8-1984

Stimulus-Reinforcer and Response-Reinforcer Relationships in the Determination of Response Latency

Bruce Edward Hesse

Western Michigan University

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

Part of the Experimental Analysis of Behavior Commons

Recommended Citation

http://scholarworks.wmich.edu/dissertations/2368

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 maira.bundza@wmich.edu.
STIMULUS-REINFORCER AND RESPONSE-REINFORCER RELATIONSHIPS
IN THE DETERMINATION OF RESPONSE LATENCY

by

Bruce Edward Hesse

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
August 1984
Response latency is measured from the onset of a stimulus to the onset of a response and is relevant to both respondent and operant control procedures. Previous research has shown response latency to be a sensitive operant dependent variable but the contribution of respondent influences was not known. The present experiment used pigeons, a two-key procedure and a two component FR schedule to study the respondent (stimulus-reinforcer) contributions to the determination of an ostensibly operant response latency. Stimuli associated with each FR component were displayed on one key (stimulus key) while responding for reinforcement was required on a second key (constant key). Components were separated by a 5 s intertrial interval. When ratios in both components were equal, response latencies to the constant key were equal. When one ratio was either increased or decreased, response latencies to the constant key were longer during the high ratio component and shorter during the low ratio component. Stimulus-key pecking occurred most often to the stimulus associated with the lower ratio.
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.
Hesse, Bruce Edward

STIMULUS-REINFORCER AND RESPONSE-REINFORCER RELATIONSHIPS IN THE DETERMINATION OF RESPONSE LATENCY

Western Michigan University

Ph.D. 1984

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

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 
   [ ]
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. Other ____________________________________________________________

University
Microfilms
International

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
ACKNOWLEDGEMENTS

I would like to acknowledge the support of Western Michigan University in the achievement of my educational goals. Without the financial support through Dr. Dykstra of the Graduate College and Dr. David Lyon, chairman of the Psychology Department, my studies would not have been possible. Dr. Lyon's support of our development of the Laboratory in the Experimental Analysis of Behavior was greatly appreciated.

Dr. Jack Michael has contributed more to this project and my intellectual development than any other individual. I thank him for being my mentor, my friend and showing me the path of a good radical behaviorist.

I would also like to thank the students in our lab for helping with the data collection. Especially Hank Schlinger, who became the motivating force to get things accomplished, keeping me actively discussing the experimental issues and always being the friend who was there in times of need.

Finally, I thank my parents, John and Helen Hesse for their understanding and support both emotional and financial.

To quote the most influential and important man of our field, it was all simply "A MATTER OF CONSEQUENCES". B. F. Skinner (1983)

Bruce Edward Hesse
# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ........................................................... ii
LIST OF FIGURES ............................................................... iv
LIST OF TABLES ............................................................... vi

INTRODUCTION .................................................................. 1

METHOD ........................................................................... 11
  Subjects ......................................................................... 11
  Apparatus ....................................................................... 11
  Procedure ....................................................................... 12

RESULTS ........................................................................... 18
  High to Low Ratio Changes ........................................... 18
  Low to High Ratio Changes ............................................ 25
  Stimulus-key Responding .............................................. 32

DISCUSSION .................................................................... 42
  Constant-key Response Latencies in Terms of
    Behavioral Contrast .................................................... 43
  Analysis of Stimulus-key Responding ............................. 44
  Stimulus-key and Constant-key Influences on
    Response Latency ....................................................... 50
  Conclusion ..................................................................... 52

BIBLIOGRAPHY ................................................................ 54
LIST OF FIGURES

1. Basic state diagram of the procedure.................................13

2. Median response latencies for Subject #571 (narrow key arrangement, high to low ratio changes)..........................19

3. Median response latencies for Subject #2717 (narrow key arrangement, high to low ratio changes)........................20

4. Median response latencies for Subject #2927 (wide key arrangement, high to low ratio changes)..........................23

5. Median response latencies for Subject #1277 (wide key arrangement, high to low ratio changes)..........................24

