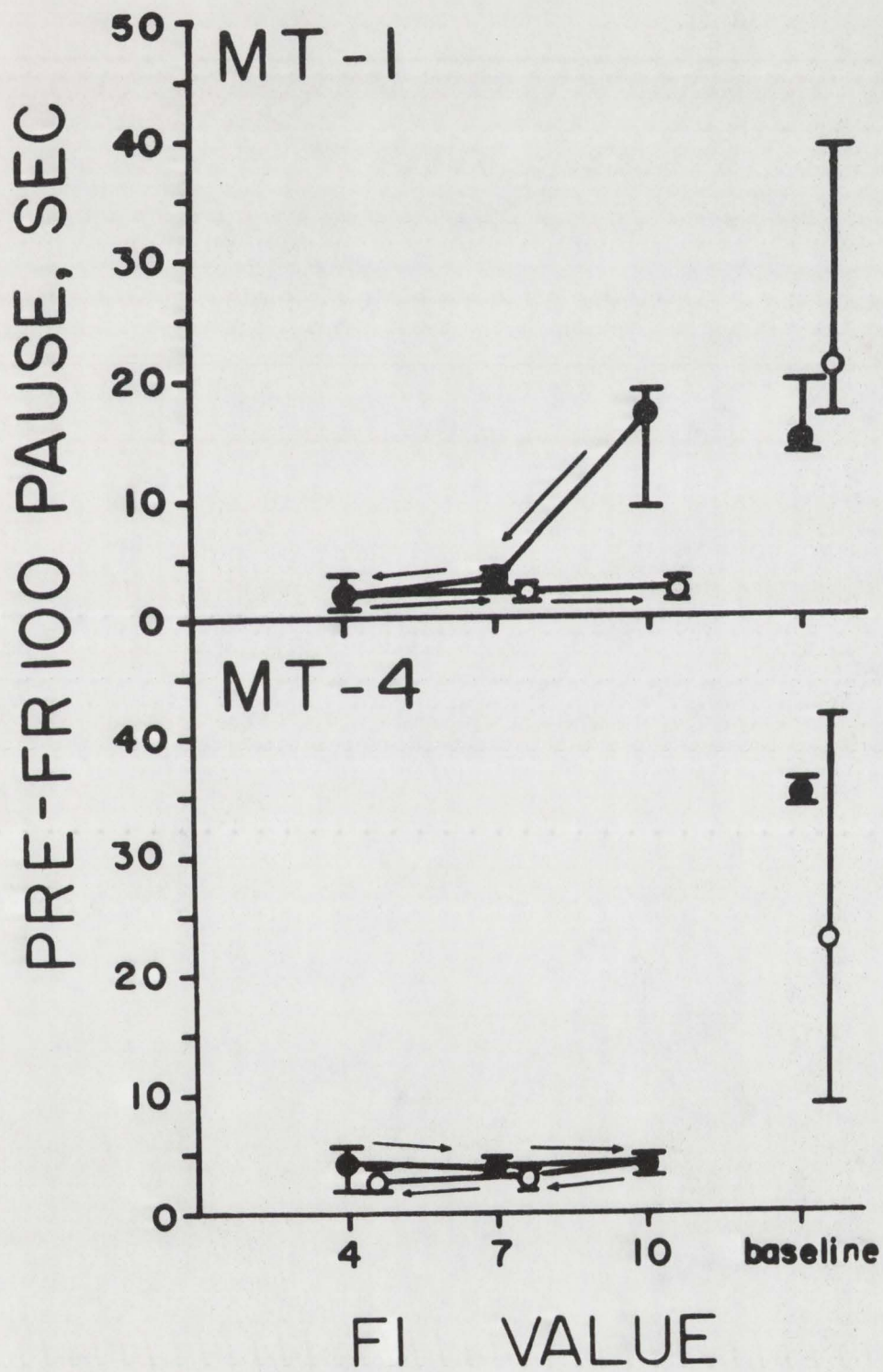
Examination of the data revealed a general shortening of the pre-FR 100 pause after the mixed schedule was introduced. Figure 2 shows the pre-FR 100 pause as a function of the FI. Each point represents the median of the last five session medians for the pre-FR 100 pause. An indication of variability is provided by the bars, which represent the range of the medians for the last five sessions. The order of the conditions is indicated by the arrows with closed circles representing the first determinations and open circles the second determinations.

On the FR 100 baseline, the pre-FR 100 pause was about 15 sec and 35 sec for MT-1 and MT-4 respectively. Pause length did not change for MT-1 when the FR 10 component was introduced according to an FI 10. An abrupt decrease to a pause of approximately two sec occurred at FI 7, and the pause





Figure 2. Median and range of median pre-FR 100 pauses on the mixed schedule for the last five sessions at each FI value. The first exposure to each condition is indicated by closed circles while the second exposures are indicated by open circles. To allow a representation of variability, second determination points are offset slightly to the right of the first determination points. Arrows above or below each line indicate the order of presentation of each FI value. The upper half of the figure represents data for MT-1 and the bottom half represents data for MT-4.





remained about this length as the FI value was decreased to FI 4 and then subsequently increased to FI 10. The pre-FR 100 pause increased when the FR 100 (baseline condition) was reinstated.

For MT-4, the occurrence of FR 10s in the mixed schedule produced a large decrease in the pre-FR 100 pause at FI 4. Little additional change in pause length occurred as the FI was varied. The pre-FR 100 pause increased for MT-4 when the FR 100 (baseline condition) was reinstated.

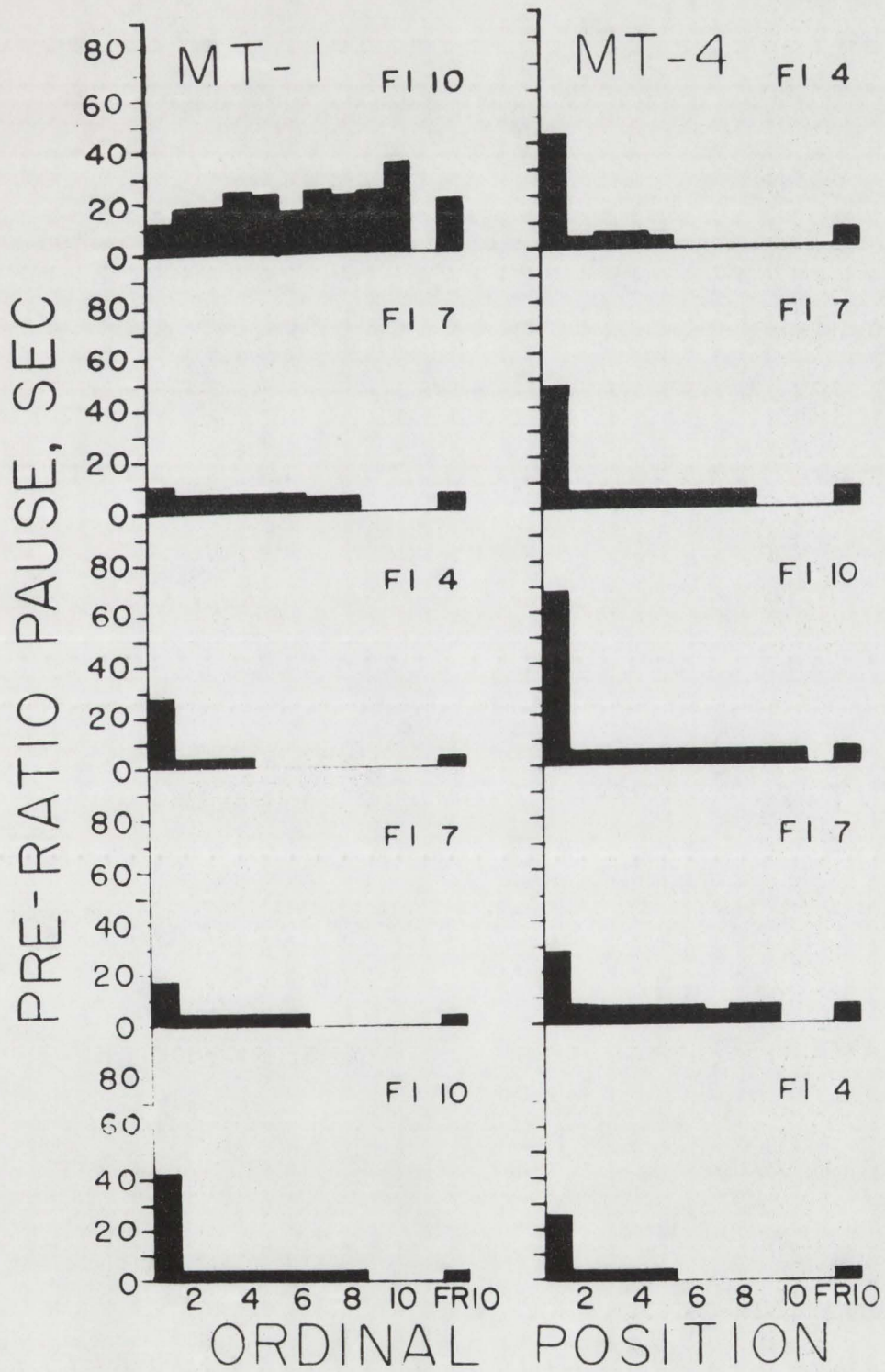
Figure 3 provides a more detailed account of the changes in pause length which occurred as a function of the introduction of the mixed schedule. On the left side of each set of bar graphs, the median pre-FR 100 pause length is plotted as a function of the ordinal position of that pause. The first pre-FR 100 pause following an FR 10 was assigned to ordinal position one, the second to position two, etc. until the next FR 10 occurred. The bars on the far right of each set of bar graphs in Figure 3 show the length of the pause preceding the FR 10 component. Each bar represents the median of the last five session median pause lengths for that ordinal position at each FI value. Those ordinal positions containing seven or fewer pauses total over the last five sessions were considered to represent an insufficient sample of the subject's behavior and were thus ignored in data calculation. This exclusion usually affected only the last ordinal position. The figure presents the FI values in order in which they occurred (from top to bottom).

For MT-1, introduction of the mixed schedule at the FI 10 value produced no change in pre-FR 100 pause length with respect to the ordinal position of that pause. At FI 7, the first pre-FR 100 pause after an FR 10 shown as position one, was slightly longer than the pre-FR 100 pauses





Figure 3. The pre-ratio pause as a function of the ordinal position at each FI value. Each bar represents the median of the last five session medians at each ordinal position. Ordinal position one represents the first pre-FR 100 pause after an FR 10, ordinal position two the second pre-FR 100 pause after an FR 10, etc. The bar on the right of each series of bars represents the median pre-FR 10 pause for that FI value. The series of bars on the left represent the median pauses for MT-1 while those on the right are for MT-4.





for all other ordinal positions. When the FI value was changed from 7 to 4, the pause in the first ordinal position increased while all other pre-FR 100 pauses decreased, further. The pre-FR 10 pause, shown on the right, was about the same length as the pre-FR 100 pauses at FI 10. However, at FI 7, the pre-FR 10 pause decreased and at FI 4 was extremely short. There was close correspondence between the length of the pre-FR 10 pause and all the pre-FR 100 pauses except for ordinal position one at FI 4 and subsequent FI values.

