Effects of Reinforcement Duration and Reinforcement on Response Latency: Stimulus-Reinforcer and Probability Response-Reinforcer Relationships

Henry David Schlinger Jr.
Western Michigan University

Follow this and additional works at: https://scholarworks.wmich.edu/dissertations

Part of the Psychology Commons

Recommended Citation

This Dissertation-Open Access is brought to you for free and open access by the Graduate College at ScholarWorks at WMU. It has been accepted for inclusion in Dissertations by an authorized administrator of ScholarWorks at WMU. For more information, please contact wmu-scholarworks@wmich.edu.
EFFECTS OF REINFORCEMENT DURATION AND REINFORCEMENT PROBABILITY ON RESPONSE LATENCY: STIMULUS-REINFORCER AND RESPONSE-REINFORCER RELATIONSHIPS

by

Henry David Schlinger, Jr.

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

Western Michigan University
Kalamazoo, Michigan
April 1985
EFFECTS OF REINFORCEMENT DURATION AND REINFORCEMENT PROBABILITY ON RESPONSE LATENCY: STIMULUS-REINFORCER AND RESPONSE-REINFORCER RELATIONSHIPS

Henry David Schlinger, Jr., Ph.D.
Western Michigan University, 1985

The purpose of the present experiment was to evaluate the stimulus-reinforcer and response-reinforcer relationships in a two-key procedure in which the key that the stimuli appeared on (stimulus key) was separated spatially from the key on which responding was required (constant key) (Hesse, 1984; Keller, 1974). Using pigeons and multiple fixed-ratio schedules, the effects of differences in reinforcement duration and reinforcement probability on response latencies to the constant key were compared. Since responding to the stimulus key was not effective in producing reinforcement, any responding that developed to that key was assumed to be due to the stimulus-reinforcer relationships. Differences in FR size and intertrial interval (ITI) length were compared across sessions. The stimuli associated with different reinforcement durations (for two birds) or reinforcement probabilities (for two birds) were displayed on the stimulus key while the responses that produced reinforcement were required on the constant key.

The results showed response latency to be sensitive to differences in reinforcement duration and probability, but only at
the higher FR values, which is consistent with the literature showing pre-ratio pause durations in FR schedules to be a function of reinforcement duration, and reinforcement probability, but only with high ratio requirements. Pecks to the stimulus key were sensitive to both reinforcement duration and reinforcement probability more often, but not always, with high FR and short ITI values. These findings suggest that response latency, at least with FR schedules, is more simply conceptualized as pre-ratio pause duration. They also suggest that, at least with pigeons and key pecking, stimulus-reinforcer and response-reinforcer contingencies are usually, if not always, simultaneously present in the same situations and, furthermore, that responding may show sensitivity to the stimulus-reinforcer contingencies irrespective of whether it shows sensitivity to the response-reinforcer contingencies.
INFORMATION TO USERS

This reproduction was made from a copy of a document sent to us for microfilming. While the most advanced technology has been used to photograph and reproduce this document, the quality of the reproduction is heavily dependent upon the quality of the material submitted.

The following explanation of techniques is provided to help clarify markings or notations which may appear on this reproduction.

1. The sign or “target” for pages apparently lacking from the document photographed is “Missing Page(s)”. If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting through an image and duplicating adjacent pages to assure complete continuity.

2. When an image on the film is obliterated with a round black mark, it is an indication of either blurred copy because of movement during exposure, duplicate copy, or copyrighted materials that should not have been filmed. For blurred pages, a good image of the page can be found in the adjacent frame. If copyrighted materials were deleted, a target note will appear listing the pages in the adjacent frame.

3. When a map, drawing or chart, etc., is part of the material being photographed, a definite method of “sectioning” the material has been followed. It is customary to begin filming at the upper left hand corner of a large sheet and to continue from left to right in equal sections with small overlaps. If necessary, sectioning is continued again—beginning below the first row and continuing on until complete.

4. For illustrations that cannot be satisfactorily reproduced by xerographic means, photographic prints can be purchased at additional cost and inserted into your xerographic copy. These prints are available upon request from the Dissertations Customer Services Department.

5. Some pages in any document may have indistinct print. In all cases the best available copy has been filmed.

University Microfilms International
300 N. Zeeb Road
Ann Arbor, MI 48106

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
Schlinger, Henry David, Jr.

EFFECTS OF REINFORCEMENT DURATION AND REINFORCEMENT PROBABILITY ON RESPONSE LATENCY: STIMULUS-REINFORCER AND RESPONSE-REINFORCER RELATIONSHIPS

Western Michigan University

University Microfilms International

Ph.D. 1985

300 N. Zeeb Road, Ann Arbor, MI 48106

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark \( \checkmark \).

1. Glossy photographs or pages ______
2. Colored illustrations, paper or print ______
3. Photographs with dark background ______
4. Illustrations are poor copy ______
5. Pages with black marks, not original copy ______
6. Print shows through as there is text on both sides of page ______
7. Indistinct, broken or small print on several pages \( \checkmark \) ______
8. Print exceeds margin requirements ______
9. Tightly bound copy with print lost in spine ______
10. Computer printout pages with indistinct print ______
11. Page(s) _______ lacking when material received, and not available from school or author.
12. Page(s) _______ seem to be missing in numbering only as text follows.
13. Two pages numbered ______. Text follows.
14. Curling and wrinkled pages ______
15. Dissertation contains pages with print at a slant, filmed as received ______
16. Other ____________________________ ____________________________ ____________________________

University
Microfilms
International
ACKNOWLEDGEMENTS

I would like to acknowledge the support of Western Michigan University, especially Dr. Sid Dykstra of The Graduate College and Dr. David O. Lyon of the Psychology Department, for their help in allowing me to devote full time to my education.

I have learned, and continue to learn, more from Dr. Jack Michael than anyone else. I thank him for being that rare combination of both teacher and friend, and for teaching me about Behavior Analysis.

I would like to thank Bruce Hesse for getting me interested in my dissertation topic, for building the lab, and for the hours of talking. I would also like to acknowledge the students in our lab for their help on the project, especially Eb Blakely, who talked with me about the data. I thank Barbara Gault for critically reading the first draft of the dissertation, and for her help during its writing.

Most of all I would like to thank my parents, Henry and Norma Schlinger, for their support, both financial and otherwise, and for their continued faith in me.

This dissertation is dedicated to the memory of Dr. Donald L. Whaley.

Henry David Schlinger, Jr.
TABLE OF CONTENTS

ACKNOWLEDGEMENTS ..................................................... ii
LIST OF TABLES ........................................................ iv
LIST OF FIGURES ........................................................ v
INTRODUCTION ............................................................. 1
METHOD ................................................................ 15
  Subjects ................................................................ 15
  Apparatus ................................................................ 15
  General Procedure .................................................. 16
  Reinforcement Duration .......................................... 18
  Reinforcement Probability ...................................... 21
  Recording Response Latencies ................................... 21
RESULTS .................................................................... 23
  Duration Differences ........................................... 23
  Probability Differences ....................................... 32
DISCUSSION ............................................................ 40
  Duration of Reinforcement .................................. 40
  Probability of Reinforcement ............................. 48
  Stimulus-key Responding ................................... 51
  Stimulus-Reinforcer and Response-Reinforcer
  Control of Response Latency .......................... 60
CONCLUSION ........................................................... 62
BIBLIOGRAPHY .......................................................... 64
LIST OF TABLES

1. Experimental conditions and number of sessions for each Reinforcement Duration subject......................19

2. Experimental conditions and number of sessions for each Reinforcement Probability subject....................20
LIST OF FIGURES

1. State diagram of the basic procedure..........................17
2. Median response latencies for Bird #1088......................24
3. Percentage of trials with a first response to the stimulus key for Bird #1088.................................26
4. Median response latencies for Bird #132.........................28
5. Percentage of trials with a first response to the stimulus key for Bird #132..................................31
6. Median response latencies for Bird #571..........................33
7. Percentage of trials with a first response to the stimulus key for Bird #571.................................34
8. Median response latencies for Bird #2927..........................36
9. Percentage of trials with a first response to the stimulus key for Bird #2927.................................38
INTRODUCTION

In 1938, in The Behavior of Organisms, B. F. Skinner first made the distinction between operant and respondent conditioning by stating that respondent behavior was elicited by an immediately prior stimulus whereas no eliciting stimulus could be identified for operant behavior. Rather, the term "operant" was meant to emphasize a "posterior event." Skinner's 1938 book consisted almost exclusively of reports of experiments on operant conditioning. Not coincidentally, the scientific enterprise known as the Experimental Analysis of Behavior, which was born from Skinner's initial investigations, also emphasized the operant relation, with almost no attention given to respondent conditioning. The subjects used in most of these operant conditioning experiments consisted of rats and pigeons, with the latter coming to be used predominantly. As a result, it could be said that the principles of operant behavior were derived primarily from experiments on bar-pressing in rats and key pecking in pigeons. While Skinner and others acknowledged that these "arbitrary" responses might have some unlearned components, it was assumed that any unlearned influences were minimized by the experimental design, and that the resulting behavioral patterns could be attributed solely to the independent variable manipulations. In the late 1960s, however, an experiment by Brown and Jenkins (1968) simultaneously changed our conception of the pigeon's keypeck and introduced respondent conditioning into the
realm of operant investigations. In their experiment Brown and Jenkins found that pigeons would begin to peck a lighted key simply as a result of the key light onset being positively correlated with food delivery, with no peck to the key required to produce food. They described their procedure as a third type of superstitious conditioning that they called "auto-shaping." According to Brown and Jenkins, the key light onset elicits orienting and looking toward the key with perhaps some small motor adjustments in the direction of the key. Because pigeons have a tendency to peck at things they look at, then the presentation of food in temporal proximity to these behaviors automatically "shapes" pecking the key. Once the pigeon pecks the key after it is illuminated and food is delivered, the key-peck then becomes no different from any other discriminated operant. Although some (e.g. Herrnstein, 1977) have analyzed autoshaping in completely operant terms, the prevailing view for a long time has been that it represents the respondent conditioning of a skeletal act, at least with respect to pigeons (c.f. Gamzu & Williams, 1971; Moore, 1973; Schwartz & Gamzu, 1977).