6. Median response latencies for Subject #4854 (narrow key arrangement, low to high ratio changes)..........................26

7. Median response latencies for Subject #3896 (narrow key arrangement, low to high ratio changes)..........................27

8. Median response latencies for Subject #132 (wide key arrangement, low to high ratio changes).............................30

9. Median response latencies for Subject #9602 (wide key arrangement, low to high ratio changes).............................31

10. Relative frequency of trials with a first response to the stimulus key for Subject #571.................................34

11. Relative frequency of trials with a first response to the stimulus key for Subject #2717.................................35

12. Relative frequency of trials with a first response to the stimulus key for Subject #4854.................................36
13. Relative frequency of trials with a first response
to the stimulus key for Subject #3896.........................37

14. Relative frequency of trials with a first response
to the stimulus key for Subject #2927.........................38

15. Relative frequency of trials with a first response
to the stimulus key for Subject #1277.........................39

16. Relative frequency of trials with a first response
to the stimulus key for Subject #132.........................40

17. Relative frequency of trials with a first response
to the stimulus key for Subject #9602.........................41
LIST OF TABLES

1. Condition changes and number of sessions for each subject...16
INTRODUCTION

Response latency refers to the period of time between the onset of a stimulus and the occurrence of the response controlled by that stimulus. Within the classical conditioning literature response latency has been a frequent dependent variable. When an unconditioned stimulus elicits an unconditioned response, the time between the two is referred to as a response latency. The same is true for the time between the conditioned stimulus and the conditioned response. As with the US-UR relationship, strength of control is inferred from the latency value. Shorter response latencies imply strong control and long response latencies imply weaker control of the response by the stimulus.

Skinner (1938) distinguished two types of behavior in terms of their sources of control and introduced the terms "operant" and "respondent" to refer to each. In his words:

The kind of behavior that is correlated with specific eliciting stimuli may be called respondent and a given correlation a respondent. The term is intended to carry the sense of a relation to a prior event. Such behavior as is not under this kind of control I shall call operant and any specific example an operant. (p. 20-21)

The position of the controlling event is important in his definitions. Respondents are elicited by prior stimuli and operants are not. Skinner goes on to describe the operant as being a function of "posterior events" and shows how the arrangement of these events

1
influences the frequency of occurrence per unit time (rate) of the response.

The importance of prior stimuli to the occurrence and reinforcement of an operant is recognized in the specification of the typical contingency involving a discriminative stimulus. Given the appropriate history, the presentation of a particular stimulus can evoke a particular operant response. As clarified by Michael (1980), the discriminative stimulus "is a stimulus condition in the presence of which some type of response has a shorter latency, greater frequency of occurrence, or greater resistance to response weakening operations than it does in the absence of that stimulus condition" (p. 47).

Prior stimuli are therefore important (in different degrees) to both the respondent and the discriminated operant. Response latency, as an indicator of response strength, is appropriate to both. With the discriminated operant, the time between the onset of the discriminative stimulus and the occurrence of the specified response can be conceptualized as an operant latency. Like the respondent latency, strength of conditioning is inferred from the latency values (short latencies indicating stronger control and long latencies weaker control).

Studies involving discriminated operants and/or stimulus control have not typically used latency as one of their main dependent variables. Rate of response is the usual dependent variable. In multiple and chained schedules, where a number of different response requirements are sequentially arranged with distinctive stimuli for
each different requirement, response rate is still the most common
dependent variable, while choice (as well as response rate) is used
in schedules where the different responses requirements are
simultaneously presented (concurrent schedules).

Skinner (1950), while pointing out the advantages of rate of
response as a basic dependent variable, criticized response latency
as a measure because it "does not vary continuously or in an orderly
fashion" (p. 197). Arnett (1973), using a multiple schedule with VI
components, collected response latency measures as well as rate
measures (local response rate and overall response rate). She was
investigating local behavioral contrast and found that both response
rate measures were more meaningful than latency measures.