For MT-4, similar changes occurred as shown in the right half of Figure 3. Comparison of the pre-FR 100 pause shown in Figure 2 for the baseline condition with the pre-FR 100 in ordinal position one at FI 4 in Figure 3 shows that the pause in ordinal position one increased from the pause length obtained in a simple FR 100. This increase was accompanied by a decrease in pause lengths for all other positions at FI 4, such that pauses at these positions were considerably shorter than position one. Likewise, the pre-FR 10 pause was short and approximately equal in length to the pre-FR 100 pauses at all ordinal positions except the first. Little change in this pattern was evident as the FI value was manipulated.

Cumulative records (selected from one of the last five sessions) are shown for each bird in Figure 4. These records allow a comparison of the FR 100 baseline for each bird with the first exposure to FI 4 for MT-1 and FI 10 for MT-4. These records generally support the observation that an FR 10 was likely to be followed by a long pause while the pause following an FR 10 tended to be short. In addition, the mixed schedule increased priming within the FR 100. Primes are indicated by the dots directly above them. Relatively fewer primes occurred in the first ordinal position than in other FR 100s.



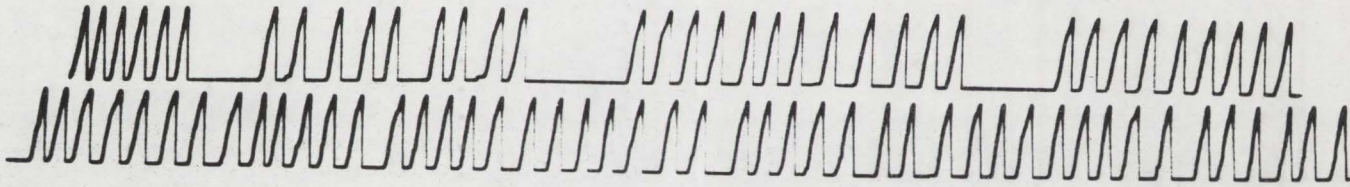


Figure 4. Selected cumulative records for both subjects for the first exposure to the FR 100 baseline and the first exposure to FI 4 (MT-1) and to FI 10 (MT-4). The pen reset with each reinforcer. Primes are indicated by dots above the cumulative record.

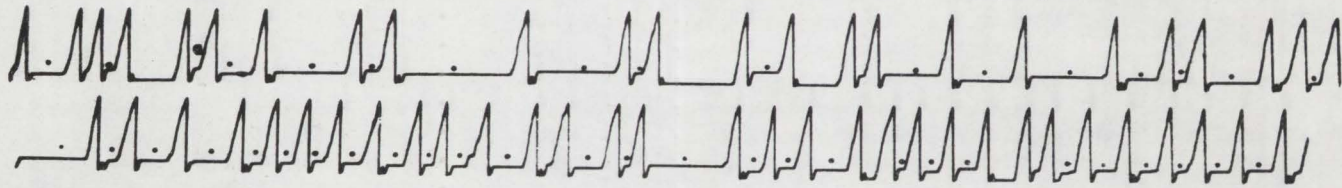
100 R  
25 MIN

MT - 1

BASELINE

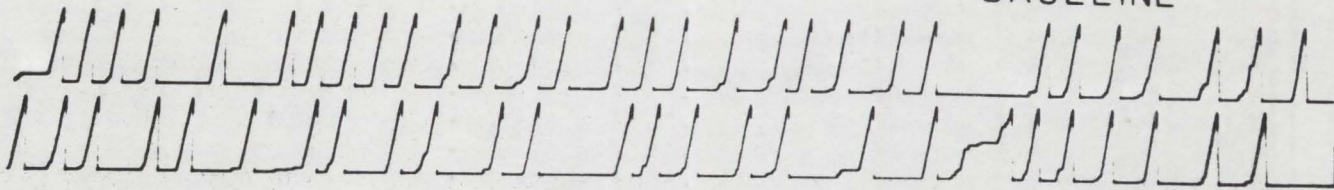


FI 4

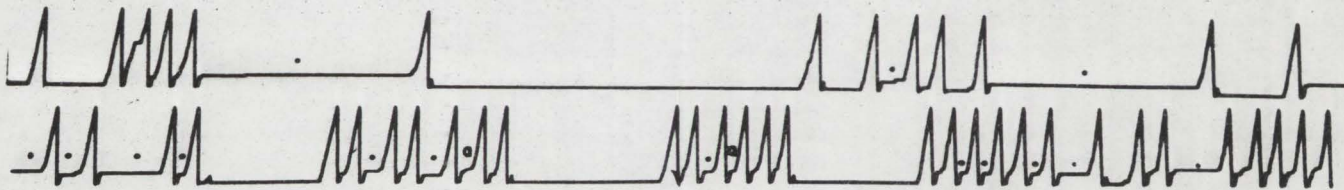


MT - 4

BASELINE



FI 10





The relationship between priming and the ordinal position of the FR 100 in which the prime occurred is shown more clearly in Figure 5. In this figure, the percent of FR 100s containing primes at each ordinal position is shown for each condition. Percent priming was obtained by dividing the total number of primes in each ordinal position for the last five sessions by the total number of FR 100s for that ordinal position.

There was little difference in priming in any position when FR 10s were first presented for MT-1 at FI 10 or subsequently at FI 7. However, at FI 4, little priming occurred in the first FR 100 to follow an FR 10, but over 80% of the other FR 100s contained primes. This pattern characterized priming for the remaining FI values for MT-1.

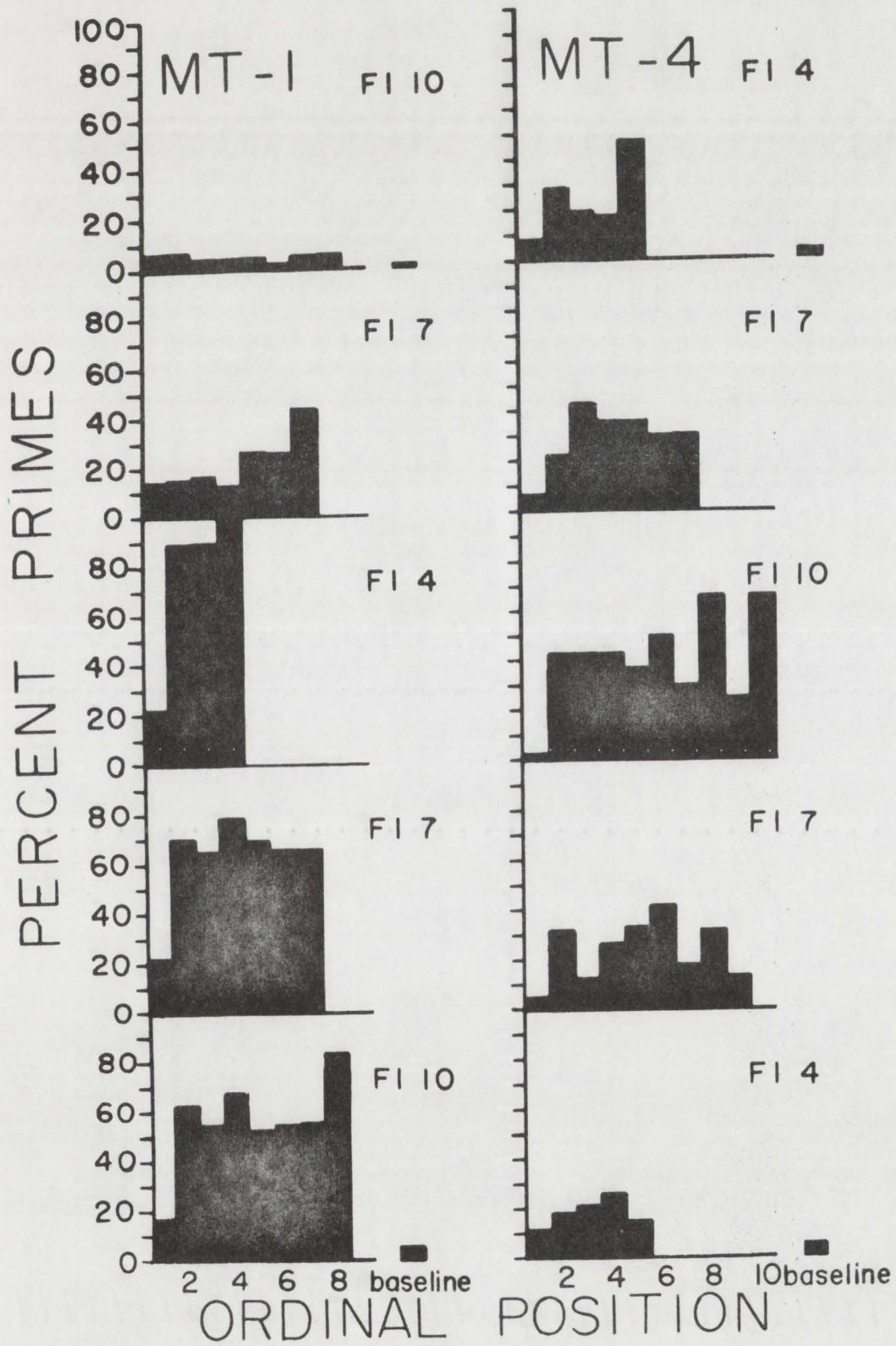
For MT-4, the first position also contained relatively fewer primes than the other ordinal positions at all FI values, but priming also occurred less frequently than was true for MT-1. Examination of cumulative records suggests that events similar to a prime occurred. These events did not satisfy the present definition and may have contributed to this decrease. Nevertheless, as for MT-1, primes were relatively infrequent for MT-4 in the first ordinal position.

These data suggest a relationship between pausing and priming. For MT-4, the mixed schedule produced short pauses at the first FI value and the pauses remained short throughout the other FI values until the FR 100 baseline was reinstated. Primes were frequent while the mixed schedule was in effect. For MT-1, short pauses did not develop until FI 4, although pauses had begun to shorten at FI 7. Likewise, primes were frequent at FI 4, infrequent at FI 10, and intermediate at FI 7. Thus, short pauses were correlated with primes. Evidence of this relationship





Figure 5. Percent of the FR 100s in which priming occurred at each ordinal position over the last five sessions for each FI value. Percent priming in the first exposure to FR 100 baseline is presented at the right of the top series of bars. The second exposure to baseline is presented at the right of the bottom series of bars. Data for MT-1 are presented in the left half of the figure while data for MT-4 are presented in the right half.





is apparent in the ordinal position data. Ordinal position one was characterized by long pauses and few primes. Other ordinal positions were characterized by short pauses and frequent primes.