The evidence for a respondent conditioning interpretation of autoshaping was first presented by Williams and Williams (1969), who showed that pigeons continued pecking a lighted key even when pecks to the key prevented food from being delivered. Although some questioned the procedure used by Williams and Williams on the grounds that it did not control for the possibility of conditioned reinforcement for pecking, subsequent studies have replicated their results with such controls (e.g. Schwartz, 1972; Schwartz &
Further evidence that autoshaping represents a respondent conditioning process was offered by Jenkins and Moore (1973), who demonstrated that the form of the autoshaped response could be predicted on the basis of the consumatory response elicited by the US. That is, when food is used the pigeon pecks the key in the same manner in which it pecks food, with its beak fairly wide open, and when water is used the pigeon pecks the key with its beak only slightly open. Despite the amount of evidence supporting a respondent conditioning interpretation of autoshaping, there is no consensus. While no one advocates a purely operant interpretation, many people currently adhere to an explanation that attributes the pigeon's keypeck to the joint influence of both response-reinforcer and stimulus-reinforcer relationships (Williams, 1981).

Although autoshaping has been extensively studied in its own right, the discovery that the pigeon's keypeck is influenced by stimulus-reinforcer relationships has led many to take advantage of its importance for other purposes. For example, because the results of the autoshaping and automaintenance experiments showed the pigeon's keypeck to be sensitive to stimulus-reinforcer contingencies and, under some conditions insensitive to response-reinforcer contingencies, psychologists with an ethological bias have questioned the generality of the principles of behavior derived from experiments in which the pigeon's keypeck was the main dependent variable (e.g. Schwartz, 1981; Seligman, 1970; Seligman & Hager, 1972). Others have used the autoshaping findings to analyze
other behavioral anomalies. An example can be found in the
literature on interactions in multiple schedules. One type of
interaction in multiple schedules is called behavioral contrast
(c.f. Reynolds, 1961). The usual procedure consists in transitions
from a multiple VI VI to a multiple VI EXT or vice versa. Typically
the response rate in the changed component decreases as one would
expect, but responding in the unchanged (VI) component increases
even though the rate of reinforcement in that component is
unaltered. One of the major theories of behavioral contrast, the
additivity theory, explains the increase in responding in the
unchanged component of a multiple VI EXT schedule as resulting from
the addition of elicited keypecks (Schwartz & Gamzu, 1977). The
rationale underlying the additivity theory is that a
stimulus-reinforcer relationship exists irrespective of whether
there is a response requirement. Thus, one would expect behavior
resulting from relationships to occur not only in situations such as
the autoshaping procedure, but also in the typical operant procedure
in which the reinforcement of a response or a sequence of responses
is differentially correlated with some stimulus condition. The
reason that keypecks are elicited in the unchanged VI component
after the other VI component is changed to EXT, but not before, has
been described in several experiments by Gamzu and his colleagues
(Gamzu & Williams, 1971, 1973; Gamzu & Schwartz, 1973). Gamzu and
Schwartz (1973) exposed naive pigeons to a series of two-component
response-independent multiple schedules in which the two components
were either identical (e.g. multiple VT VT) or different (e.g.
multiple VT EXT or multiple VT VT). All of the subjects were initially exposed to a multiple VT EXT schedule which was sufficient for key pecking to develop. Responding continued to occur at high rates in the VT schedule and at lower, though still substantial rates during EXT. When the schedule was changed to a multiple VT 33 VT 33 responding decreased for all birds. Additional manipulations revealed the same pattern: responding increased when the components were unequal and decreased when the components were equal. Thus, the differential correlation of a stimulus with a higher frequency of food delivery appears to be at least a sufficient condition for autoshaping of the pigeon's keypeck.

In many of the experiments on behavioral contrast the schedule components were correlated with stimuli that were presented in succession on a single response key. Thus, the conclusion that both operant and respondent key pecks are present in the same situation has been difficult to substantiate because, not only are the forms of the responses essentially identical, but they are both directed toward the same location. Some attempts have been made to distinguish the form of operant from respondent key pecks using one-key procedures. For instance, Schwartz and Williams (1972) reported that the duration of pecks during the negative automaticaintenance (omission) procedure was shorter than that of pecks during the autoshaping procedure (but see Moore, 1973, and Schwartz et al., 1975). Furthermore, they reported that such short-duration pecks could not be differentially reinforced, suggesting that they were indeed elicited.
The problem of isolating respondent key pecks and separating them from operant key pecks that occur under the same conditions came closer to being solved with the development of a procedure by Keller (1974) whereby the key on which the stimuli were projected was separated spatially from the response key. Specifically, the stimuli that were correlated with the prevailing reinforcement schedule were projected on one key of a two-key chamber, while pecks to the second, constantly illuminated key produced food according to the schedule. Pecks to the "stimulus key" had no effect in producing food. With this arrangement Keller exposed the pigeons to the sequence of multiple VI VI and VI EXT schedules that typically produces behavioral contrast in one key procedures. The results showed no contrast effects on the constant key while, at the same time, two out of three birds began pecking the stimulus key during the differential condition. Subsequent to Keller's (1974) experiment many other experiments have been conducted using his procedure (e.g. Schwartz, 1975, 1978; Schwartz, Hamilton, & Silberberg, 1975; Spealman, 1976; Spealman, Katz, & Witkins, 1978; White & Braunstein, 1979; Williams & Heyneman, 1981; and Woodruff, 1979). All of these researchers were interested in the role of elicited responding, particularly with respect to behavioral contrast, and all found stimulus-key pecking to different degrees. Of primary interest to the present study is the use of the two-key procedure in determining the role of response-reinforcer and stimulus-reinforcer contingencies on responding in two-component multiple fixed-ratio (FR) schedules. The primary operant dependent
variable is response latency to the constant key.

Latency as an operant dependent variable has had a dubious history. Skinner (1950) pointed out that operant response latency differs in many respects from the latencies in respondent conditioning. He argued against the use of latency in operant conditioning experiments on the grounds that the important relationship in operant behavior is between a response and its consequence and not any prior stimulus. But even when there is a discriminative stimulus, for instance in a discrete trial procedure, Skinner maintained that the time from the stimulus onset to the first response, that is, the response latency, "does not vary continuously or in an orderly fashion." Others, however, have contradicted Skinner's conclusions concerning the orderliness of operant response latency. Stebbins (1962) and Stebbins and Lanson (1962) showed that with rats, latency was inversely related both to frequency of reinforcement and amount of reinforcement, where amount referred to different concentrations of sucrose. Using pigeons, Schuster (1959) showed that latencies in one component of a multiple fixed-ratio had an inverse relationship to the ratio requirement in the other component, in other words a "contrast effect." When the ratio requirement in one component was increased, the response latencies to the stimulus associated with the other, unchanged, component decreased, and vice versa. Furthermore, pilot studies conducted in the present author's laboratory using multiple fixed-ratio schedules and response latency as a dependent variable have shown a direct relationship between response latency and both
ratio requirement and delay to reinforcement, and an inverse relationship between response latency and duration of reinforcement and probability of reinforcement (Hesse, Michael, Whitley, Nuzzo, & Sundberg, 1984). Since these variables typically bear a direct relationship to response rate, it seems safe to assume that response latency is also inversely related to response rate. If true, then response latency should be a sensitive and useful dependent measure in operant conditioning experiments.

The present study represents a systematic extension of a thematic line of research with pigeons (conducted by students in the Laboratory in the Experimental Analysis of Behavior at Western Michigan University) in which the effects of fixed-ratio size, duration of reinforcement, and probability of reinforcement on response latency were examined using a multiple fixed-ratio schedule and a single-key procedure. As already mentioned, response latency has been shown to vary inversely with all of those variables. Specifically, differences in ratio size produced the biggest effects on latency, while the effects of probability and duration of reinforcement were smaller. In general, with ratio-size as the independent variable, low fixed-ratio values (e.g. FR 3) resulted in median latencies that varied from .4 to .7 s and high fixed-ratio values (e.g. FR 15) resulted in median latencies that varied from .5 to 3.0 s. Although the effects on response latency were initially interpreted operantly, the fact that the stimulus changes and responses occurred on the same key meant that both response-reinforcer and stimulus-reinforcer relationships were
present. Therefore, response latencies could have been jointly controlled by the respondent (eliciting) as well as the operant (evocative) effects of keylight onset. The respondent effects would be produced by having different values of the independent variable differentially correlated with the stimuli within the same session, a condition which has previously been shown to be sufficient to produce keypecking in pigeons (Gamzu & Schwartz, 1973). If respondent (elicited) keypecks were present, then any explanation of the obtained differences based strictly on operant principles would be misleading. For example, the short latencies measured to the FR 3 might actually reflect both an operant and respondent effect which might summate to produce shorter latencies than the operant (or respondent) variable might produce alone.