On the positive side, Schuster (1959) used response latency as a
dependent variable in a multiple schedule involving fixed ratio
components. Initially both components had equal ratios, then one
ratio was increased. In general, longer response latencies occurred
to the stimulus associated with the higher ratio component. In
addition a type of "latency contrast" was reported. When the ratio
requirement in one component was increased, response latencies in the
unchanged component shortened, (positive contrast) and when the ratio
in one component was reduced, the response latencies in the unchanged
component lengthened (negative contrast). Jenkins (1961) used mean
response latency as a measure of response strength during extinction
as a function of different training conditions. He was interested in
the way intermittent reinforcement influenced responding in
discrimination and nondiscrimination training. The procedure involved
brief stimulus presentations separated by intertrial intervals. The pigeon's first peck turned off the stimulus and produced food, but if no peck occurred within 5 s the stimulus was removed and the intertrial interval began. The results were a shortening of response latencies to the S+ stimulus and a lengthening of response latencies to the S- as a result of discrimination training. There was no effect on response latency to the S+ when the S- was absent (nondiscrimination training).

Response latency measures were extensively used by Stebbins and his colleagues (Stebbins and Lanson, 1961; 1962; Stebbins, 1962; 1966; Stebbins and Reynolds, 1964; Stebbins and Miller, 1964; Moody, Stebbins, and Iglauer, 1971). Their procedure required a preparatory response in the presence of one stimulus (such as the holding down of a lever in the presence of a light) followed by a stimulus change and a second response (release of the lever when a tone was sounded) to receive reinforcement. Of interest was the latency between the second stimulus change and the response which followed. Orderly changes in these response latency values were obtained when reinforcement frequency and quality of reinforcement (percent of sucrose) were manipulated. This "reaction time" procedure involved two time periods, a "warning" period and a "reaction" period. The "warning" period (or "foreperiod") was the interval between the first stimulus and the stimulus which evoked the response. The length of the foreperiod has been shown to have a direct affect on reaction period latencies (Keller and van der Schoot, 1978).
Recently, the sensitivity of response latency to ratio size, reinforcement probability, reinforcement duration, delay to reinforcement and intertrial interval length was studied using a nonreaction time procedure (Hesse, Michael, Whitley, Nuzzo & Sundberg, 1984; Nuzzo, 1984). Their procedure involved a two component, multiple fixed ratio schedule in which components were separated by an intertrial interval (ITI) of various lengths (2 s, 5 s, 10 s, 20 s or 30 s). Pigeons were trained to peck a single key when it was transilluminated by colors. An ITI period always followed reinforcement and preceded stimulus onset and could be thought of as a foreperiod. Pecks during the ITI reset the period timer. After the ITI, one of the discriminative stimuli (randomly arranged) appeared on the key. Completion of a fixed ratio produced reinforcement. The time between the stimulus onset and the first response of the ratio was recorded as the response latency. In general the latencies to the component stimuli differed when reinforcement conditions differed and were similar when reinforcement conditions were the same. Ratio size differences along with delay to reinforcement differences produced the largest and most robust changes in response latencies. Differences in duration of reinforcement and probability of reinforcement delivery for completed ratios produced less clear-cut effects. Effects were seen most dramatically with a 5 s ITI. Usually, the latencies were shorter to those stimuli associated with more favorable reinforcement conditions. The authors concluded that response latency was a
reasonable operant measure of response strength because it varied in an orderly fashion.

The operant interpretation of these results is questionable if the stimulus-reinforcer relationship is carefully examined (instead of focusing only upon the response-reinforcer relationship). Brown and Jenkins (1968) demonstrated that pigeons will peck a localized stimulus predictive of response-independent reinforcement. In their study a key was lighted briefly (3 or 8 seconds) once every minute (on the average) and food was delivered immediately at stimulus offset. After food delivery the key light remained off (the intertrial interval) until the next cycle. Under these conditions the birds would first orient toward, then approach and finally peck the lighted key (even though food was not contingent on this pecking). The pecking was referred to as an example of classical conditioning. The light was the conditioned stimulus (CS), the food was the unconditioned stimulus (US), pecking the food was the unconditioned response (UR) and pecking the light was the conditioned response (CR). The procedure involved a "delayed conditioning" paradigm; light (CS) onset followed by food (US) which elicited the pecking. After several trials the light (CS) began to elicit pecking (CR). The relevant event in this form of conditioning was the arrangement of the CS and US (also referred as the stimulus-reinforcer relationship). Responding produced by this relationship was considered under respondent control.