Appendix A contains summary data on changes in body weight, number of reinforcers earned and the mean inter-FR 10 interval. Neither body-weight nor number of reinforcers earned showed any relationship with pause length. Local response rate on the FR 100 is also presented in Appendix A and was generally lower for the mixed schedule than for the FR 100 baseline.

#### Experiment II - multiple schedule

Subjects. One White Carneaux Pigeon (MT-2) and one homing pigeon (MT-3) served as the subjects. Both subjects were experimentally naive. MT-3 was a female but the age was not known. The age and sex of MT-2 was unknown.

Apparatus. The apparatus was the same as in Experiment I.

Procedure. The procedure was the same as that in Experiment I with the following exception. The schedule was a multiple FR 100 FR 10 with a red key correlated with FR 100 and a green key correlated with FR 10.

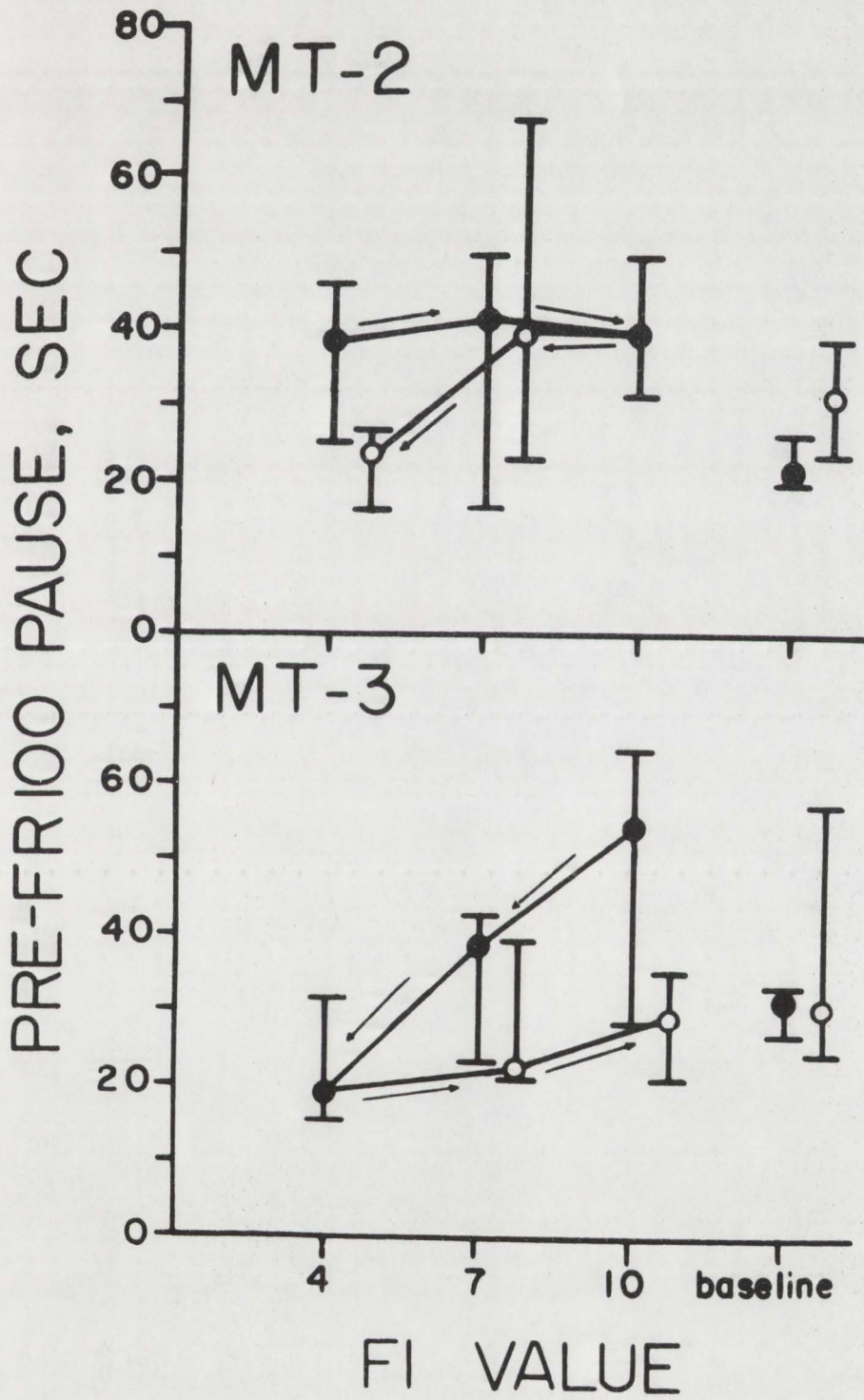
The sequence of FI values was 4, 7, 10, 7 and 4 min for MT-2 and 10, 7, 4, 7 and 10 min for MT-3. An FR 100 baseline condition preceded and followed the multiple schedule. Each condition remained in effect for approximately 18 sessions and until no trend was evident in the median pre-FR 100 pause.

Results. The introduction of the multiple schedule and manipulation of the FI value had little effect on the pre-FR 100 pause. In Figure 6, the median pre-FR 100 pause for the last five sessions is plotted for both birds for each condition. An indication of variability is provided





Figure 6. Median and range of median pre-FR 100 pauses for the last five sessions at each FI value. The first exposure to each condition is indicated by closed circles while second exposures are indicated by open circles. To allow a representation of variability, second determination points are offset slightly to the right of the first determination points. Arrows above or below each line indicate the order of presentation of each FI value. The upper half of the figure represents data for MT-2 and the bottom half represents data for MT-3.





by the lines associated with each point. These lines indicate the range of medians for the last five sessions. Although MT-3 evidenced a trend toward shorter pausing as the FI value decreased, considerable overlap is evident. Except for the second determination at FI 4, MT-2 did not show this trend.

In Figure 7, the median pre-FR 100 pause is plotted as a function of the ordinal position for each FI value. The sequence in which the subjects were exposed to the values of the FI are represented from top to bottom. As was true in Figure 6, Figure 7 shows no effect of FI value on pause length. Likewise, no effect due to ordinal position is evident. Sometimes, the pre-FR 100 pause increased with ordinal position, sometimes it decreased and sometimes it remained unchanged. In general, the pre-FR 100 pause remained constant across all ordinal positions in the multiple schedule.

On the right side of each set of graphs, the median pre-FR 10 pause is plotted at each FI value. This pause was short relative to the pre-FR 100 pauses. The pre-FR 10 pause also remained constant with changes in the FI.

Several selected cumulative records are presented for each subject in Figure 8. One session was selected from the first exposure to the FR 100 baseline and one session from the first exposure to FI 4 for each subject. These records show little difference between the FR 100 performance in the baseline and in the multiple schedule. The records also confirm the observation that the pre-FR 100 pause is long while the pre-FR 10 pause is short. Primes were virtually absent.

Neither bodyweight nor number of reinforcers per session showed any relationship with pause lengths. These data are presented in Appendix B.





Figure 7. The pre-ratio pauses in the multiple schedule as a function of the ordinal position at each FI value. Each bar represents the median of the last five session medians at each ordinal position. Ordinal position one represents the first pre-FR 100 pause after an FR 10, ordinal position two the second pre-FR 100 pause after an FR 10, etc. The bar on the right of each graph represents the median pre-FR 10 pause for that FI value. The series of graphs on the left represent the median pauses for MT-2 while those on the right are for MT-3.