The possibility that latencies in the one-key study were jointly affected by response-reinforcer and stimulus-reinforcer relationships was addressed in an experiment by Hesse (1984). Hesse again compared the effects of different ratio sizes, but instead of a one-key procedure, he used a modified version of the two-key procedure designed by Keller (1974). In Hesse's experiment the stimuli correlated with each component of the multiple fixed-ratio schedule were on one key (the stimulus key), while the second (constant) key functioned as the response key. He found that, just as in the one-key procedure, latencies to the constant key in the two-key procedure were sensitive to differences in ratio size. In addition, median response latencies to the constant key were longer on the average, and the differences between latencies were less than
those found using one key. Responding also developed to the stimulus key in all birds except one, and was measured as the proportion of first pecks on that key to total first pecks in a session. Responding to the stimulus key showed an inverse relation to the schedule in effect on the constant key. In other words, with low ratios (FR 3) more stimulus-key pecks occurred than with high ratios (FR 15). Hesse attributed the stimulus-key responses to the respondent control by the stimulus change and the constant-key responses to the "leftover" operant control, an interpretation also shared by others who favor the additivity theory of behavioral contrast (e.g. Keller, 1974; Schwartz et al., 1975; Woodruff, 1979). Despite the higher proportion of stimulus-key responses in the "favorable" (low-ratio) conditions, the latencies to the constant key were still shorter than they were in the "unfavorable" (high-ratio) conditions, suggesting that even after stimulus-reinforcer influences had been separated, response latencies to the constant key were still sensitive to the response-reinforcer contingencies.

It is possible, however, that even after presumably separating the operant from the respondent influences in the two-key procedure, stimulus-key pecking may be operantly reinforced. Such possibilities have previously been considered in several experiments in which the two-key procedure was used with response rate as the dependent measure (Schwartz et al., 1975; Spealman, 1976; White & Braunstein, 1979; Williams & Heyneman, 1981). In those cases, however, the multiple schedules consisted of VI components where it
was possible to switch responding from the stimulus key to the constant key and have the next peck produce a reinforcer. Williams and Heyneman (1981), for example, have shown that when a significantly long change-over-delay (COD) is used, stimulus-key pecking is reduced considerably, thus supporting their argument that much of the stimulus-key pecking is operant. In the study by Hesse (1984), a similar interpretation could be made. If one conceptualizes the FR schedule as a temporal relation, then the difference between the "low" and "high" ratios used by Hesse could be considered in terms of the time from the first response (whether to the stimulus key or the constant key) to reinforcement, depending of course on how fast the pigeon pecks. As noted by Hesse, with an FR 3, the average time to reinforcement was about 1.5 s and with an FR 15 from about 5 to 7.5 s. Thus, the development of stimulus-key responding with the low (FR 3) ratio could be partially a function of the temporal proximity of food delivery to such responding. From the pigeon's perspective, seeing the yellow constant key after the stimulus associated with the low ratio condition appears on the stimulus key is better then seeing the yellow constant key after the stimulus associated with the high ratio condition appears on the stimulus key. The pigeons in Hesse's experiment already had a tendency to peck keys on which lights were projected as a result of their initial autoshaping training. Any pecks occurring to the stimulus key would now be followed immediately by seeing the yellow constant key. If the yellow constant key functions as conditional conditioned reinforcement, pecks to the stimulus key would be
expected to be differentially affected by the differences in fixed-ratio size associated with each of the stimuli. Thus, the two-key procedure would function in a manner similar to a chain schedule. The lack of substantial stimulus-key responding with the high ratios might attest to the importance of the temporal proximity of reinforcement to a response on the stimulus key. If the two components of the multiple fixed-ratio schedule were held constant at high values, any "accidental" temporal contiguity between stimulus-key responses and food delivery would be precluded, and thus, any stimulus-key responding might be more reliably attributed to uncontaminated respondent (stimulus-reinforcer) influences.

The purpose of the present experiment was to further evaluate the stimulus-reinforcer and response-reinforcer contributions to stimulus-key and constant-key responding in the two-key procedure using multiple fixed-ratio schedules. By holding both ratio values constant at the same levels (either low or high), the present experiment sought to compare the effects of differences in reinforcement duration and reinforcement probability on response latencies to the constant key. Since responding to the stimulus key was not effective in producing reinforcement, any responding that developed to the stimulus key was of equal interest to response latency as a dependent variable. In previous studies using the Keller (1974) procedure, stimulus-key pecking was measured in terms of rate of responding and was referred to as elicited responding. The notion of elicitation, however, requires that a stimulus change immediately precede the response. Conceptualizing rate of
responding as a respondent measure is contrary to the typical measures of respondent behavior, that is, either the percentage of stimuli that elicit a response, the magnitude of the response, or response latency. Therefore, in the present study, although all pecks occurring to the stimulus key were counted, those that were prime candidates as elicited pecks were those that represented the first peck following the stimulus onset that began each trial. Because fixed-ratio rather than variable-interval schedules were used, it was not possible for switching from the stimulus key to the response key to be reinforced by the next peck on the constant key producing a reinforcer, thus, no COD was needed.

The use of reinforcement duration and probability as independent variables in the present study extends the results of Hesse et al. (1984) with a one-key procedure, which showed response latency to be more or less sensitive to both of those variables, and the results of Hesse (1984), which showed response latency to be sensitive to differences in ratio size when the stimulus-reinforcer and response-reinforcer relationships were separated using a two-key procedure. Furthermore, by holding both ratio sizes constant (at either high or low levels) within sessions, the stimulus-reinforcer influences on stimulus-key responding could be assessed without being confounded by the variables associated with different ratio sizes. Finally, by comparing different values of reinforcement duration and reinforcement probability against different intertrial interval (ITI) lengths, the effects of the temporal spacing of trials on any elicited keypecks could be evaluated (c.f. Terrace,

To summarize, the present study can be characterized by the following questions. Using a two-key procedure with multiple fixed-ratio schedules: (1) What are the effects of within-session differences in duration of food on latencies to the constant key, with high and low ratios, and long and short ITIs? (2) What are the effects of within-session differences in probability of food on latencies to the constant key, with high and low ratios, and long and short ITIs? (3) What are the effects of the within-session differences in duration and probability of food on stimulus-key pecking, given high and low ratios and long and short ITIs?
METHOD

Subjects

Four White Carneaux, barren hen pigeons were maintained at approximately 80% of their free-feeding weight. The birds received all of their food in the experimental chamber contingent on responding during the experimental sessions. Sessions occurred between 11 am and 2 pm, seven days a week. Water and grit were always available in the home cages, which were located in a constantly illuminated room. None of the birds was experimentally naive, and three of them had previous training relevant to the manipulations in the current experiment.

Apparatus

A single two-key pigeon chamber measuring 38 cm on all sides was used. The keys measured 2.5 cm in diameter and 7.6 cm from center to center, and were located 22.5 cm above the floor. Each key could be transilluminated with a variety of stimuli from an Industrial Electronics Engineers, Inc. projector and a peck with a force of .2 N was required to operate either key. A food hopper measuring 6 cm by 5 cm was located 8.5 cm above the floor and 12 cm from either side. The chamber could be illuminated by a 7.5 W houselight which was located in the ceiling, and a fan, located in the rear wall of the chamber, provided masking noise and ventilation. The experiment
was controlled by a Digital Equipment PDP-8E computer equipped with Super Sked software and interfacing, which was located in an adjacent room.

General Procedure

Because all of the birds had histories relevant to operant conditioning of key pecking, neither hopper training nor shaping of the key peck was necessary. All four pigeons were exposed to a discrete trial two-component multiple fixed-ratio (FR FR) schedule in which the values of both ratios were equal either at high levels (e.g. 10, 15, or 20) or at low levels (e.g. 3). While maintaining the fixed-ratio sizes and the intertrial interval (ITI) length constant within sessions, different values of reinforcement probability were compared for two of the birds, and different values of reinforcement duration were compared for the other two birds. In addition, long (e.g. 20") versus short (e.g. 5") intertrial-intervals (ITI), and high (e.g. FR 10, FR 15, or FR 20) versus low (e.g. FR 3) ratio sizes were compared across sessions for all birds. The sequence of conditions is given in Table 1.

Each schedule component was preceded by either a 5 s or a 20 s ITI. (See Figure 1 for a diagram of the basic procedure.) During this time the houselight was on, the left (constant) key was
Figure 1. State diagram of the basic procedure.

illuminated with a yellow light, and the right (stimulus) key was dark. If a response to either key occurred during the ITI the timer was reset and the ITI began again. If no response occurred, then, when the timer timed out, with a probability of .5, the stimulus key became illuminated with either red or blue, and food became available for pecking the constant key. After the bird completed the ratio, with a specified probability (e.g. .9), the stimulus-key became dark (though the constant key remained yellow), and the hopper was raised. On those occasions when the hopper was not scheduled to be raised following completion of the ratio, the stimulus keylight was turned off, the houselight and constant key stimulus flashed off for one-half second and a new trial was begun. The purpose of flashing the houselight and constant keylight was to provide a stimulus change when completing the required ratio didn't produce grain just as there was a stimulus change (e.g. the sound of the hopper) when completing the required ratio did produce grain.
If the bird didn't complete the ratio requirement within 30 s after the stimulus key became illuminated, the stimulus key became dark, the ITI timer was reset, and the trial was considered aborted. All birds were initially exposed to a baseline condition in which not only the values of the fixed-ratio were equivalent, but also the values of reinforcement probability and duration (see Tables 1 & 2). Baselines were terminated when there were no visible trends in the data, or when the median response latencies were stable for at least five consecutive days. On the average, conditions lasted 16 days. Except for time constraints, the criterion for changing conditions was that no visible trends in the data occurred. Sessions were programmed to terminate either after 75 trials in which reinforcement occurred or 40 min, whichever came first.