The nonreaction time procedure used by Nuzzo (1984) and Hesse et. al. (1984) involved a dark key period followed by a stimulus
onset. A completed ratio (or response initiated fixed time) turned off the stimulus and produced reinforcement. The fact that birds pecked the key containing the relevant stimulus was probably a function of both respondent (stimulus-reinforcer) control and operant (response-reinforcer) control since reinforcement contingencies and stimulus changes were on the same key. The response latency could be operant, respondent or both.

A method for identifying sources of control for different responses was introduced by Catania (1971). Responses were "tagged" with a distinctive location. Using pigeons and a two key standard pigeon chamber, a variety of peck sequences between the two keys was reinforced on a variable interval (VI) schedule. By measuring the proportional rate of responding on each key Catania was able to determine the effect of reinforcement (delivered by the final peck in the sequence) on other responses in the sequence. The response rate on the second key increased relative to the position of second key pecks in the reinforced sequence. The closer their position to reinforcement, the higher their relative frequency.

Keller (1974) used a similar two-key procedure to determine the role of stimulus-reinforcer relationships in behavioral contrast. A typical two-component multiple VI schedule arranged reinforcement. The right key was illuminated constantly with three vertical white lines. Responses to this key produced the reinforcement according to the current VI schedule and it was referred to as the "constant key". The left key (or "stimulus key") was illuminated with green during one component and red during the other component. Responses to this
Key had no scheduled effects. The intention was to separate operant from respondent pecks. Respondent pecks were assumed to be directed toward the stimuli differentially paired with reinforcement (stimulus key) while operant pecks were assumed to be directed at whatever produced reinforcement (constant key). In general the birds tended to peck the stimulus-key color associated with reinforcement only when the other component color was associated with extinction. Differential rates also occurred on the constant key.

Further investigations of behavioral contrast have used the two-key procedure (Schwartz, 1975; Schwartz, Hamilton & Silberberg, 1975; Spealman, 1976; Schwartz, 1978; Woodruff, 1979; White & Braunstein, 1979; Williams & Heyneman, 1981). In all studies stimulus-key pecking occurred but with highly variable rates. Each used VI schedules with rate of responding as their dependent variable. Schwartz, Hamilton and Silberberg (1975) found a higher proportion of stimulus-key pecks just after the stimulus change from extinction to VI. There was no similar pattern in response rate to the constant key. Increases in local response rate to the stimulus key during the initial seconds of the VI component were also reported by Schwartz (1978) and by Spealman (1976).

Williams & Heyneman (1981) reduced the amount of stimulus-key responding by imposing a 2 second change-over-delay between pecks to the stimulus key and pecks to the constant key. They argued that some stimulus-key pecking was adventitiously reinforced by food delivery and that a two-key procedure needed a COD to prevent this. They noted that after the COD was introduced, birds continued to
direct pecks toward the key but did not contact it. They theorized that the stimulus-reinforcer relationship continued to elicit pecks but the COD directed these pecks away from the key.

Since response latency is measured from stimulus onset to response onset it is highly likely that single-key latency studies (involving stimulus changes on the response key) are measuring respondent aspects of the situation. The present experiment was designed to study the effects of ratio size on response latency when stimulus-reinforcer and response-reinforcer relationships were separated. Of primary interest was whether differences in latency values could be obtained when the discriminative stimuli were located on a second key. The two-key procedure was easily adapted to this problem. Rather than rate of response as the dependent variable, latency to the constant key and latency to the stimulus key were recorded. Further adaptations were the use of fixed ratios (rather than VI's) in the multiple schedule and an intertrial interval between components. Of secondary interest was the development of stimulus-key responding with FR schedules. The relative number of trials where the first response of the trial was to the stimulus key rather than to the constant key, is relevant to latency measures (since both involve a single response during the initial part of the component). This measure relates to the differential aspects of respondent control and relates to studies involving differential stimuli and response-independent reinforcement. Use of ratio schedules reduced the need for a change-over-delay between stimulus-key responses and constant-key responses. If the pattern of
stimulus-key responding was similar to that reported by others (see Schwartz, 1978), the stimulus-key responses would occur first and be separated from reinforcement by response bursts on the constant key (typical of short ratio schedules) leading to food reinforcement.