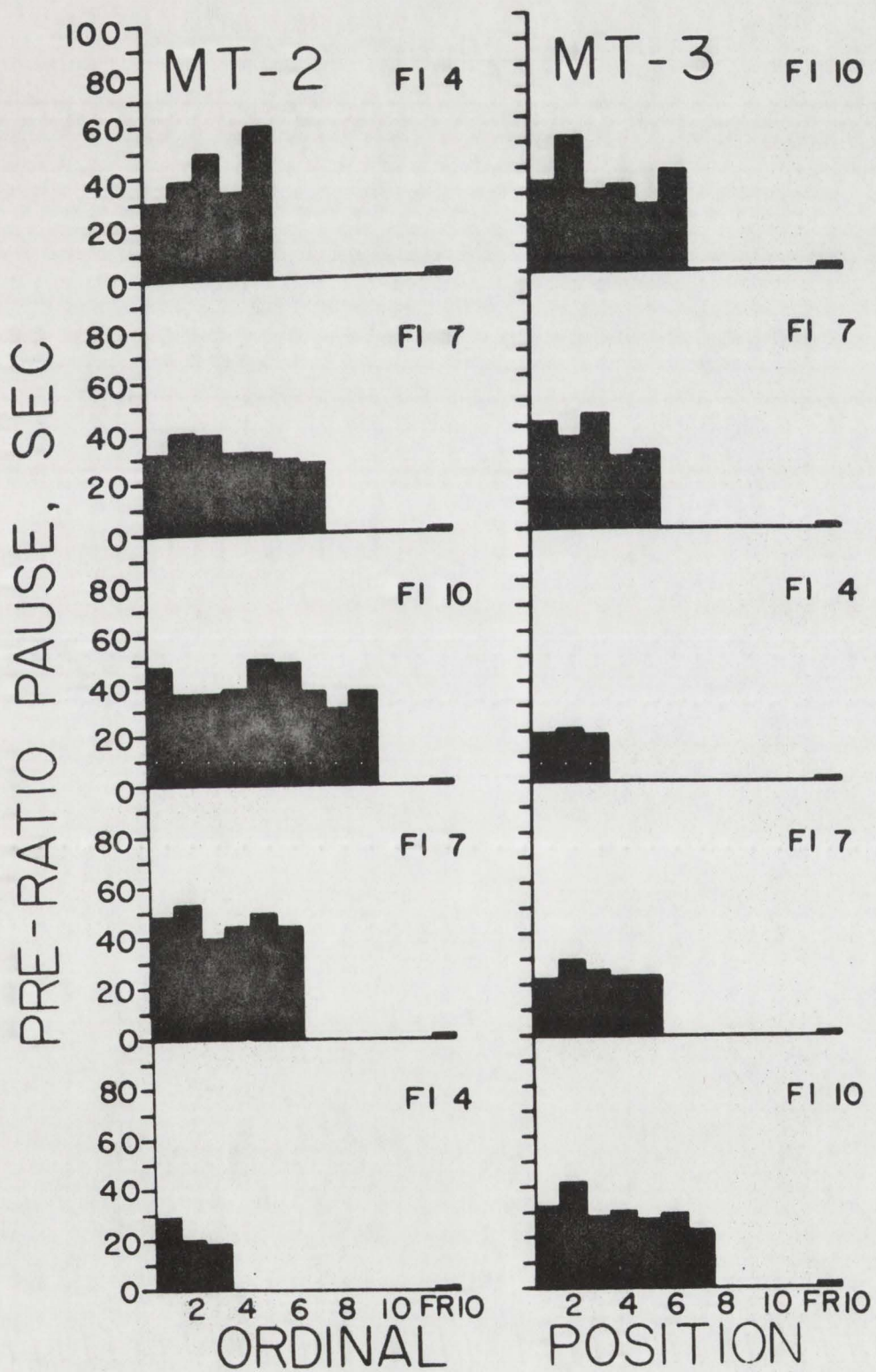






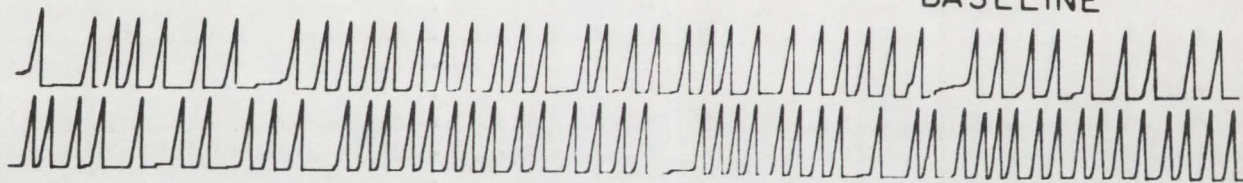
Figure 8. Selected cumulative records from the first exposure to the FR 100 baseline and the first exposure to FI 4 for each subject. The pen reset with each reinforcer. The key was red during FR 100 and green during FR 10.



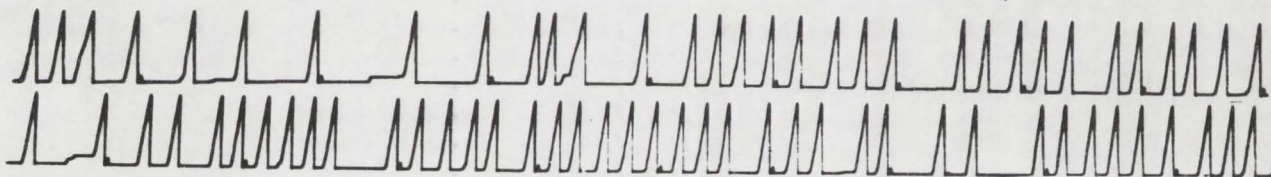
100  $\mu$ s  
2.5 MIN

MT - 2

BASELINE

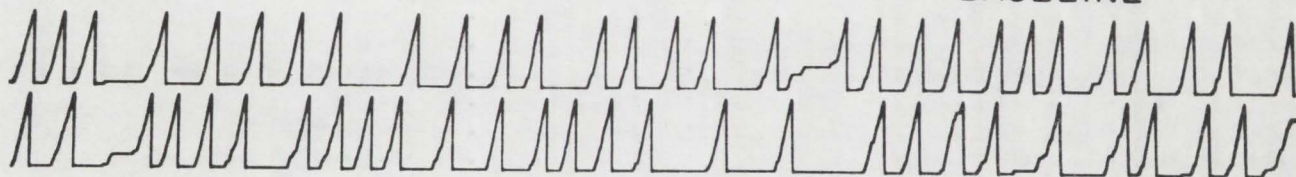


FI 4

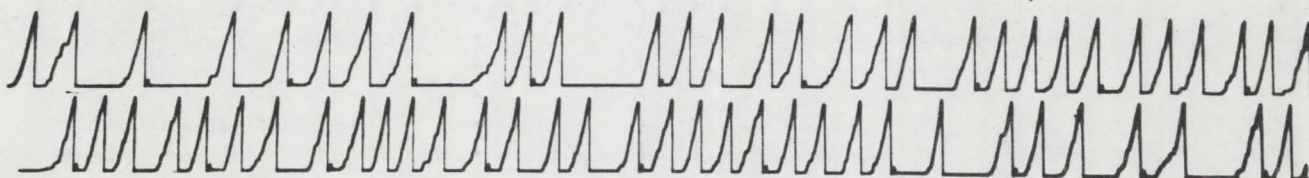


MT - 3

BASELINE



FI 4



Likewise, changes in the local FR 100 response rate in the multiple schedule showed no consistent relationship with changes in the FI value.



## DISCUSSION

The pattern of responding obtained in the present study does not support the hypothesis that the opportunity to emit an FR 10 on an FI functioned as a reinforcer for performance on the FR 100 in the mixed or multiple schedules. Instead the pattern of responding in the mixed schedule was similar to that obtained by Crossman and Silverman (in press). In the mixed schedule, FR 10s were followed by long pauses while pauses following FR 100s were short. These results indicate that the pattern of responding was not controlled by the schedule contingency. Instead, the pattern was due to the order in which the components occurred.

### Effects of fixed-interval value

If the FR 10 functioned as a reinforcer, decreasing the FI value should have produced decreases in the length of the pre-FR 100 pauses. This did not occur in the multiple schedule. Not only did the introduction of the multiple schedule fail to change the pre-FR 100 pause from that established during baseline, but little change was evident as the length of the superimposed FI contingency was manipulated. The fact that pause was not controlled by the FI contingency within the range of values investigated questions the reinforcing function of the FR 10 and the usefulness of the superimposed FI contingency in the multiple schedule.

In the mixed schedule, the pre-FR 100 pause length did vary with the FI value for MT-1. Pause lengths decreased as the FI decreased and more FR 10s occurred. However, pause lengths did not increase when the FI was subsequently increased. Also pause length did not change with changes in the FI for MT-4.



Since MT-4 began with an ascending sequence of FI values and MT-1 with a descending sequence, the difference in the pause lengths for these two subjects was probably a sequential effect. Pre-FR 100 pause lengths did not decrease for MT-1 until the FR 10s occurred at approximately one every seven minutes. Once this value had occurred, pause lengths remained short even when the frequency of FR 10s decreased to approximately one every ten minutes, a value at which short pause lengths had not previously developed. MT-4, on the other hand, began at FI 4, a value which also produced short pauses for MT-1. When the FI 10 was introduced, short pauses had already developed at FI 4 and were maintained at this value. Changing the frequency of FR 10s did not change the pre-FR 100 pause lengths for MT-4 within the range of FI values investigated.

This suggests that a minimum frequency of FR 10s must occur before the pre-FR 100 pause lengths shorten in a mixed FR 100 FR 10 schedule. However, once this minimum frequency of FR 10s has been attained, short pre-FR 100 pauses can be maintained even when the frequency of FR 10s is decreased below this critical frequency. Since the initial mixed schedule for MT-1 apparently did not have a sufficient frequency of FR 10s, it was necessary to increase the frequency of FR 10s by decreasing the FI to shorten pause lengths.

This conclusion is supported by data obtained in mixed schedules by Crossman and Silverman. They presented FR 10s after the completion of a fixed number of FR 100s and found that the pre-FR 100 pauses had not completely shortened until the proportion was changed from 99:1 to approximately 7:1. When the proportion of FR 100s to FR 10s subsequently increased, the short pause lengths were maintained up to proportions of 20:1. Thus, the inability to recover the long pause lengths obtained at



higher proportions in the present study was a case of hysteresis due to sequential effects. Once short pausing develops in the mixed schedule, it can be maintained by a lower frequency of FR 10s than was necessary to initially produce it. Primes showed a similar relationship. Like short pauses, priming did not fully develop for MT-1 until the FI was decreased to FI 4. Like pauses, primes showed hysteresis. Decreasing the FI value did not affect priming.

Thus, the decreases in the pre-FR 100 pause lengths which occurred in the mixed schedule were not due to the reinforcing function of the FR 10, but were due either to priming or the sequence of components. Likewise, the present data do not support the hypothesis that pause lengths in a mixed schedule are a function of the mean of the ratios (Ferster and Skinner, 1957). The mean of the ratios decreased as the FI decreased, but pause length did not necessarily vary.

#### Sequence effects - multiple schedule

Although it was noted in the previous section that, overall, the pre-FR 100 pause did not change as a function of FI value, this does not rule out the possibility of "scalloping", i.e., a progressive decrease in the pre-FR 100 pause as the interval elapsed. To investigate this possibility, the pre-FR 100 pause length was plotted as a function of its ordinal position in the sequence of pauses. No scalloping occurred. Rather, the pre-FR 100 pauses were approximately equal over the sequence.

Compared to the pre-FR 100 pause, the pre-FR 10 pause was short. This result is not particularly surprising if the multiple schedule produced the pattern of responding associated with the simple schedules in effect. However, there is some reason to believe that multiple schedules do not simply produce behavior appropriate to the schedule in effect.



This would occur only if the components were independent of each other. If an interaction exists, contrast is likely. Thus, Mintz, Mourer and Gofseyeff (1967) alternated two FR 50s with two FR 10s in a multiple schedule and found that the pause between the FR 10 and the FR 50 was longer than the other pauses. Likewise Silverman (1970) alternated three FR 75s with an FR 10 and found similar results. However, in the current study, the first pre-FR 100 pause after an FR 10 was no longer than any other pre-FR 100 pause in the multiple schedule.

Why contrast did not occur in the multiple schedule is not clear. One possible explanation is that contrast is transient, lasting only about ten sessions (Keehn, 1965). Since a minimum of eighteen sessions occurred at each FI value, the contrast effect could have disappeared. Another possibility is that the failure to obtain contrast was due to the difference in contingencies. Silverman (1970), for example, required a fixed number of FR 75s per FR 10 while in the current study, a fixed-interval contingency was used.

#### Sequence effects - mixed schedule

The mixed schedule had a considerably different effect than the multiple schedule. In this case, the pre-FR 100 pause in ordinal position one was long while the other pre-FR 100 pauses were short and approximately equal in length to the pre-FR 10 pause. This result is consistent with that obtained in mixed schedules using a fixed-number contingency (Silverman, 1970; Crossman and Silverman, in press). The fact that this effect was also obtained with a fixed-number contingency questions whether the effect was due to the FI contingency. Instead, the long pause was due to the order or sequence of the schedule components. The role of the FI contingency was restricted to its ability



to generate a sequence of FR 100s followed by a single FR 10. Given that this sequence occurs, the post-FR 10 pause will be long.

The hysteresis previously noted for MT-1 is again illustrated in the sequence of pauses. This effect is particularly revealing because it suggests a relationship between the pre-FR 100 and the pre-FR 10 pause. At FI 10, the first value of the mixed schedule for MT-1, all pauses were long. At FI 7, the pre-FR 10 pause began to shorten. Concomitantly, the pre-FR 100 pauses in ordinal positions other than the first one also shortened and were approximately the length of the pre-FR 10 pause. At FI 4, this shortening of the pre-FR 10 and these pre-FR 100 pauses was completed.