**Reinforcement Duration**

For Bird #1088 and #132 the baseline values of reinforcement duration were 3 s for both the red and blue stimulus conditions. Thereafter, beginning with values of 8 s and 3 s, the shorter reinforcement duration was decreased to 1.5 s and the longer duration was decreased to 6 s. As with the probability birds, these values were compared with equal high ratios (FR 15) and equal low ratios (FR 3) and with 5 and 20 s ITI lengths (see Table 1).
Table 1

Experimental Conditions and Number of Sessions for each Reinforcement Duration Subject

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>132</td>
<td>B</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>5&quot;</td>
<td>14</td>
<td>B</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>15</td>
</tr>
<tr>
<td>1</td>
<td>8&quot;</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>5&quot;</td>
<td>17</td>
<td>1</td>
<td>2&quot;</td>
<td>8&quot;</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>3&quot;</td>
<td>8&quot;</td>
<td>3&quot;</td>
<td>5&quot;</td>
<td>18</td>
<td>2</td>
<td>8&quot;</td>
<td>2&quot;</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>3&quot;</td>
<td>8&quot;</td>
<td>3&quot;</td>
<td>20&quot;</td>
<td>19</td>
<td>3</td>
<td>8&quot;</td>
<td>2&quot;</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>8&quot;</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>20&quot;</td>
<td>13</td>
<td>4</td>
<td>2&quot;</td>
<td>8&quot;</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>8&quot;</td>
<td>3&quot;</td>
<td>15</td>
<td>20&quot;</td>
<td>7</td>
<td>5</td>
<td>2&quot;</td>
<td>8&quot;</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>8&quot;</td>
<td>1.5&quot;</td>
<td>15</td>
<td>20&quot;</td>
<td>19</td>
<td>6</td>
<td>8&quot;</td>
<td>2&quot;</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>1.5&quot;</td>
<td>8&quot;</td>
<td>15</td>
<td>20&quot;</td>
<td>20</td>
<td>7</td>
<td>8&quot;</td>
<td>2&quot;</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>1.5&quot;</td>
<td>8&quot;</td>
<td>15</td>
<td>5&quot;</td>
<td>16</td>
<td>8</td>
<td>8&quot;</td>
<td>1.5&quot;</td>
<td>15</td>
</tr>
<tr>
<td>9</td>
<td>8&quot;</td>
<td>1.5&quot;</td>
<td>15</td>
<td>5&quot;</td>
<td>9</td>
<td>9</td>
<td>1.5&quot;</td>
<td>8&quot;</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
<td>6&quot;</td>
<td>1.5&quot;</td>
<td>15</td>
<td>5&quot;</td>
<td>21</td>
<td>10</td>
<td>1.5&quot;</td>
<td>8&quot;</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>6&quot;</td>
<td>1.5&quot;</td>
<td>3</td>
<td>5&quot;</td>
<td>15</td>
<td>11</td>
<td>1.5&quot;</td>
<td>8&quot;</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td>1.5&quot;</td>
<td>6&quot;</td>
<td>3</td>
<td>5&quot;</td>
<td>16</td>
<td>B</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>5&quot;</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2

Experimental Conditions and Number of Sessions for each Reinforcement Probability Subject

| Subj | Phase | Prob. | FR | ITI | Ses. | Subj | Phase | Prob. | FR | ITI | Ses. |
|------|-------|-------|----|-----|-----|------|-------|-------|----|-----|-----|-----|
| 571  | B     | .9    | .9 | 15  | 5"  | 15   | 2927  | B     | .9  | .9  | 10  | 5"  | 17   |
| 1    | .5    | 1.0   | 15 | 5"  | 21  |      | 1     | .5   | 1.0 | 10  | 5"  | 26   |
| 2    | 1.0   | .5    | 15 | 5"  | 19  |      | 2     | 1.0  | .5  | 10  | 5"  | 16   |
| 3    | 1.0   | .5    | 15 | 20" | 15  |      | 3     | 1.0  | .5  | 3   | 5"  | 18   |
| 4    | .5    | 1.0   | 15 | 20" | 25  |      | 4     | .5   | 1.0 | 3   | 5"  | 23   |
| 5    | .5    | 1.0   | 3  | 20" | 23  |      | 5     | .5   | 1.0 | 3   | 20" | 22   |
| 6    | 1.0   | .5    | 3  | 20" | 12  |      | 6     | 1.0  | .5  | 3   | 20" | 12   |
| 7    | 1.0   | .4    | 3  | 20" | 11  |      | 7     | 1.0  | .4  | 3   | 20" | 11   |
| 8    | 1.0   | .3    | 3  | 20" | 11  |      | 8     | 1.0  | .3  | 3   | 20" | 14   |
| 9    | 1.0   | .3    | 20 | 20" | 11  |      | 9     | 1.0  | .3  | 10 | 20" | 16   |
| 10   | .9    | .3    | 20 | 20" | 16  |      | 10    | .9   | .3  | 10 | 20" | 15   |
| 11   | .3    | .9    | 20 | 20" | 15  |      | 11    | .3   | .9  | 10 | 20" | 16   |
| 12   | .3    | .9    | 20 | 5"  | 17  |      | 12    | .3   | .9  | 10 | 5"  | 18   |
| 13   | .9    | .3    | 20 | 5"  | 17  |      | 13    | .9   | .3  | 10 | 5"  |       |
| B    | .9    | .9    | 20 | 5"  | 21  |      |       |       |     |     |     |      |
Reinforcement Probability

For Bird #571 and #2927 the baseline values of reinforcement probability were .9 for both the red and blue stimulus. Thereafter, beginning with values of 1.0 and .5, the lower probability value was decreased to .4 and then .3, and the higher probability was decreased to .9. For Bird #571 these probability comparisons were made with equal high ratios of 15 and 20, and equal low ratios of 3. For Bird #2927 the equal high ratios were 10 and the equal low ratios were 3. For both birds these comparisons were made with 5 and 20 s ITI lengths (see Table 2).

Recording Response Latencies

Latencies on individual trials were recorded on both the stimulus key and the constant key. Each trial began with the illumination of the stimulus key by either a red or blue light and, simultaneously, a timer associated with each key began timing. A response to the stimulus key turned off one timer and a response to the constant key turned off the other timer. Latencies to each of the keys were collected and sorted into frequency distribution bins for each session by the computer, and the median latency for each component was calculated manually. Because of the nature of the latency measure, the shorter the latency, the smaller the difference between latencies must be to be significant. Conversely, with longer latencies differences must be proportionately larger to be significant. This was reflected in the interval widths of the
frequency distribution bins. For example, the distribution began with an interval width of .05 s, and each subsequent interval width was obtained by multiplying the preceding width by the constant 1.2. This produced a distribution in which each successive bin width was slightly larger than the preceding one. The result was a logarithmic distribution which permitted the collection of the entire range of latencies using a convenient number of latencies (see Hesse, 1984).
RESULTS

Duration Differences

In general, the results of the present experiment showed response latency to be only moderately sensitive to differences in reinforcement duration, but that the size of that difference depends on the size of the FR schedules. Figure 2 shows median latencies to the constant key for all conditions for Bird #1088. Each data point represents the average median latency for three consecutive sessions. Averaging in blocks of three eliminated much of the between-session variability, but maintained the within- and between-session relationship between latencies in each of the stimulus conditions. The closed circles connected by the solid lines represent median latencies for the conditions associated with the red keylight. The open circles connected by the dashed lines represent median latencies for conditions associated with the blue keylight.

The evidence that latencies are sensitive to differences in reinforcement duration would consist in shorter latencies to the stimulus associated with the longer durations and vice versa. Such effects can be seen for Bird #1088 in Figure 2 only in Phases 2, 7, 8 and 11, although they are negligible. In all four phases in which a difference was found, high ratios (FR 15 or FR 20) were in effect, but the more significant "splits" occurred in both high
ratios and a 5 s ITI. That the more significant differences occurred with a 5 s ITI and high ratios, but not with a 20 s ITI and high ratios suggests that the weak effects produced by differences in duration might be slightly accentuated by different combinations of ratio size and ITI length. In Phase 8 the 2 s duration was decreased to 1.5 s, but still no differences in latencies were found. It should be noted that differences in latencies did occur in Phase 4, but the shorter latencies were to the stimulus
associated with the shorter and not the longer duration. The effect of changing ITI length (Phases 5 and 11) was to increase the overall median latencies.

In view of the fact that differences in latencies to the constant key were minimal for Bird #1088, responding to the stimulus key appeared to be more sensitive to the variables manipulated. Stimulus-key responding was measured as the percentage of trials per session in which the first peck after each stimulus onset to that key occurred. (A trial is defined here by the presence of at least one peck either to the stimulus or constant key, even if the ratio is not completed before the 30 s time limit.) Figure 3 shows the percentage of stimulus-key pecks (also grouped into three-session blocks) for Bird #1088. In Phase 1 more first pecks occurred to the stimulus associated with the longer duration. A sizable number of first pecks also occurred to the stimulus associated with the shorter duration, but it declined by the end of the phase. In Phase 2, when the conditions were reversed, the percentage of first pecks also reversed. That split was maintained but was attenuated in Phase 3 when the ratio was changed from FR 15 to FR 3. Then, in Phase 4, when the durations were reversed, more first pecks occurred to the shorter duration stimulus, and thereafter, until Phase 7, no differences in percentage of first pecks to the stimulus key were evident. By the end of the Phase 7 more first pecks were occurring to the longer duration stimulus, and in Phase 8, that difference was enhanced when the 2 s duration was changed to 1.5 s. The difference was lost, however, with the reversal in the next phase, and was not
Figure 3. Percentage of trials with a first response to the stimulus key for Bird #1088.
regained until the end of Phase 11 when the ITI was changed to 5 s. With the exception of Phase 1, Bird #1088 showed differences both in median latency to the constant key and in percentage of first pecks to the stimulus key under the same conditions, although the effects on first pecks to the stimulus key appeared to be greater.