Williams and Heyneman (1981) considered the typical two-key procedure to be flawed as a method of assessing operant responding because it is "confounded by changes in the type of behavior that is measured". They argued that when discriminative stimuli are located on a second key, two types of response units exist. One is looking at the stimulus key then pecking the constant key when reinforcement conditions in each component are different and the other is directly pecking the constant key (without looking at the stimulus key) when reinforcement conditions are the same. The components in the typical multiple VI schedule change regularly, with no time when a discriminative stimulus is not present. The typical experimental design begins with equal VIs, changes to unequal VIs then returns to the initial condition of equality. Thus, the comparisons are not simply between different reinforcement conditions but between different basic response units as well. This problem was avoided in the current procedure by placing an intertrial interval between reinforcement components. 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).
METHOD

Subjects

Eight White Carneaux, barren hen pigeons were maintained at a constant weight less than their free feeding weight. For some birds this was 80% (+/- 15 grams) but for others it was as high as 95% of their free feeding weights. The birds received all food in the experimental chambers contingent on responding during the experimental session. Sessions occurred between 9 and 11 am, 7 days a week with 23 hours between feedings. Water and grit were always available in home cages, located in a constantly illuminated room. None of the birds had any prior training relevant to the experimental procedure.

Apparatus

Two different pigeon chambers were used. The chambers were equipped with two translucent response keys 2.5 cm in diameter. Each key could be transilluminated with a variety of stimuli from its own projector (Industrial Electronics Engineers, Inc.). The keys in chamber one (referred to as the wide key box) were set 24 cm above the chamber floor, 16.5 cm apart center to center, in a horizontal row. A 6 cm by 5 cm food hopper aperture was located between and below the two keys, 8.5 cm above the chamber floor and 12 cm from either side wall. A 7.5 W houselight was located in the ceiling of the chamber which measured 29 cm deep and wide and 33 cm high.
Chamber two (referred to as the narrow key box) was larger and had the keys closer together. The chamber measured 38 cm on all sides with the keys located 22.5 cm above the floor and 7.6 cm from center to center. The size and location of the food hopper aperture was the same as in the wide key box along with the location and style of the houselight. A ventilation fan pulled air through the box and provided masking noise. Chamber one had no masking noise nor fan but was isolated in a separate wooden enclosure. A peck with a force greater than .2 N to any key activated the recording and control equipment. A Digital Equipment PDP-8E computer equipped with Super Sked software and interfacing controlled experimental contingencies and was located in a different room.

Procedure

The birds were exposed to a hopper training program for one day. Initially the hopper was raised for 60 seconds once every 80 seconds. When the birds began to eat from the hopper the time was reduced gradually to 4 seconds. The birds were autoshaped to peck the left key (constant key) when it was illuminated with a yellow light. During this training the right key (stimulus key) remained dark.