Priming showed a relationship similar to pausing. Again, hysteresis was evident for MT-1. At FI 10, priming was almost absent and differed little from that obtained in the preceding baseline condition. At FI 7, priming began to develop, and this development was completed by FI 4. The development of priming thus corresponds with the development of short pauses.

The pattern of priming shows an interesting relation to the pattern of pausing. Relatively little priming occurred in the first FR 100 to follow an FR 10. Primes were quite frequent at other ordinal positions. Pre-FR 100 pauses were short in positions containing primes and long in those positions in which primes were absent. Although short pauses also preceded FR 10s, the tendency to prime on an FR 10 was difficult to determine since the reinforcer was delivered following the tenth response. This precluded the possibility of obtaining a prime, except in the case of "undershooting" where a pause occurred after nine responses. Infre-



quent "primes" after nine responses on the FR 10 did occur. These "primes" suggest that the FR 10 was a priming run "cut off" by the reinforcer.

The pattern of priming was more variable for MT-4, although the same general pattern was obtained. Observation of the cumulative records suggests that a higher frequency of "prime-like" behavior occurred for MT-4 than did for MT-1. If the definition of a prime were modified to include priming runs of more than 18 responses or a pause of less than nine sec, a considerable increase in primes would occur for MT-4. Presumably, this increase would be accompanied by a decrease in variability. However, the cumulative records also show that even a modified definition would have little effect on the frequency of primes for the first ordinal position. Changing the definition of a prime would only result in greater consistency in priming for other ordinal positions.

#### Analysis of pausing and priming

In the present study, the results could most clearly be described in terms of a pre-ratio pause (i.e., the pre-FR 100 or pre-FR 10 pause) for the multiple schedule and a post-ratio pause (i.e., post-FR 100 or post-FR 10 pause) for the mixed schedule. In the mixed schedule, the first FR 100 following an FR 10 was preceded by a long pause and contained relatively few primes. Other ratios were preceded by short pauses and primes were frequent. In the multiple schedule, FR 100s were preceded by long pauses independent of the position in the sequence; FR 10s were preceded by short pauses.

Ferster and Skinner (1957) suggested that an S-delta condition exists immediately following reinforcement on fixed-ratio schedules.



Since the probability of another reinforcer under these conditions is low, so is the probability of a response.

In the multiple schedule, reinforcement never occurred after ten responses in the presence of a red key, but always did in the presence of a green key. Key-color provided information about the size of the ratio coming up. The S-delta is based on the current key-color rather than the size of the ratio just completed. Therefore, it makes sense to talk about pre-ratio pauses in the multiple schedule.

In the mixed schedule, it is not clear why long pauses should precede FR 100s in the first ordinal position and short pauses other FR 100s. Since a red key was present for both the FR 100 and the FR 10, differences in pausing can not be based on key-color as was true for the multiple schedule. The differences in pause length must be due to the subject's contact with the reinforcement contingencies.

Once a single FR 100 has occurred, a pattern similar to that obtained under random alternation might be expected. The occurrence of an FR 100 would set the occasion for a short pause appropriate to an FR 10 if FR 10s occurred frequently enough. On the other hand, an FR 10 was always followed by an FR 100 and never by another FR 10. Reinforcement after an FR 10 produced an S-delta condition informing the subject that one hundred responses were required for the next reinforcer. Thus, the sources of control in the mixed schedule were the cues arising from the preceding ratio and the term, post-ratio pause, is appropriate.

The close relationship between pausing and priming suggests that a similar analysis should hold for priming. In ordinal positions having short pauses, frequent primes occurred. In positions with long pauses, primes were less frequent. Similarly, examination of the development of



mixed schedule performance for MT-1 revealed that primes were almost nonexistent when the post-FR 100 pause was long. When the post-FR 100 pause began to shorten, some priming developed. When the post-FR 100 pause reached its lowest value, priming was well developed.

The multiple schedule, which contained no primes, was characterized by long pre-FR 100 pauses. In the mixed schedule, both primes and short pre-FR 100 pauses occurred. Thus, priming and short pauses were closely related.

Hendry, (1969) provided further evidence for the relationship between pausing and priming. When an observing response occurred, a mix FR FR was changed to a mult FR FR, and the pause following the observing response was appropriate to the schedule in effect. When an observing response did not occur, the pause was short before both ratios. Secondly, if an observing response did not occur at the beginning of the ratio, it frequently occurred after the number of responses in the smaller ratio had been completed. Thus, in the absence of information at the beginning of a ratio as to which ratio was in effect, a short pause and a "prime" occurred. In the presence of such information, the pause was appropriate to the ratio and no prime occurred. This supports the relationship between pausing and priming found in the current study.

Since primes provide information about which schedule is in effect, primes may be observing responses maintained by the information they provide. However, several lines of evidence suggest they are not. In Hendry's (1969) study, observing responses were frequent after the number of responses in the smaller ratio had been completed. Yet, once the number of responses in the smaller ratio had been completed, the animal has all the information needed to predict which schedule is in effect.



The information provided by the observing response is redundant and redundant information does not function as a conditioned reinforcer (Egger and Miller, 1963).

Primes did not occur in the present study when FR 10s were initially presented according to an FI 10 contingency. Crossman and Silverman (in press) also found that primes did not occur if FR 10s were infrequent. The information provided by a prime did not vary as a function of FR 10 frequency, but was constant. Either the schedule was FR 10 or FR 100. Thus, information per se does not control priming. However, studies with observing responses showed that only certain information was reinforcing (Dinsmoor, Flint, Smith and Viemeister, 1969). Observing responses were not maintained if they provided information about the occurrence of shock superimposed on a food schedule, but were maintained if they provided information about the absence of shock. This suggests that primes would be maintained only when they provide information about an FR 10 and not an FR 100. However, the information following a run of ten responses when an FR 10 is in effect was provided by food delivery. Clearly, there is no need to invoke a conditioned reinforcer called "information" to maintain a run of ten responses when an FR 10 is in effect. And since information about the FR 100 is probably not a conditioned reinforcer (Dinsmoor, et al., 1969) a run of ten responses can not be maintained by the information provided when an FR 100 is in effect. Thus, primes are not maintained by the information they provide.

#### The FR 10 as a unit

A different account of priming has been suggested by Crossman and Silverman (in press). They considered the prime to be a unit of behavior. Since the prime consists of ten responses at the beginning of a ratio,



this unit is reinforced if an FR 10 occurs. Since the unit of ten responses is reinforced only if the FR 10 is in effect, Crossman and Silverman suggested that the prime was maintained by the intermittent occurrence of the reinforcer for the performance on the FR 10.

In support of the prime as a unit, Crossman and Silverman (in press) noted that the development of priming was dependent on FR 10 frequency. They suggested that priming was "shaped up" much as simple responses are. Since acquisition requires a greater frequency of reinforcement than does maintenance, priming can be maintained at a lower FR 10 frequency than was required to shape it. Once FR 10s become too infrequent, priming extinguished. Ferster and Skinner (1957, p. 587-588) noted that "the discontinuation of the reinforcement on the shorter ratio (in a mixed FR FR schedule) permits extinction of the priming break".

The results in the present study suggest that Crossman and Silverman have incorrectly identified the priming run as the unit of behavior. In the present study, priming and short pauses were closely related. Thus, the unit includes both the prime and the pauses preceding and following the priming run. The unit is "FR 10-like behavior", rather than simply the priming run, which is maintained by the intermittent reinforcement which occurs after a run of ten responses.

Reinforcement of this more general priming unit accounts for the development of the run of ten responses and the pause preceding this run, but it fails to account for the pause which follows the priming run. This is where information plays a role. If the priming run is not followed by a reinforcer, information exists that the schedule is FR 100. This information produces an S-delta condition and the resulting pause. The function of the information provided by the prime is not the



maintenance of that prime, for that is provided by the reinforcer following performance on the FR 10. The information functions as a discriminative stimulus for pausing. Taken separately, either the information hypothesis (Hendry, 1969) or the unit account (Crossman and Silverman, in press) are insufficient to account for the behavior on a mixed schedule. Both are necessary. The unit account explains the development of the run of ten responses and the pause which preceded it as a unit. The information provided by the prime explains the pause after the prime.

Treating fixed ratios as units in mixed and multiple schedules is justified in several ways. Even though "scalloping" was not obtained, the present study provided further evidence that the means of programming the sequence of components controlled the pattern of responding in the mixed schedule. Although the pattern may not be a function of the sequence for a multiple schedule, a multiple schedule is useful in controlling for the effects of priming. These results suggest a need for the investigation of other means of producing component sequences. In addition, the use of a sequence of FR 100s followed by an FR 10 suggested a new account of priming as part of the FR 10 as a unit. Further research is necessary to establish the usefulness of this account.



## SUMMARY

The purpose of the present study was to determine the effects of presenting an FR 10 following the emission of the FR 100 which satisfied the superimposed FI contingency. One of two patterns was anticipated. The FI contingency could have produced scalloping, i.e., a progressive shortening of the pre-FR 100 pauses as the FR 10 approached. This would have provided evidence that the pattern of responding in the FR 100 component was a function of the superimposed fixed-interval contingency according to which the FR 10 occurred. The second pattern expected was that the first pre-FR 100 pause after an FR 10 would be longer than the other pre-FR 100 pauses. This would provide evidence that the pattern was a function of the sequential arrangement of the FR 100s and FR 10s. Comparison between mixed and multiple schedules allowed for the determination of whether the short pauses in the mixed schedule resulted from priming. In addition, the FI value was manipulated to determine the effect of FR 10 frequency on pause relationships in mixed and multiple schedules.

The mixed schedule produced a pattern of responding in which the first pre-FR 100 pause after an FR 10 was long while all other pauses were short and approximately equal in length. In the multiple schedule, all pre-FR 100 pauses were long while the pre-FR 10 pause was short. No indication of an exceptionally long pre-FR 100 pause for the first ordinal position was present in the multiple schedule. Similarly, manipulation of the FI value had little effect. These results suggested that the pattern of responding in the mixed schedule was a function of the



sequential arrangement of the FR 100s and FR 10s rather than the FI contingency. In addition, the results indicated that short pauses and primes in the mixed schedule occurred together. Secondly, long pauses in both the mixed and multiple schedules were not accompanied by primes.

The relationship of short pauses and primes suggested that priming was due to the establishment of the FR 10 as a unit of behavior. Runs of ten responses were reinforced intermittently by the occurrence of food for runs of ten responses. The long pause after the priming run was suggested to be a function of the information provided by the priming run. If food delivery did not occur following a run of ten responses, information existed that the schedule was FR 100 and a long pause occurred.