In addition to Bird #1088, the effects of differences in reinforcement duration were assessed with Bird #132, but with a different sequence of conditions. Figures 4 and 5 show the median latencies to the constant key, and the percentage of first pecks to the stimulus key respectively for Bird #132. The results for Bird #132 show no differences either in median latency or percentage of first pecks to the stimulus key until Phase 6, except for a slight split in first pecks in Phase 1.

In Phase 6 the 3 s duration was decreased to 1.5 s. The results were that the median latencies in that condition rose dramatically to levels which were just short enough to still enable the bird to complete the ratio most of the time before the programmed time limit aborted the trial. This large difference in median latency suggested that latency was sensitive to the difference between 8 and 1.5 s of grain, whereas before it was insensitive to the difference between 8 and 3 s. The only fact which may temper this conclusion is that in Phase 6, the number of aborted trials during the short-duration condition increased significantly. The first abort occurred in the twelfth session (the fourth open circle in Phase 6, Figure 4), with the total number of aborted trials for that condition reaching twenty. Although it was initially thought
that 1.5 s might not be enough time for the bird to get grain after completing the ratio, direct observation by the experimenter revealed that the bird was usually able to get its head into the hopper and peck the grain at least once before the hopper was removed.

In Phase 7 when the reinforcement durations were reversed, the difference in latencies also reversed, but the effect was transient and, by the 15th session, the latency difference reversed in the opposite direction. In Phase 8 when the ITI was dropped from 20 s
to 5 s, long median latencies were once again occurring to the stimulus associated with the 1.5 s duration condition. Although median latencies to the stimulus associated with the 8 s duration condition were significantly shorter than those associated with the 1.5 s condition, they were relatively higher with the 5 s ITI in Phase 8 than they had been previously when the ITI was either 5 or 20 s. Interestingly, the number of aborted trials dramatically increased, and not only for the stimulus associated with the 1.5 s reinforcement duration. Even though the number of aborted trials increased (in one session to as much as 31 times), the bird was still completing from half to all of the ratio requirements in the presence of the stimulus associated with the short reinforcement duration. There were also sessions with no aborted trials that were adjacent to ones containing many. In both cases, irrespective of the number of aborts, latencies in the short-duration condition were longer than latencies in the long-duration condition. In Phase 10 the 8 s duration was reduced to 6 s in order to determine whether the effect found in the previous four phases would be maintained with the smaller duration difference. With the exception of sessions 13-15, latencies were significantly shorter to the 6 s duration than to the 1.5 s duration. The effect was diminished, but not entirely lost in Phases 11 and 12 when the FR requirement was changed from FR 15 to FR 3.

Although response latency to the stimulus key was not the primary dependent variable, median latencies on that key were nevertheless calculated for all birds. As would be expected in the absence of a
response requirement, there were several trials per session in which no pecking occurred to the stimulus key. When pecks to that key did occur, they tended to follow the same general pattern as pecks to the constant key, but the differences were not as great. Although median latencies to the stimulus key are not shown, in Phases 6 and 7, and 10 and 11 median latencies to the color associated with the 1.5 s condition rose to levels that were comparable to those with the constant key, but showed a considerable amount of variability, as would be expected when responding is not required to produce food.

The results for Bird 132 showing the percentage of first pecks to the stimulus key are displayed in Figure 5. The pattern follows that of Figure 4, that is, no significant differences occurred until Phase 6, although Phase 1 did show a slight split. When the 3 s duration was reduced to 1.5 s in Phase 6, the percentage of first pecks to the stimulus key in the 8 s duration stimulus rose dramatically. As with the median latencies in the same phase, first pecks to the stimulus key in the 1.5 s duration stimulus also rose slightly, representing a possible induction effect. When the conditions were reversed in Phase 7, the percentage of first pecks in both duration conditions decreased but they didn't reverse until after 12 sessions. This pattern looked almost identical to the pattern of median latencies in the same phase. The difference was that the median latencies reversed immediately after the reinforcement durations were reversed, but then reversed in the
Figure 5. Percentage of trials with a first response to the stimulus key for Bird #132.
opposite direction after 12 sessions. When the ITI was changed to 5 s in Phase 8, the split was maintained, and with a larger difference. Significant differences continued to be seen in Phases 9 and 10. In Phase 11 the schedule was changed to FR 3 and the differences in the percentage of first pecks became attenuated and was slow to reverse in Phase 12 when the reinforcement durations were reversed. The final baseline condition returned the percentages to relatively equal values.

Probability Differences

Just as with reinforcement duration, the present experiment showed response latency to be only moderately sensitive to reinforcement probability, using the two-key procedure, although the effects with Bird #2927 were more significant than with Bird #571.

Figure 6 shows the median latencies to the constant key for all conditions for Bird #571 averaged in three-session blocks. The only Phases in which differences occurred in the predicted direction were Phase 6, 10, and toward the end of Phase 13. The small split in Phase 6 appears to be a continuation of the split in the previous phase. While the differences in latency in Phase 10 appear to be significant, when conditions were reversed in Phase 11, the differences in latency were enhanced, but in the opposite direction from that predicted. It also appears that latency may be showing some sensitivity at the end of Phase 13, but due to time constraints the condition could neither be continued nor reversed. Differences in latency in the direction opposite from what would be predicted
occurred to different degrees in Phases 1-5, 8, and 11, with the biggest difference seen in Phase 11.

Figure 7 shows the percentage of first pecks to the stimulus key for Bird #571. In Phase 1, with FR 15 and a 5 s ITI, there was a significantly higher percentage of first pecks to the stimulus key associated with the 100% (1.0) reinforcement condition. When the conditions were reversed in Phase 2, the percentage of first pecks...
Figure 7. Percentage of trials with a first response to the stimulus key for Bird #571.
also reversed and showed an even greater difference than in the first phase. Imposing a 20 s ITI in Phase 3 attenuated that difference, which was even further diminished when the conditions were reversed in Phase 4. When the schedule was changed to FR 3 in Phase 5, first pecks to the stimulus key in both stimulus conditions decreased dramatically. In Phases 6-8 the lower reinforcement probability was reduced from .5 to .4 and .3 respectively, but with only moderate increases in the difference between the percentage of first pecks to the stimulus associated with the certainty condition and the stimulus associated with the low-probability condition. The transition from a difference between 1.0 and .4 to one of 1.0 and .3 (Phase 8) slightly accentuated the differences in the percentage of first pecks, although percentages in both conditions decreased. It is possible that the differences would have been further enhanced in Phase 9 when the schedule was changed to FR 20, but as was the case for both of the probability birds, when the lower ratio schedule was changed to a higher ratio schedule, overall latencies to the constant key and percentage of first pecks to the stimulus key increased (see Phase 9 in Figures 7, 8, 9, and 10). That increase continued in Phase 10 for first pecks to the stimulus key when the certainty condition was changed to a probability of .9. When the reinforcement probabilities were reversed in Phase 11, the differences were once again quite significant. The change to a 5 s ITI in Phase 12 amplified the differences, which reversed quickly after the probabilities were reversed in Phase 13. The percentage
of first pecks in both stimulus conditions was equalized in the final baseline condition with equal probabilities. Thus, stimulus-key pecking was sensitive to within-session differences in probability of reinforcement relative to ratio size and ITI length.

Figure 8 shows the median latencies to the constant key for Bird #2927. As was the case with Bird #571, longer latencies were associated with higher ratio sizes. The results for Bird #2927, however, showed response latency to be more sensitive.

Figure 8. Median response latencies for Bird #2927.
to probability differences than did the results for 571. Such differences can be seen toward the end of Phase 1, to a lesser degree in Phases 2 and 3, and in Phases 9, 10, and 12. The more significant differences were found when the ITI was 5 s and the ratio size was high (e.g. Phases 1, 2, and 12). In Phases 4 and 5, though, differences in latency occurred in directions opposite to those that would be predicted. Reducing the lower probability from .5 to .4 and finally .3 (Phases 6–8) had no apparent effect. In Phase 9 the ratio was increased from FR 3 to FR 10. Differences in latency were then found with differences in reinforcement probability of 1.0 and .3.

Figure 9 shows the percentage of first pecks to the stimulus key for Bird #2927. While the overall frequency of first pecks to the stimulus key was much less than for Bird #571, differences were found in almost all phases, and they showed a similar pattern to stimulus-key responding for Bird #571. Though somewhat variable, differences can be seen beginning in Phase 1. In Phase 2 the difference was enhanced and the variability simultaneously reduced. Changing to a FR 3 in Phase 3 decreased responding to the stimulus key, especially in the high-probability condition (see also Phase 3 in Figure 8 for a similar effect in latency), but the split was maintained, albeit with smaller differences, through Phase 8. When the schedule was changed back to FR 10 in Phase 9, the difference in the percentage of first pecks reversed even though the probabilities were the same as in the previous phase.
Figure 9. Percentage of trials with a first response to the stimulus key for Bird #2927.
The difference was regained toward the end of Phase 9 and in Phase 10 when the certainty condition was lowered to .9 probability. Reversing the probabilities resulted in an amplified difference in Phase 11, which continued when the ITI in Phase 12 was lowered to 5 s.