The initial schedule consisted of a two-component FR3 FR3 multiple schedule (see Figure 1). Each component onset was preceded by a 5 second intertrial interval during which the right keylight (stimulus key) was off, the left keylight (constant key) was yellow and the houselight was on. Responses to either key during this
Figure 1. Basic state diagram of the procedure.
interval reset the 5 second timer thus delaying the component onset. If no responses occurred, the ITI was a fixed 5 s. After the ITI, either red or green in the wide key box or red or blue in the narrow key box appeared on the stimulus key. Three pecks to the constant key would (with a probability of .9) turn off the stimulus key (but leave the constant key yellow), turn on the hopper light and operate the food magazine. On those occasions when reinforcement was not scheduled after completion of the ratio, the stimulus key went off, the houselight and constant key stimulus flashed off for one-half second and the intertrial interval began again. If the bird did not complete the ratio requirement within 30 seconds of stimulus key light onset, the stimulus key light was turned off, the ITI began and a new trial was arranged. All birds were initially exposed to this schedule until their median response latencies across sessions stabilized. Conditions lasted for an average of 15 sessions and until no obvious trends continued in the data. Sessions usually lasted from 30 to 35 minutes each. Initially a session terminated with 64 trials. This was later raised to 100 trials to provide more exposure to the schedule. For three birds the number of trials was lowered to 70 when they began to gain more weight in a session then what was lost in 24 hours.

Individual trial latencies were recorded to both the stimulus key and the constant key. Since the constant-key stimulus was always on, two timers began with the onset of the stimulus key. A response to the stimulus key turned off one timer and a response to the constant key turned off the other timer. Constant-key and stimulus-key
latencies were sorted into separate frequency distribution bins for each session and a median latency for each component was calculated using the usual frequency distribution method for calculating medians.

With short latencies small differences are important, but when latencies are long, differences must be proportionately larger to be meaningful. The interval widths of the bins in the latency frequency distribution reflected this. The distribution began with a very short interval width (.05 seconds). The subsequent interval widths were obtained by multiplying the preceding width by the constant 1.2. This constant was chosen because it provided a medium increase in bin size. Lower numbers required too many bins and higher numbers too quickly provided very wide bins. Each successive bin width was slightly larger than the preceding width. This type of logarithmic distribution permitted the collection of the entire range of latencies using a convenient number of intervals.

The basic design of the experiment was a single-subject, within-session comparison of ratio differences on response latency. Some between-subject as well as between-session comparisons were also possible. Refer to Table 1 for a summary of individual condition changes. Initially a baseline level of response latencies in equal ratio components was taken. Four birds were studied in the wide key box and four were studied in the narrow key box (to detect differences due to width of key separation). Two birds in each box went from equal low ratios (FR 3) to equal medium ratios (FR 10) to equal high ratios (FR15). This allowed a comparison of absolute
Table 1
Experimental Conditions and Number of Sessions for each Subject

<table>
<thead>
<tr>
<th>Subject</th>
<th>Red Ratio</th>
<th>Blue Ratio</th>
<th>Green Ratio</th>
<th>Sessions</th>
<th>Subject</th>
<th>Red Ratio</th>
<th>Green Ratio</th>
<th>Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>571</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>2927</td>
<td>3</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>7</td>
<td></td>
<td></td>
<td>10</td>
<td>10</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>7</td>
<td></td>
<td></td>
<td>15</td>
<td>15</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>16</td>
<td></td>
<td></td>
<td>15</td>
<td>3</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>15</td>
<td></td>
<td></td>
<td>3</td>
<td>15</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>18</td>
<td></td>
<td></td>
<td>15</td>
<td>15</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2717</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>1277</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>7</td>
<td></td>
<td></td>
<td>20</td>
<td>20</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>8</td>
<td></td>
<td></td>
<td>20</td>
<td>5</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
<td>5</td>
<td>20</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>19</td>
<td></td>
<td></td>
<td>20</td>
<td>20</td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>8</td>
<td></td>
<td></td>
<td>Total</td>
<td>76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>114</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4854</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>132</td>
<td>3</td>
<td>3</td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>8</td>
<td></td>
<td></td>
<td>3</td>
<td>6</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>11</td>
<td></td>
<td></td>
<td>3</td>
<td>12</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>16</td>
<td></td>
<td></td>
<td>3</td>
<td>24</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>11</td>
<td></td>
<td></td>
<td>24</td>
<td>3</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>15</td>
<td></td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>15</td>
<td></td>
<td></td>
<td>Total</td>
<td>77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>82</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3896</td>
<td>3</td>
<td>3</td>
<td>8</td>
<td>9602</td>
<td>3</td>
<td>3</td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>7</td>
<td></td>
<td></td>
<td>6</td>
<td>3</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>15</td>
<td></td>
<td></td>
<td>12</td>
<td>3</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>8</td>
<td></td>
<td></td>
<td>24</td>
<td>3</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>14</td>
<td></td>
<td></td>
<td>3</td>
<td>24</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>15</td>
<td></td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>12</td>
<td></td>
<td></td>
<td>Total</td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
latencies at different ratio sizes. When median latencies appeared stable in each color, one ratio was dropped to FR3 (referred to as a high-to-low change). This FR3 FR15 comparison was continued for an average of 15 sessions and then reversed (the FR3 color became the FR15 and the FR15 color became the FR3). This comparison was continued for an average of 15 sessions before both components were made equal again at FR15. The remaining two birds in each box started with FR 3 in each component and the ratio in one component was increased in a step-by-step fashion (FR3 to FR6 to FR12). This method (referred to as the low-to-high change) was intended to determine if response latency was sensitive to steadily increasing differences in ratios. The final step was FR15 in the narrow key box and FR24 in the wide key box (it took a larger difference in ratios to produce an effect when the stimulus and constant keys were further apart). When median latencies looked stable and an average of 15 sessions had passed, the ratios were reversed in each color. The final phase was a return to the baseline condition of equal low ratios (FR3).