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APPENDIXES

Appendix ATable 1

| Condition | Session Time(min)<br>Number of FR 10s | Mean Bodyweight(gms) | Mean Number of<br>Reinforcers/<br>Session |
|-----------|---------------------------------------|----------------------|---|
|-----------|---------------------------------------|----------------------|---|

## Bird MT-1, Experiment I

|          |       |       |      |
|----------|-------|-------|------|
| Baseline | ----- | 498.2 | 76.4 |
| FI 10    | 11.00 | 517.2 | 83.6 |
| FI 7     | 8.54  | 515.0 | 72.2 |
| FI 4     | 5.20  | 509.8 | 68.6 |
| FI 7     | 7.90  | 489.2 | 71.4 |
| FI 10    | 11.25 | 475.0 | 67.6 |
| Baseline | ----- | 460.8 | 64.6 |

## Bird MT-4, Experiment I

|          |       |       |      |
|----------|-------|-------|------|
| Baseline | ----- | 356.2 | 50.0 |
| FI 4     | 9.10  | 363.6 | 53.0 |
| FI 7     | 9.40  | 370.6 | 60.6 |
| FI 10    | 18.60 | 379.0 | 58.8 |
| FI 7     | 8.90  | 393.6 | 78.2 |
| FI 4     | 6.34  | 387.6 | 64.0 |
| Baseline | ----- | 386.4 | 49.2 |



Table 2

| Bird MT-1 (Last 5 Sessions) |                                     |   | Bird MT-4 (Last 5 Sessions) |                                     |   |
|-----------------------------|-------------------------------------|---|-----------------------------|-------------------------------------|---|
|                             | Median<br>Pre-FR 100<br>Pause (Sec) | FR 100 Rate<br>(Excluding<br>Pause)Rs/min |                             | Median<br>Pre-FR 100<br>Pause (Sec) | FR 100 Rate<br>(Excluding<br>Pause)Rs/min |
| Base-<br>line               | 19.2                                | 172.4                                     | Base-<br>line               | 35.4                                | 147.0                                     |
|                             | 14.6                                | 153.8                                     |                             | 37.5                                | 142.8                                     |
|                             | 14.3                                | 185.2                                     |                             | 34.0                                | 114.9                                     |
|                             | 19.4                                | 81.9                                      |                             | 34.7                                | 119.0                                     |
|                             | 14.2                                | 188.7                                     |                             | 37.5                                | 133.3                                     |
| FI 10                       | 9.2                                 | 131.5                                     | FI 4                        | 4.2                                 | 73.5                                      |
|                             | 18.2                                | 133.3                                     |                             | 3.9                                 | 52.9                                      |
|                             | 17.1                                | 126.5                                     |                             | 5.2                                 | 80.6                                      |
|                             | 18.2                                | 147.0                                     |                             | 2.2                                 | 16.0                                      |
|                             | 15.9                                | 149.2                                     |                             | 2.5                                 | 104.2                                     |
| FI 7                        | 3.3                                 | 185.2                                     | FI 7                        | 3.5                                 | 84.0                                      |
|                             | 3.5                                 | 116.3                                     |                             | 3.1                                 | 86.9                                      |
|                             | 3.8                                 | 149.2                                     |                             | 3.1                                 | 111.1                                     |
|                             | 3.1                                 | 121.9                                     |                             | 3.2                                 | 104.2                                     |
|                             | 2.8                                 | 185.2                                     |                             | 3.1                                 | 76.3                                      |
| FI 4                        | 2.2                                 | 70.9                                      | FI 10                       | 3.7                                 | 98.0                                      |
|                             | 1.8                                 | 65.8                                      |                             | 4.4                                 | 78.1                                      |
|                             | 3.0                                 | 77.5                                      |                             | 3.6                                 | 106.3                                     |
|                             | 2.1                                 | 78.7                                      |                             | 3.8                                 | 83.3                                      |
|                             | 1.4                                 | 81.9                                      |                             | 3.8                                 | 90.9                                      |
| FI 7                        | 2.3                                 | 64.5                                      | FI 7                        | 3.9                                 | 149.2                                     |
|                             | 2.1                                 | 58.5                                      |                             | 3.3                                 | 111.1                                     |
|                             | 2.3                                 | 74.6                                      |                             | 2.4                                 | 51.8                                      |
|                             | 2.4                                 | 78.1                                      |                             | 2.2                                 | 131.5                                     |
|                             | 2.4                                 | 81.3                                      |                             | 3.4                                 | 73.0                                      |
| FI 10                       | 2.1                                 | 74.6                                      | FI 4                        | 3.3                                 | 81.9                                      |
|                             | 1.9                                 | 82.6                                      |                             | 2.4                                 | 128.2                                     |
|                             | 2.7                                 | 71.9                                      |                             | 2.9                                 | 100.0                                     |
|                             | 2.1                                 | 83.3                                      |                             | 2.4                                 | 78.1                                      |
|                             | 2.2                                 | 76.3                                      |                             | 2.5                                 | 84.7                                      |
| Base-<br>line               | 21.8                                | 149.2                                     | Base-<br>line               | 29.0                                | 120.4                                     |
|                             | 19.6                                | 140.8                                     |                             | 9.2                                 | 128.2                                     |
|                             | 17.8                                | 99.0                                      |                             | 41.9                                | 131.5                                     |
|                             | 28.5                                | 131.5                                     |                             | 23.9                                | 116.2                                     |
|                             | 30.6                                | 133.3                                     |                             | 20.6                                | 108.6                                     |

Table 3

Pre-Ratio Pauses as a Function of Ordinal Position (Last 5 Sessions)  
Bird MT-1

|       | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11  | FR 10 |
|-------|------|------|------|------|------|------|------|------|------|------|-----|-------|
| FI 10 | 18.2 | 11.7 | 9.7  | 12.9 | 13.0 | 14.5 | 17.9 | 11.1 | 23.3 | 35.7 | 2.2 | 14.1  |
|       | 14.7 | 26.9 | 19.5 | 24.2 | 35.6 | 23.0 | 24.4 | 21.5 | 14.0 | 33.1 |     | 20.1  |
|       | 13.9 | 27.4 | 17.9 | 20.2 | 23.2 | 37.8 | 24.7 | 28.5 | 22.0 | 21.7 |     | 21.8  |
|       | 10.9 | 18.0 | 36.0 | 24.6 | 18.0 | 16.6 | 29.8 | 17.7 | 33.8 |      |     | 28.2  |
|       | 12.7 | 16.8 | 17.0 | 26.1 | 22.0 | 16.6 | 25.9 | 33.7 | 75.2 |      |     | 20.0  |
| FI 7  | 10.7 | 5.9  | 6.0  | 6.3  | 5.2  | 6.2  | 5.5  | 5.8  |      |      |     | 5.7   |
|       | 8.1  | 5.8  | 5.9  | 6.0  | 6.1  | 5.6  | 7.5  |      |      |      |     | 5.4   |
|       | 14.7 | 6.3  | 6.0  | 7.5  | 6.1  | 6.7  | 6.6  |      |      |      |     | 5.7   |
|       | 9.1  | 5.6  | 5.6  | 5.7  | 5.7  | 5.8  | 6.6  |      |      |      |     | 5.4   |
|       | 16.6 | 4.9  | 6.5  | 4.9  | 6.1  | 5.1  | 6.7  | 6.6  |      |      |     | 5.0   |
| FI 4  | 57.3 | 1.7  | 1.7  | 1.8  |      |      |      |      |      |      |     | 1.6   |
|       | 12.2 | 1.7  | 1.4  | 1.7  |      |      |      |      |      |      |     | 1.4   |
|       | 48.6 | 1.5  | 1.5  | 1.4  |      |      |      |      |      |      |     | 1.4   |
|       | 28.0 | 1.6  | 1.5  | 1.9  |      |      |      |      |      |      |     | 1.5   |
|       | 3.1  | 1.4  | 1.8  | 1.4  |      |      |      |      |      |      |     | 1.5   |
| FI 7  | 36.4 | 2.0  | 2.2  | 2.5  | 1.6  | 2.0  |      |      |      |      |     | 2.1   |
|       | 18.5 | 1.8  | 1.9  | 1.6  | 2.1  | 2.0  |      |      |      |      |     | 1.8   |
|       | 30.7 | 1.8  | 1.9  | 1.6  | 2.1  | 2.0  |      |      |      |      |     | 1.9   |
|       | 13.3 | 2.0  | 2.6  | 1.9  | 2.0  | 2.4  |      |      |      |      |     | 1.9   |
|       | 7.3  | 2.4  | 2.2  | 2.2  | 2.3  | 2.7  |      |      |      |      |     | 1.8   |
| FI 10 | 50.6 | 2.1  | 2.0  | 1.8  | 1.7  | 2.2  | 2.1  |      |      |      |     | 1.9   |
|       | 41.1 | 2.1  | 2.1  | 1.9  | 1.0  | 2.0  | 2.2  | 2.5  |      |      |     | 1.9   |
|       | 5.1  | 2.0  | 2.1  | 2.0  | 1.9  | 3.4  |      |      |      |      |     | 1.6   |
|       | 43.3 | 1.7  | 1.7  | 2.0  | 2.5  | 2.0  | 2.7  | 1.9  |      |      |     | 1.8   |
|       | 35.7 | 2.2  | 2.2  | 2.1  | 2.1  | 2.1  | 1.9  | 1.7  |      |      |     | 1.9   |



Table 3 (cont.)