In general, then, stimulus-key responding did show sensitivity to within-session differences in reinforcement probability, depending upon ratio size and, to a lesser extent, ITI length.
DISCUSSION

The results of the present experiment showed that, with a few exceptions, response latency on the constant key was only moderately sensitive to differences in reinforcement duration and probability. Differences in ratio size and ITI length appeared to be important, and they seemed to interact with duration and probability of reinforcement, as well as with each other, to produce some effects on response latency. Stimulus-key pecking, as contrasted with response latencies to the constant key, varied directly with probability of reinforcement, and in some instances with duration of reinforcement. Thus, the general conclusion is that, with the two-key procedure (Hesse, 1984; Keller, 1974), stimulus-key pecking was consistently more sensitive to differences in the duration and probability of food than response latencies to the constant key.

Duration of Reinforcement

Previous experiments on the effects of reinforcement magnitude report different findings. For example, Stebbins (1962) reported that reaction time (response latency) and variability in reaction time in rats was inversely related to amount of reinforcement. Others have reported that rate of responding was not sensitive to differences in reinforcement magnitude (Catania, 1963; Neuringer, 1967). Neuringer (1967) compared choice and response rate as a function of different durations of grain in a two key procedure.
When both keys were illuminated, one peck to either key caused the other key to become dark, and the "chosen" key to become operative. The first response to occur on the operative key after a 5 s interval had timed out produced grain if a reinforcer had been set up by a variable-interval programmer, or produced a brief blackout. One key was associated with a constant amount (2 s) of grain for responding and the other key was associated with a variable amount of grain ranging from 2 to 10 s. In this way, Neuringer compared the choice of reinforcement duration (either a standard 2 s of grain or a variable amount of grain with a mean duration of 3.96 s) with the response rate on the "chosen" key. He found that choice varied directly with reinforcement duration, but rate of responding did not. In other words, the pigeons consistently "chose" the key associated with the variable duration of food, but once on that key, rate of responding actually decreased as reinforcement duration increased. Others have also reported that response rate was insensitive to differences in reinforcement magnitude (e.g. Lowe, Davey, & Harzem, 1974; Powell, 1969).

To the extent that response latency varies inversely with response rate, the present experiment extends the findings that show response rate to be relatively insensitive to reinforcement duration. Bird #1088 showed only a few transient effects that could be attributed to differences in duration. Previous pilot work using a one-key procedure, however, has shown that differences in reinforcement duration of 2 s vs 6 s can result in shorter latencies to the stimulus correlated with 6 s of food and longer latencies to
the stimulus correlated with 2 s of food. However, these differences are much smaller and more variable than the effects due to differences either in ratio size or probability of reinforcement (Hesse et al., 1984). The present experiment also showed that response latency can be sensitive to differences in reinforcement duration, but only after the differences in reinforcement duration are made extreme. For example, the data for Bird #132 did not show any effects of reinforcement duration until the shorter duration was reduced from 3 to 1.5 s. That change produced significant increases in latencies in the short-duration condition and, although the effect was variable, it continued for the remainder of the experiment.

It was thought that 1.5 s might be too short to allow the bird to get any grain, thus making the actual comparison between 8 s of grain and EXT. If that were the case, then one of two possibilities might obtain. First, failure to get food after responding might result in extinction during that condition, in which case a dramatic rise in aborts would be expected. Second, responding might become intermittently reinforced, with some completed ratios ending in food, but some ending simply in the sound of the hopper. Because the sound of the hopper would still be correlated frequently with food in the long-duration condition, and less frequently in the short-duration condition, it would function as conditioned reinforcement. Responding would thus be expected to be maintained, and a rise in aborted trials would not be predicted. It is also possible, of course, that response latency might be sensitive to
duration if the difference is great enough. In the present experiment the increase in latencies to the short duration stimulus might have been due to the difference between 8 and 1.5 s duration of grain. The session-by-session data reveal that in Phase 6 (Figure 4), when the difference in duration became 8 vs 1.5 s, the median latencies to the stimulus associated with 1.5 s duration increased dramatically, in some sessions to as much as 29 s. The data also show that the number of aborted trials increased, to as many as 31 in one session. Was responding to the stimulus associated with the 1.5 s duration extinguishing, or being maintained with less strength by the sound of the hopper as conditioned reinforcement?

There is another, more parsimonious explanation of the simultaneous increase in response latencies and aborts for Bird #132. Once the bird emitted the first peck to the constant key, it would be expected to work quickly to complete the ratio requirement. It is possible, however, that if the bird waited too long to begin the ratio, the 30 s timer would time out during responding, causing the trial to be aborted and grain not to be delivered. This possibility seems supported by the finding of median latencies as long as 29 s. Latencies this long were collected by the computer in the bin that collected latencies from 28.595 to 30.000 s. In some sessions with very high median latencies, as many as 23/35 of the latencies were collected in that bin. However, there would be a type of self-corrective contingency with median latencies near 30 s: waiting too long would result in the trial aborting. Thus, median
latencies to the stimulus associated with 1.5 s of grain would be predicted to be longer than those associated with 8 s of grain, but would be "forced" down from levels approaching 30 s. This is indeed what happened. The 1.5 s duration of grain, however, did not become entirely unimportant to the bird. This is evinced by the simple fact that responding to the stimulus associated with the short reinforcement duration continued. Data from Bird #1088 also confirm the importance that 1.5 s of grain can have. For that bird, changing from 2 to 1.5 s produced negligible effects on response latency and no aborted trials. In addition, there are other data that suggest that even when the duration of food is only 1 s, pigeons have enough time to peck the grain (Perkins et al., 1975).

The effects of reinforcement duration on response latency in the present experiment can be better understood by considering other studies in which the effects of reinforcement duration were examined using ratio schedules. For example, it has been shown that the length of the pre-ratio (post-reinforcement) pause in FR schedules increases as the response requirement is increased, while effects on response rate are inconsistent (Felton & Lyon, 1966; Powell, 1968). Powell (1969) extended these findings by comparing the effects of different durations of reinforcement in relation to different ratio sizes. Specifically, he compared the effects of 2.5 s and 4 s of grain with ratio sizes in pigeons that varied from FR 10 to FR 70. His dependent variables were response rate and pre-ratio pause duration. In addition, once he showed effects on pause duration, he gradually reduced the initial response requirement until the
differences in the pause durations disappeared. His results showed an inverse relationship between duration of reinforcement and duration of pre-ratio pause: the greater the duration of grain, the shorter the pause. But, this relationship between reinforcement duration and pause duration depended on the size of the fixed-ratio. When Powell reduced the response requirements from FR 50 or FR 60 to FR 10 or FR 20, the duration of the pre-ratio pauses decreased from approximately 8 s to less than 2 s. Furthermore, reducing the response requirements also reduced the differences in pause length due to differences in reinforcement duration. In addition to the effects on pause duration, Powell found that, exclusive of pause duration, response rates were no higher with longer durations of food. The findings of the present experiment with response latency are consistent with Powell's on pause duration. When the response requirement in the present experiment was FR 3, overall response latencies were shorter than when the response requirement was FR 10, FR 15, or FR 20. Furthermore, when differences in latencies due to reinforcement duration and reinforcement probability were found, they were more significant with higher than with lower response requirements. Perhaps, then, it is better to describe how response latency varies with post-reinforcement pause duration rather than response rate when FR schedules are used. Thus, the longer the duration of reinforcement, the shorter the pause length and the shorter the response latency, depending on the response requirements of the ratio schedule.

The failure with Bird #1088 to find any difference in response
latency due to duration of reinforcement in the present study could be explained in several ways. One possibility is that response latency, like response rate, does not, in fact, consistently vary with reinforcement duration, though some of the results with Bird #132 seem to contradict this. Another possibility is that the effects of differences in reinforcement duration are only evident with high fixed-ratios (Powell, 1969). The only differences in response latency in the present study with Bird #1088 were found with the higher ratio sizes (FR 15 and FR 20) (see Figure 2, Phases 2, 8, and 11). With Bird #132 greater differences due to reinforcement duration were found, but also only at high fixed-ratio values (Figure 4, Phases 6-10). When the ratio size was decreased to FR 3 (Phase 11 and 12) the differences were attenuated. The highest response requirement used in the present study was FR 20, which in Powell's study was not sufficient to reveal any differences due to reinforcement durations of 2.5 and 4 s. Perhaps if the response requirement in the present arrangement were increased (e.g. to FR 60), differences resulting from reinforcement duration would become more evident.

The temporal proximity of reinforcement to all three responses in low ratio schedules may serve to mask any effects on response latency to the constant key due to differences in reinforcement duration. This seems to be supported by the finding of overall shorter response latencies in the low ratio conditions, and the fact that differences in latencies were attenuated when high ratio schedules were changed to low ratio schedules. Thus, from the
animal's perspective, during an FR 3 condition, when the stimulus key is illuminated, food is only about 1.5 s away, irrespective of the duration of access to that food. During an FR 15 condition, because food is more delayed, and more work is required to obtain the food (see discussion below), not only are the latencies to both stimuli longer, but it is more likely that the amount of food that can be obtained becomes more important.

The fact that differences due to reinforcement duration were found with Bird #132 has been discussed already. It is difficult to explain the inconsistent findings of the two duration birds except to speculate on their different histories. The fact that neither of them was naive, and one of them (Bird #132) had recent experience with the two-key procedure with different ratio sizes should be noted, even though it has no explicit explanatory value. A more tangible explanation, however, is that the the same FR requirement may have different effects with different birds. These effects may be thought of as the relative "effort" involved in completing the ratio. A study by Crossman et al. (1974) found that when either work time or interreinforcement interval was controlled, the length of pre-ratio pause was directly related to the number of responses required to complete the ratio: the more responses in the ratio, the longer the pre-ratio pause. This is consistent with Powell's (1969) findings which also showed that pause duration varied with the response requirement in fixed-ratio schedules. In the present study, direct observation of different birds responding on equal fixed-ratio schedules showed that they responded at different rates.
This was confirmed by comparing the relative time per trial across birds under equal low FR and equal high FR schedules. Although the relative time per trial was influenced by the prevailing ITI, the comparisons (not displayed) showed a substantial amount of variability across birds under otherwise equal conditions.

Differences in results between the two duration birds can also be explained by the interaction of response-reinforcer and stimulus-reinforcer contingencies in discrete trial procedures using pigeons and keypecks (see discussion below). Response latency as an operant dependent variable would be expected to be affected by such an interaction more than rate of response because of the interference of operant response latency by the respondent elicitation effects of the stimulus onset.

Probability of Reinforcement

As with duration of reinforcement, previous experiments on the effects of reinforcement probability also report inconsistent findings. For example, some studies have shown that percentage reinforcement with fixed-ratio schedules results in an increase in both the mean duration and variability of pre ratio pauses (Ferster & Skinner, 1957, pp. 67-71; Zimmerman, 1960). Davenport and Thompson (1965), however, reported that percentage reinforcement with fixed-ratio schedules produced shorter pauses after reinforcement was not delivered. Their results were confirmed in a study by McMillan (1971), in which percentages of reinforcement ranging from 20% to 80% were scheduled for pigeons responding on an
FR 80. He found that pausing after reinforcement gradually increased for most of the percentage reinforcement values relative to baseline value for each condition. In addition, within the same percentage reinforcement schedule, nonreinforcement resulted in shorter pauses than reinforcement, but this was partially a decreasing function of the percentage schedule; that is, as the percentage of reinforcement increased the average duration of pauses after nonreinforcement decreased.

In previous pilot studies using a one-key procedure and a multiple fixed-ratio schedule, within-session comparisons showed response latencies to be more sensitive to differences in reinforcement probability than to duration of reinforcement, but less sensitive than to differences in ratio size. In the present experiment only negligible differences in response latency were found with one probability bird (Bird #571), and, although the differences found with the other probability bird (Bird #2927) were more significant, they were inconsistent. As with duration of reinforcement, higher overall response latencies with probability of reinforcement were associated with high ratio schedules (see Figure 7, Phases 1–4 and 9–14 and Figure 9, Phases 1 and 2, and 9–13), indicating that the variables controlling pre-ratio pauses may interact with the variables controlling response latency in a discrete-trial procedure. In addition, with the exception of one brief phase (Phase 6, Figure 7), all the differences in latency produced by probability of reinforcement occurred with high ratio sizes.
With Bird #571 latency did not appear to be sensitive to the probability manipulations. One possible explanation is in terms of the high absolute and relative levels of stimulus-key pecking produced (see discussion below). Another possibility is that, as with the duration birds, the response requirement was not high enough to reveal any differences due to reinforcement probability. A third possibility is that if reinforcement generates longer pauses as McMillan (1971) has reported, then those long pauses might mask any effects produced by probability differences on response latency. Such an effect, however, should depend on the ITI. For instance, pauses normally produced after reinforcement on a 90% percentage schedule would be expected to be longer than pauses after nonreinforcement. Latencies, however, are predicted to be shorter with 90% reinforcement than with 30% reinforcement. With an ITI of 5 s, then, the long pauses generated by the preponderance of trials ending in reinforcement might mask any effects on latency by the high percentage schedule by lasting beyond the ITI into the next trial. With a 20 s ITI this would be less likely unless the ratio requirement was higher than those used in the present study. While this might explain the results for Bird #571 with the 5 s ITI, it neither explains the lack of effect with the 20 s ITI nor the positive effects on response latency with Bird #2927 with a 5 s ITI (Figure 9, Phases 1, 2, 3, and 12).

As with the duration birds, it is difficult to explain the difference in results between the two probability birds. While Bird #571 appeared to show no sensitivity of response latency to
probability differences, Bird #2927 did. No other explanation other than the differential effects of different probabilities seems required for Bird #2927. However, in Phases 4 and 5, and 11 to some extent, the effects occurred in the direction opposite of what would be predicted.

Stimulus-key Responding

Several experiments have reported that when the key on which the stimuli are projected is separated spatially from the response key, not only does behavioral contrast not occur on the response key, but the pigeons start to peck the stimulus key even though pecks to that key have no effect in producing food (Keller, 1974; Schwartz, 1975, 1978; Schwartz et al., 1975; Spealman, 1976). Theoretically, when summated with responding on the constant key, pecks to the stimulus key would reveal the phenomenon known as behavioral contrast. Although, it has been shown that some responding to the stimulus key was maintained by operant reinforcement, when change-over-delays (COD) are imposed, some, but not all of the pecks to the stimulus key are eliminated. Furthermore, when a COD is in effect, it has been found that pecks continue to be directed toward the stimulus key, but do not make contact with it (Williams & Heyneman, 1981). While the prevailing view is that stimulus-key pecking consists primarily of elicited pecks, Williams and Heyneman (1981) argue that most of the stimulus-key pecks are operant.

The controversy over whether stimulus-key pecks are respondent or operant is difficult to resolve, because of several problems
associated with mult VI VI schedules, as well as with the two-key procedure itself. Williams and Heyneman (1981) argue that the two-key procedure fails in its attempts to separate elicited from emitted key pecks because it introduces a new unit of operant behavior. According to Williams and Heyneman, with nondifferential reinforcement, the pigeon need not look at the stimulus key. However, with differential reinforcement the pigeon must look at the stimulus key before pecking the constant key. Thus, a sequence of behavior involving looking at the stimulus key before either pecking or not pecking the constant key will be differentially reinforced relative to sequences involving only pecking the constant key. Such an analysis applies to the two-key procedure when the schedule is a mult VI VI. However, in the present procedure, the problem was precluded by the use of an intertrial interval: "The birds had to look at the stimulus key during conditions of equal components as well as unequal components because pecks to the constant key went unreinforced (as well as delayed the onset of a reinforcement component) when the stimulus key was dark (during the ITI)" (Hesse, 1984, p. 10). Thus, Williams and Heyneman's criticism of the two-key procedure does not appear to apply to the present adaptation of that procedure.

Another advantage of the present procedure over previous two-key procedures is the manner in which pecks to the stimulus key were measured. Previously, stimulus-key pecking was measured in terms of rate, the traditional operant response measure. In the present experiment, however, rate of responding on the stimulus key was not
a relevant measure because of the use of fixed-ratio schedules which generated typical break-and-run sequences on the constant key. Such patterns of responding on FR schedules made it extremely unlikely that the pigeon would interrupt a FR run to peck the stimulus key. Indeed, very few, if any, instances of such responding were observed. Thus, instead of measuring rate of responding, first pecks in every trial to both keys were counted. It was reasoned that because of the response-reinforcer contingencies, first pecks to the constant key will be operantly controlled; and because of the stimulus-reinforcer contingencies present, first pecks to the stimulus key would be respondently controlled. The percentage of first pecks to the stimulus key, then, is analogous to one of the traditional measures of respondent strength, namely, the percentage of stimuli that elicit a response.

In an attempt to analyze the effects of different ratio sizes on response latency using a two key procedure, Hesse (1984) found that not only did response latency vary inversely with ratio size, but also that the birds began pecking the stimulus-key, with a higher percentage of first pecks to the stimulus associated with FR 3 than to the stimulus associated with FR 15. Although, he interpreted the stimulus-key pecking as respondently elicited, it is possible that pecks to the stimulus key were adventitiously reinforced in the low-ratio condition by virtue of the temporal proximity of a peck to the stimulus key and reinforcer delivery. This would be analogous to the way that stimulus-key responses in two-key procedures using VI schedules could be reinforced by changing over from the stimulus
key to the constant key. That possibility was addressed in the present experiment by using equal fixed-ratio components. If the temporal proximity of reinforcer delivery to pecks on the stimulus key in the low-ratio condition was important, then more stimulus-key pecks would be expected in general with equal low ratios than with equal high ratios. However, this was not found. On the contrary, for the two probability birds, when the schedule was changed from FR 15 (Bird #571) or FR 10 (Bird #2927) to FR 3, the percentage of stimulus-key pecks declined significantly (see Figure 8, Phase 5 and Figure 10, Phase 3). Only for Bird #1088 was a rise in stimulus-key pecking associated with changing from a high FR to a low FR (Figure 3, Phase 3), but it was no higher than when the FR 15 was in effect.

Results of the present experiment show that the percentage of first pecks to the stimulus key was consistently higher in the longer duration and higher probability conditions for all birds. Furthermore, when reinforcement conditions were equal, that is in baseline, the percentage of first pecks to the stimulus key decreased for both conditions and became relatively equal. These results are consistent with a number of studies which show that unequal (differential), but not equal, response-independent reinforcement conditions will produce keypecking in pigeons (Gamzu & Schwartz, 1973; Gamzu & Williams, 1971, 1973). Specifically, the present results with reinforcement duration and probability extend the findings of Gamzu and his colleagues on reinforcement frequency. In addition, the percentage of first pecks to the stimulus key was also influenced by changes in both ratio size and ITI length. In
general, the higher the ratio size and the shorter the ITI, the higher the percentage of stimulus-key pecks and the greater the difference between them due to reinforcement duration or reinforcement probability.