Bird MT-4

|       | 1     | 2    | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | FR 10 |
|-------|-------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| FI 4  | 43.7  | 2.2  | 2.8 | 2.4 | 2.2 |     |     |     |     |     |     | 2.2   |
|       | 116.0 | 2.3  | 2.6 | 3.5 |     |     |     |     |     |     |     | 2.1   |
|       | 11.4  | 5.8  | 3.7 |     |     |     |     |     |     |     |     | 5.5   |
|       | 59.9  | 2.4  | 3.0 |     |     |     |     |     |     |     |     | 2.3   |
|       | 37.2  | 3.2  | 4.3 | 4.5 | 2.4 |     |     |     |     |     |     | 3.1   |
| FI 7  | 48.0  | 3.4  | 3.3 | 3.5 | 3.3 | 2.6 |     |     |     |     |     | 3.3   |
|       | 63.3  | 2.9  | 3.1 | 2.3 | 2.7 | 3.4 |     |     |     |     |     | 2.3   |
|       | 46.0  | 2.8  | 2.6 | 3.5 | 3.8 | 3.0 | 3.1 | 3.4 |     |     |     | 2.7   |
|       | 33.1  | 4.3  | 2.8 | 2.8 | 3.1 | 2.5 | 3.2 | 4.2 |     |     |     | 2.8   |
|       | 129.3 | 2.8  | 2.8 | 2.9 | 3.0 | 3.1 | 2.7 |     |     |     |     | 2.4   |
| FI 10 | 47.1  | 3.5  | 3.8 | 3.3 | 3.2 | 3.3 | 3.2 | 2.9 | 3.0 | 6.5 | 3.0 | 2.7   |
|       | 19.8  | 55.6 | 4.4 |     |     |     |     |     |     |     |     | 2.1   |
|       | 67.5  | 3.2  | 3.6 | 3.3 | 3.4 | 3.5 | 3.7 | 3.6 | 3.7 | 3.9 |     | 3.4   |
|       | 81.0  | 1.9  | 2.9 | 3.2 | 3.7 | 6.1 | 5.0 | 3.1 |     |     |     | 4.4   |
|       | 68.9  | 3.4  | 4.9 | 3.5 | 3.6 | 3.9 | 3.7 | 3.8 | 3.9 | 3.6 |     | 2.7   |
| FI 7  | 27.1  | 3.1  | 3.9 | 4.1 | 3.9 | 4.2 | 3.4 | 3.5 | 3.6 |     |     | 3.6   |
|       | 27.6  | 4.1  | 3.1 | 3.3 | 3.3 | 3.3 | 2.6 | 3.8 | 3.8 |     |     | 2.8   |
|       | 144.6 | 2.0  | 4.5 | 2.5 |     |     |     |     |     |     |     | 1.8   |
|       | 28.5  | 2.0  | 2.2 | 2.5 | 2.3 | 2.0 | 2.2 | 2.5 |     |     |     | 2.2   |
|       | 35.4  | 3.0  | 2.6 | 3.5 | 4.1 | 3.0 |     |     |     |     |     | 4.3   |
| FI 4  | 27.0  | 2.7  | 2.6 | 2.6 | 2.7 |     |     |     |     |     |     | 2.2   |
|       | 23.6  | 2.3  | 2.3 | 2.2 |     |     |     |     |     |     |     | 2.3   |
|       | 7.0   | 2.6  | 2.9 | 2.3 | 2.1 |     |     |     |     |     |     | 2.3   |
|       | 11.4  | 2.3  | 2.2 | 2.0 | 2.0 |     |     |     |     |     |     | 2.0   |
|       | 40.8  | 4.7  | 2.1 | 2.2 | 2.0 |     |     |     |     |     |     | 1.8   |

Table 4

Proportion of Primes in Each Ordinal Position (Last 5 Sessions)  
Bird MT-1

|       | 1     | 2     | 3     | 4    | 5    | 6    | 7   | 8   | 9   | 10  |
|-------|-------|-------|-------|------|------|------|-----|-----|-----|-----|
| FI 10 | 2/10  | 1/10  | 0/10  | 1/10 | 1/10 | 0/10 | 1/9 | 1/8 | 0/6 | 0/1 |
|       | 0/9   | 0/9   | 0/9   | 0/9  | 0/9  | 0/8  | 1/8 | 0/8 | 0/5 | 0/2 |
|       | 0/8   | 0/8   | 0/8   | 0/8  | 1/7  | 0/7  | 0/7 | 0/7 | 0/4 | 0/1 |
|       | 0/9   | 1/9   | 1/9   | 1/9  | 0/9  | 0/8  | 0/8 | 1/8 | 0/4 |     |
|       | 1/9   | 1/9   | 1/9   | 0/9  | 0/8  | 1/8  | 0/8 | 0/7 | 0/4 |     |
| FI 7  | 1/13  | 1/12  | 3/12  | 1/12 | 2/12 | 4/11 | 2/8 | 0/3 |     |     |
|       | 3/11  | 0/10  | 0/10  | 1/8  | 0/8  | 0/6  | 3/3 |     |     |     |
|       | 1/12  | 4/12  | 1/12  | 1/11 | 5/9  | 1/4  | 0/1 |     |     |     |
|       | 2/10  | 2/10  | 2/9   | 3/8  | 3/7  | 1/6  | 1/1 |     |     |     |
|       | 1/11  | 1/10  | 3/10  | 0/10 | 2/9  | 3/7  | 0/1 | 0/1 |     |     |
| FI 4  | 1/18  | 15/17 | 10/12 | 4/4  |      |      |     |     |     |     |
|       | 6/19  | 17/18 | 11/14 | 3/3  |      |      |     |     |     |     |
|       | 2/18  | 14/16 | 8/9   | 4/4  |      |      |     |     |     |     |
|       | 2/18  | 17/18 | 11/12 | 1/1  |      |      |     |     |     |     |
|       | 10/19 | 14/17 | 12/13 | 7/7  |      |      |     |     |     |     |
| FI 7  | 1/12  | 7/12  | 5/12  | 9/11 | 8/9  | 1/2  |     |     |     |     |
|       | 3/11  | 9/11  | 10/11 | 8/11 | 7/9  | 5/5  | 0/1 |     |     |     |
|       | 1/12  | 10/11 | 8/10  | 9/9  | 3/6  | 2/3  | 1/1 |     |     |     |
|       | 4/13  | 10/13 | 8/12  | 8/12 | 6/10 | 3/4  |     |     |     |     |
|       | 4/13  | 6/13  | 7/13  | 9/11 | 5/8  | 1/4  | 3/4 |     |     |     |
| FI 10 | 0/9   | 7/9   | 5/9   | 7/9  | 4/9  | 4/8  | 4/5 | 1/1 |     |     |
|       | 0/9   | 3/9   | 6/9   | 6/9  | 8/9  | 2/6  | 3/6 | 3/3 |     |     |
|       | 5/9   | 7/9   | 6/9   | 5/9  | 2/8  | 7/8  | 3/5 |     |     |     |
|       | 1/9   | 6/9   | 5/9   | 7/9  | 5/8  | 3/7  | 3/6 | 3/5 |     |     |
|       | 2/9   | 5/9   | 3/9   | 6/9  | 3/8  | 4/8  | 2/5 | 3/3 |     |     |



Table 4 (cont.)

## Bird MT-4

|       | 1                                    | 2                                   | 3                                  | 4                                  | 5                                  | 6                                 | 7                                | 8                        | 9                        | 10                | 11                |
|-------|--------------------------------------|-------------------------------------|------------------------------------|------------------------------------|------------------------------------|-----------------------------------|----------------------------------|--------------------------|--------------------------|-------------------|-------------------|
| FI 4  | 1/17<br>1/5<br>3/14<br>0/11<br>0/13  | 2/15<br>3/5<br>6/14<br>2/7<br>1/9   | 1/14<br>1/2<br>4/12<br>0/5<br>2/8  | 3/10<br>0/8<br>1/5<br>1/5          | 1/6<br>3/7<br>2/3<br>3/3           | 0/2<br>1/2                        |                                  |                          |                          |                   |                   |
| FI 7  | 1/11<br>2/11<br>0/9<br>0/10<br>1/10  | 2/10<br>0/10<br>3/9<br>3/10<br>2/6  | 3/10<br>5/10<br>2/9<br>6/10<br>3/5 | 3/9<br>3/8<br>2/7<br>4/9<br>2/5    | 3/8<br>2/6<br>1/5<br>4/9<br>2/5    | 1/7<br>1/4<br>2/5<br>3/6<br>0/1   | 2/4<br>0/3<br>2/4<br>0/1<br>0/1  | 1/2<br>1/1<br>1/1        |                          |                   |                   |
| FI 10 | 0/7<br>0/2<br>1/9<br>0/8<br>0/8      | 6/7<br>0/2<br>3/9<br>2/7<br>3/8     | 4/7<br>0/2<br>4/9<br>5/7<br>1/8    | 3/7<br>0/2<br>4/9<br>2/7<br>5/8    | 3/7<br>1/1<br>3/9<br>3/7<br>2/8    | 3/7<br>3/7<br>3/8<br>2/5<br>6/8   | 3/5<br>1/6<br>1/3<br>2/5<br>1/6  | 3/4<br>4/6<br>1/1<br>2/4 | 1/4<br>1/5<br>1/3<br>1/3 | 3/3<br>1/3<br>2/3 | 0/1<br>0/3<br>2/2 |
| FI 7  | 1/13<br>1/13<br>0/10<br>1/12<br>0/8  | 2/13<br>4/12<br>3/9<br>4/12<br>4/7  | 2/13<br>6/12<br>2/4<br>2/12<br>4/7 | 0/12<br>3/11<br>1/2<br>2/12<br>6/7 | 0/12<br>5/11<br>0/1<br>5/12<br>4/6 | 3/11<br>4/8<br>0/1<br>5/12<br>3/4 | 1/8<br>0/5<br>0/1<br>2/11<br>2/3 | 0/7<br>2/4<br>0/1<br>4/7 | 0/4<br>0/1<br>1/1<br>0/2 |                   |                   |
| FI 4  | 2/14<br>1/11<br>3/18<br>2/16<br>1/16 | 0/10<br>0/9<br>3/13<br>2/14<br>6/15 | 1/10<br>1/8<br>2/12<br>4/13<br>3/9 | 1/8<br>2/7<br>1/8<br>2/8<br>4/7    | 0/6<br>0/3<br>1/6<br>1/3<br>1/2    |                                   |                                  |                          |                          |                   |                   |

Appendix BTable 5

|                          | Session Time(min)<br>Number of FR 10s | Mean Bodyweight(gms) | Mean Number of<br>Reinforcers/<br>Session |
|--------------------------|---------------------------------------|----------------------|---|
| Bird MT-2, Experiment II |                                       |                      |   |
| Baseline                 | ----                                  | 492.4                | 73.8                                      |
| FI 4                     | 4.9                                   | 508.2                | 77.4                                      |
| FI 7                     | 8.2                                   | 509.0                | 63.4                                      |
| FI 10                    | 11.2                                  | 504.8                | 64.8                                      |
| FI 7                     | 8.8                                   | 514.6                | 50.2                                      |
| FI 4                     | 5.5                                   | 529.6                | 55.8                                      |
| Baseline                 | ----                                  | 522.2                | 49.4                                      |
| Bird MT-3, Experiment II |                                       |                      |   |
| Baseline                 | ----                                  | 325.4                | 54.2                                      |
| FI 10                    | 15.7                                  | 318.0                | 40.6                                      |
| FI 7                     | 7.9                                   | 322.4                | 57.8                                      |
| FI 4                     | 5.1                                   | 328.2                | 76.0                                      |
| FI 7                     | 8.4                                   | 341.4                | 59.8                                      |
| FI 10                    | 11.6                                  | 344.0                | 53.4                                      |
| Baseline                 | ----                                  | 324.0                | 51.8                                      |