Hesse (1984) analyzed the stimulus-key responding in terms of respondent conditioning processes involving the temporal relations between the duration of the stimulus period, the delivery of food, and the time between trials, or intertrial interval (ITI), or, in other words, "the temporal spacing of trials" (Jenkins, Barnes, & Barrera, 1981). The evidence for such temporal spacing as an important determinant of autoshaping shows that the shorter the intertrial interval (ITI) the more trials are necessary to produce acquisition of responding (autoshaping), and the longer the ITI the fewer number of trials are required (Perkins et al., 1975; Terrace, Gibbon, Farrell, and Baldock, 1975). This explanation of the stimulus-key responding in the Hesse study is based on the theories of autoshaping by Gibbon and Balsam (1981) and Jenkins, Barnes, and Barrera (1981), and states that the number of trials required to produce "autoshaped" responding (or, the strength of the correlation between a stimulus and food delivery) is a function of an improvement in the average delay to food delivery in the presence of a stimulus as compared with the overall average delay (Gibbon and Balsam, 1981). This notion is incorporated into Gibbon's Scalar Expectancy Theory (Gibbon, 1977). According to that theory "...the relevant time values are estimated by animal subjects and compared by a 'ratio comparator' that may be thought of as a mechanism
indexing the relative excitatory strength associated with two alternative delays to reinforcement" Gibbon and Balsam (1981). A simpler and related version of this theory, and one which does not depend on hypothetical cognitive mechanisms of the subject, is the Relative Waiting Time Hypothesis of Jenkins, which states that "...the effectiveness of the reference trial depends on the waiting time in the reference trial relative to the overall waiting time between feedings no matter whether, or by what stimulus, the feedings are signaled" (Jenkins et al., 1981). Thus, a Relative Waiting Time analysis of Hesse's (1984) stimulus-key responding with FR 3 versus FR 15 and a 5 s ITI is as follows. The onset of the stimulus associated with the FR 3 (waiting time of @1.5") was correlated with a waiting time of only 23% of the overall waiting time (6.5"), and the onset of the stimulus associated with the FR 15 (waiting time of @7.5") was correlated with a waiting time of 40% of the overall waiting time (12.5"). The analysis accurately predicts more responding to the stimulus key with the stimulus associated with the shorter relative waiting time to food, that is, the stimulus associated with the FR 3. In the present experiment there were several variables that contributed to the overall waiting time to food. Those variables were (1) ITI length (either 5 or 20 s); (2) fixed-ratio size (either FR 3 or FR 10, FR 15 or FR 20); (3) duration of food; and, (4) probability of food.

While some of the conditions in the present experiment that generated stimulus-key pecking would have been accurately predicted by the temporal theories of autoshaping, many would not. For
instance, the finding of more stimulus-key pecking with a 5 s ITI than with a 20 s ITI (e.g. Figure 6, Phases 10 and 6 respectively) contradicts predictions based on the Relative Waiting Time Hypothesis. That hypothesis would predict that the relative waiting time with a 5 s ITI and an FR 15 (with a duration of approximately 4 s), and the different duration values would be 12% of the total waiting time. With a 20 s ITI, an FR 15 and the different reinforcement duration values, the relative waiting time would be only 5%. Thus, more stimulus-key pecking should occur with the 20 s ITI. Similar effects can be seen in Figures 8 and 10, where more stimulus-key pecking occurred with 5 s ITIs than with 20 s ITIs. Furthermore, the finding of such large differences in stimulus-key pecking with high versus low reinforcement probabilities also contradicts predictions made by the temporal theories of autoshaping. Probability of food affects the relative waiting time in that the waiting time in a nonreinforced trial accrues until food is eventually presented. For instance, the waiting time for two nonreinforced trials is simply summed and, if reinforcement occurs on the next trial, the relative waiting time is the combined time of the three trials divided by the combined total time to food. Since the ratio of trial duration to overall cycle duration (the time between reinforcers) remains the same whether reinforcement probabilities are .9 or .3, no difference in speed of acquisition of autoshaped responding is expected. Such predictions were indeed supported by an experiment by Perkins et al., (1975, Experiment 3) which showed that stimuli followed by food 30% of the
time generated as much responding as stimuli that were followed by food 100% of the time.

The finding of significant differences in stimulus-key pecking with differences in reinforcement probability in the present experiment is consistent with findings by Gonzales (1973) and Schwartz and Williams (1972) which showed more autopecking with higher probabilities of food. Perhaps one explanation of the inconsistency between these results and those predicted by the Relative Waiting Time Hypothesis lies in the difference between the conditions that are necessary to produce autoshaping and those that are necessary or sufficient to maintain it. It is even possible that auto-shaped and auto-maintained pecks represent two different controlling relations and, thus, two different types of behavior in the pigeon (c.f. Williams, 1981). For the purposes of the present discussion it seems reasonable to distinguish between behavior that is elicited immediately by the onset of a stimulus, and behavior that is measured in terms of rate. As mentioned earlier, the measure of stimulus-key pecking in the present experiment, that is, the percentage of first pecks, differs qualitatively from usual measures of autopecking, rate of response. This distinction is called for by the difference between the present procedure and the usual procedures that examine autoshaping. In the present procedure the pecks to the stimulus-key are truly evoked by the stimulus onset; their median latencies are always shorter than the median latencies to the constant key, in many instances as short as .25 s.

Although it is tempting to talk about separating
stimulus-reinforcer from response-reinforcer influences, it is more likely that they are inextricably related. Thus, in the present procedure, although the key light onset elicits pecks to the stimulus key, the fixed-ratio contingency precludes continued pecking to the that key. Also, the more the pigeon pecks the stimulus key the longer reinforcement is delayed. However, the delay that occurs when only one peck (or a quick burst of pecks) occurs to the stimulus key is minimal and, can possibly be made up by responding faster on the constant key. The finding in the present experiment that stimulus-key pecking is reduced with FR 3 schedules can be explained in terms of the relative delay to food. For instance, assume that the time it takes the bird to peck the stimulus key and then move over to peck the constant key is 1 s. In addition, the time it takes to complete the FR 3 is 1.5 s, and the time it takes to complete the FR 15 is 5 s. When the stimulus key is illuminated and the schedule on the constant key is FR 3, a peck to the stimulus key increases the relative delay to food by 40%, whereas when the schedule on the constant key is FR 15, a peck to the stimulus key increases the average delay to food by only 17%. Therefore, any variables controlling pecks to the stimulus key would be expected to be more powerful when the FR is high rather than low. While this explanation accounts for the differences in the present experiment between stimulus-key responding with low and high ratios, it does not account for the stimulus-key responding found by Hesse (1984). One difference between the two studies is that Hesse compared different ratio sizes within sessions and the present
experiment compared them between sessions. Thus, in Hesse's experiment the stimuli within a session were already differentially correlated with different relative delays to food. In the present study the stimuli were correlated either with different reinforcement durations or different reinforcement probabilities. The relative delays to food associated with the FR schedule were held constant within sessions and, therefore, only exerted parametric control of stimulus-key responding.

Stimulus-Reinforcer and Response-Reinforcer Control of Response Latency

The results of the present experiment were inconsistent in that they showed response latency to be sensitive to reinforcement duration and probability under some conditions but not under other conditions. However, this is compatible with other published reports. It is also compatible with unpublished pilot work which showed response latency in a one-key procedure to be sensitive, in rank order of sensitivity, to ratio size, reinforcement probability, and reinforcement duration (Hesse et al., 1984). The fact that effects on response latency in the present study were more irregular and variable than those found in the one-key studies can probably be understood in terms of the difference in procedures. Using response latency as an operant dependent measure is inherently confounded with response latency as a respondent measure. Hesse (1984) interpreted his findings as successfully separating operant from respondent control and still showing both differential operant control of response latency by ratio size, as well as differential
respondent control of stimulus-key pecks. The present experiment showed differential control of stimulus-key responding to be more consistent than that of response latency. When response latency varied with reinforcement duration or reinforcement probability, so did the percentage of first pecks to the stimulus-key. However, during several phases, when differences were seen in stimulus-key pecking, response latencies to the constant key either showed no difference, or varied in the direction opposite from that predicted. Although it is tempting to explain the lack of difference in response latency in those situations as resulting from the interference from stimulus-key pecking, such an explanation falters when significant differences in response latency were accompanied by relatively equal differences in first pecks to the stimulus-key (see Figures 4 & 5, Phases 6-8 & 10-12, and Figures 8 & 9, Phases 1-3, 9, 10, & 12).
CONCLUSION

The results of the present experiment show that response latency was generally higher with FR 15 than with FR 3 schedules. Furthermore, differences in response latency due to reinforcement duration and probability were more likely to occur with the higher ratio sizes. These findings are consistent with other studies on the effects of reinforcement duration and reinforcement probability on pre-ratio pause durations in fixed-ratio schedules. Thus, operant response latency as a dependent measure, at least with FR schedules, is more simply described as pre-ratio pause duration. Such a practice will reduce the confusion that would result from having two names for the same event.

The results of the present experiment are also consistent with other findings which show that a change in the quality of reinforcement (e.g. rate, duration, probability, and delay) simultaneously affects behavior maintained by response-reinforcer contingencies and behavior maintained by stimulus-reinforcer contingencies (Hesse, 1984; Marcucella, 1981). The present experiment showed that stimulus-key pecking and constant-key pecking could be differentially sensitive to changes in reinforcement duration or probability. It confirms other findings (e.g. Marcucella, 1981) by showing that a difference in reinforcement duration or reinforcement probability was sufficient to maintain stimulus-key pecking, but was not necessarily reflected in response-latencies to the constant key. This conclusion should be tempered, however, by the consideration that either the number of
responses and/or the interreinforcement interval associated with FR schedules, as well as the ITIs used in the present experiment contributed to the effects of reinforcement duration and reinforcement probability on responding to the constant key as well as to the stimulus key.


Schwartz, B. (1972). The role of positive conditioned reinforcement in the maintenance of key pecking which prevents delivery of primary reinforcement. Psychonomic Science, 28, 277-278.