Table 6

| Bird MT-2 (Last 5 Sessions) |                                     |   | Bird MT-3 (Last 5 Sessions) |                                     |   |
|-----------------------------|-------------------------------------|---|-----------------------------|-------------------------------------|---|
|                             | Median<br>Pre-FR 100<br>Pause (Sec) | FR 100 Rate<br>(Excluding<br>Pause)Rs/min |                             | Median<br>Pre-FR 100<br>Pause (Sec) | FR 100 Rate<br>(Excluding<br>Pause)Rs/min |
| Base-<br>line               | 21.1                                | 87.7                                      | Base-<br>line               | 28.5                                | 142.8                                     |
|                             | 25.9                                | 149.2                                     |                             | 32.5                                | 185.2                                     |
|                             | 23.7                                | 158.7                                     |                             | 34.6                                | 103.1                                     |
|                             | 19.3                                | 140.8                                     |                             | 27.1                                | 106.3                                     |
|                             | 21.1                                | 200.0                                     |                             | 33.4                                | 79.4                                      |
| FI 4                        | 24.9                                | 172.4                                     | FI 10                       | 64.0                                | 46.0                                      |
|                             | 45.6                                | 144.9                                     |                             | 55.5                                | 72.9                                      |
|                             | 36.0                                | 149.2                                     |                             | 28.4                                | 59.8                                      |
|                             | 37.9                                | 125.0                                     |                             | 54.3                                | 116.3                                     |
|                             | 38.2                                | 133.3                                     |                             | 42.7                                | 64.9                                      |
| FI 7                        | 25.4                                | 128.2                                     | FI 7                        | 34.0                                | 107.5                                     |
|                             | 16.5                                | 158.7                                     |                             | 38.7                                | 105.2                                     |
|                             | 41.0                                | 125.0                                     |                             | 42.6                                | 97.1                                      |
|                             | 42.3                                | 138.8                                     |                             | 40.8                                | 100.0                                     |
|                             | 49.7                                | 125.0                                     |                             | 23.3                                | 86.2                                      |
| FI 10                       | 34.7                                | 138.8                                     | FI 4                        | 32.1                                | 98.0                                      |
|                             | 49.1                                | 125.0                                     |                             | 17.6                                | 125.0                                     |
|                             | 38.8                                | 111.1                                     |                             | 18.8                                | 128.2                                     |
|                             | 48.3                                | 102.0                                     |                             | 15.5                                | 126.5                                     |
|                             | 31.3                                | 140.8                                     |                             | 21.4                                | 104.1                                     |
| FI 7                        | 67.0                                | 128.2                                     | FI 7                        | 20.8                                | 133.3                                     |
|                             | 23.0                                | 125.0                                     |                             | 39.1                                | 70.4                                      |
|                             | 41.6                                | 79.4                                      |                             | 21.7                                | 97.0                                      |
|                             | 39.7                                | 60.6                                      |                             | 22.6                                | 108.6                                     |
|                             | 35.0                                | 82.6                                      |                             | 25.9                                | 107.5                                     |
| FI 4                        | 20.9                                | 60.9                                      | FI 10                       | 35.2                                | 109.8                                     |
|                             | 23.8                                | 56.8                                      |                             | 26.0                                | 103.1                                     |
|                             | 16.1                                | 44.4                                      |                             | 21.0                                | 92.6                                      |
|                             | 24.7                                | 72.4                                      |                             | 28.6                                | 70.9                                      |
|                             | 26.5                                | 76.3                                      |                             | 31.2                                | 117.6                                     |
| Base-<br>line               | 32.8                                | 74.1                                      | Base-<br>line               | 30.5                                | 112.3                                     |
|                             | 24.7                                | 138.8                                     |                             | 24.1                                | 117.6                                     |
|                             | 31.2                                | 126.6                                     |                             | 25.1                                | 106.4                                     |
|                             | 38.1                                | 67.1                                      |                             | 34.7                                | 109.8                                     |
|                             | 23.5                                | 105.2                                     |                             | 57.1                                | 96.1                                      |

Table 7

Pre-Ratio Pause as a Function of Ordinal Position (Last 5 Sessions)  
Bird MT-2

|       | 1    | 2    | 3    | 4     | 5    | 6     | 7    | 8    | 9    | FR 10 |
|-------|------|------|------|-------|------|-------|------|------|------|-------|
| FI 4  | 24.5 | 32.2 | 27.4 | 20.4  | 35.0 |       |      |      |      | 1.25  |
|       | 36.0 | 46.7 | 56.0 | 51.8  | 55.9 |       |      |      |      | 1.13  |
|       | 24.8 | 35.3 | 47.3 | 7.9   |      |       |      |      |      | 1.10  |
|       | 29.8 | 39.8 | 62.6 | 56.6  |      |       |      |      |      | 1.18  |
|       | 40.4 | 31.1 | 48.2 | 31.2  | 67.2 |       |      |      |      | 1.33  |
| FI 7  | 50.0 | 25.4 | 22.9 | 23.9  | 31.3 | 32.1  | 11.8 |      |      | 1.01  |
|       | 41.2 | 47.2 | 35.8 | 29.7  | 21.4 | 23.3  | 19.5 |      |      | 1.05  |
|       | 51.7 | 21.5 | 37.0 | 44.1  | 31.9 | 26.7  | 30.3 |      |      | 1.01  |
|       | 61.9 | 58.0 | 37.2 | 38.9  | 23.9 | 44.9  | 34.2 |      |      | 1.10  |
|       | 61.5 | 38.2 | 51.4 | 31.2  | 58.8 | 17.8  |      |      |      | 1.03  |
| FI 10 | 17.0 | 35.1 | 28.7 | 35.6  | 47.8 | 25.5  | 25.9 | 19.8 | 35.0 | 1.01  |
|       | 46.3 | 50.8 | 46.1 | 49.3  | 54.4 | 56.7  | 38.0 |      |      | 1.05  |
|       | 49.0 | 30.2 | 33.2 | 40.2  | 38.7 | 43.2  | 24.1 | 39.0 |      | 1.04  |
|       | 45.3 | 50.5 | 74.9 | 37.3  | 61.8 | 45.3  | 47.0 |      |      | 1.02  |
|       | 29.5 | 24.7 | 35.5 | 34.8  | 32.4 | 30.5  | 33.9 | 25.6 | 28.1 | 1.05  |
| FI 7  | 28.1 | 30.5 | 21.4 | 27.7  | 27.9 | 42.8  |      |      |      | 1.11  |
|       | 48.9 | 51.8 | 38.0 | 43.2  | 19.2 | 39.9  |      |      |      | 1.03  |
|       | 46.5 | 19.2 | 36.1 | 30.8  | 51.5 |       |      |      |      | 1.06  |
|       | 81.2 | 60.7 | 42.7 | 73.4  | 48.5 |       |      |      |      | 1.08  |
|       | 50.3 | 84.1 | 94.0 | 103.7 | 64.1 | 121.3 |      |      |      | 1.25  |
| FI 4  | 34.3 | 22.3 | 10.0 |       |      |       |      |      |      | 1.04  |
|       | 36.2 | 9.0  | 8.3  |       |      |       |      |      |      | 1.0   |
|       | 20.3 | 10.7 | 15.6 |       |      |       |      |      |      | .98   |
|       | 19.7 | 28.3 | 30.2 |       |      |       |      |      |      | 1.0   |
|       | 28.7 | 18.3 | 14.2 |       |      |       |      |      |      | 1.0   |



Table 7 (cont.)

Bird MT-3

|       | 1    | 2    | 3    | 4     | 5     | 6    | 7    | 8    | 9 | FR 10 |
|-------|------|------|------|-------|-------|------|------|------|---|-------|
| FI 10 | 32.6 | 64.0 | 29.6 | 95.7  |       |      |      |      |   | 1.20  |
|       | 48.1 | 44.6 | 52.9 | 105.5 | 20.2  |      |      |      |   | 1.20  |
|       | 30.9 | 38.6 | 36.5 | 31.0  | 27.8  | 22.9 |      |      |   | 1.24  |
|       | 49.4 | 63.8 | 30.9 | 27.2  | 12.9  |      |      |      |   | 1.25  |
|       | 34.5 | 51.1 | 30.6 | 32.7  | 29.6  | 51.2 |      |      |   | 1.25  |
| FI 7  | 38.9 | 35.6 | 28.7 | 27.3  | 38.3  |      |      |      |   | 1.03  |
|       | 43.5 | 36.6 | 44.6 | 26.1  | 14.5  |      |      |      |   | 1.07  |
|       | 60.8 | 27.0 | 63.4 | 42.6  |       |      |      |      |   | 1.02  |
|       | 32.4 | 34.6 | 45.5 | 23.3  | 104.5 |      |      |      |   | 1.00  |
|       | 41.4 | 21.4 | 42.9 | 18.4  | 20.6  |      |      |      |   | 1.02  |
| FI 4  | 28.1 | 51.9 | 33.7 |       |       |      |      |      |   | .98   |
|       | 21.1 | 16.1 | 15.8 |       |       |      |      |      |   | .99   |
|       | 17.6 | 20.4 | 17.0 |       |       |      |      |      |   | .96   |
|       | 19.2 | 16.1 | 11.7 |       |       |      |      |      |   | 1.00  |
|       | 19.5 | 33.0 | 17.8 |       |       |      |      |      |   | .98   |
| FI 7  | 18.3 | 24.4 | 44.3 | 21.1  |       |      |      |      |   | 1.1   |
|       | 45.7 | 60.3 | 26.7 |       |       |      |      |      |   | 1.1   |
|       | 21.7 | 28.4 | 20.1 | 58.5  | 30.3  |      |      |      |   | 1.03  |
|       | 22.8 | 31.1 | 24.7 | 19.1  | 17.4  |      |      |      |   | .95   |
|       | 21.4 | 24.6 | 24.6 | 20.7  | 20.2  |      |      |      |   | .95   |
| FI 10 | 31.6 | 35.6 | 52.8 | 26.4  | 45.6  | 27.8 | 27.8 | 20.7 |   | .98   |
|       | 32.2 | 49.3 | 34.9 | 49.0  | 42.3  | 20.2 | 20.2 |      |   | 1.02  |
|       | 30.6 | 14.3 | 27.7 | 46.6  | 18.3  | 18.7 | 18.7 | 30.9 |   | 1.03  |
|       | 40.5 | 41.0 | 15.3 | 29.3  | 15.2  | 29.6 | 29.6 | 20.0 |   | 1.08  |
|       | 59.5 | 56.7 | 25.4 | 28.8  | 25.9  | 30.2 | 30.2 | 9.6  |   | 1.05  |

## VITA

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\_\_\_\_\_ and Crossman, E.K. An Experimental Analysis of Responding in the Presence of Free Food. Paper presented at the Rocky Mountain Psychological Association, Albuquerque, May, 1972.

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\_\_\_\_\_. Memory Transfer in the Digital Computer. The Worm Runner's Digest, 1972, 14, 56.

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