Some birds took longer to come under the control of different conditions in the multiple schedule. The variable session numbers per condition reflect these individual differences.
RESULTS

Generally, response latencies to the low ratio stimulus were in the .8 s to 1.75 s range while response latencies to the high ratio stimulus were in the 2 s to 6 s range.

Response latencies to the stimulus key were usually very short (in the .4 to .6 s range). The daily medians showed no orderly relationship to condition changes and were dropped from the data presentation. The average number of signal-key pecks and the proportion of trials in which the first response of the trial was to the stimulus key did show orderly effects. There were both a higher average number of signal-key pecks per trial and a greater proportion of trials with the initial peck to the stimulus associated with the short ratio.

High to Low Ratio Changes

As can be seen in Figures 2 and 3 (the narrow key box) median response latencies lengthened for Bird #571 as the ratios were increased while median response latencies shortened for Bird #2717. When the ratio was lowered from 15 to 3 in one of the components, both latencies for Bird #571 shortened (a type of induction effect) before latencies associated with the FR15 (the unchanged component) lengthened significantly (negative behavioral contrast). The short response latencies for this bird stabilized at a point slightly higher than the FR3 FR3 baseline. The response latencies for Bird
Figure 2. Median response latencies for Subject #571 (narrow key arrangement with high to low changes).
Figure 3. Median response latencies for Subject #2717 (narrow key arrangement, high to low ratio changes).
#2717 were short during the high ratio baseline condition. Therefore, rather than the FR3 component median response latencies getting shorter, the median response latencies in the unchanged FR15 component lengthened (again negative behavioral contrast). When ratio requirements were reversed for each bird, response latencies for #571 reversed quickly (within 3 sessions) while response latencies for #2717 did not. The long latencies for this bird shortened when the ratio was switched from FR15 to FR3 but the latencies in the FR15 component never lengthened. Conditions were returned to equal FR15 ratios for both birds. Latencies for Bird #571 returned to the approximate level of the first FR15 baseline but near equal latencies never stabilized. Positive behavioral contrast occurred during this condition. The latencies in the unchanged FR15 component became shorter when the ratio in the changed component was increased. Latencies for Bird #2717 became quite similar in both components but their absolute values changed very little. The condition changes were repeated to test the reliability of the first results. Again a lengthening of response latencies occurred in the unchanged component when the ratio was shortened in the changed component. This effect was smaller than in the first condition change and 6 sessions were required before the latency difference began to increase. During the reversal, 9 sessions passed before the latency values reversed. This new difference between latencies was small and unstable. A return to baseline conditions (FR15 FR15) produced similar short latencies. With both birds the response
latencies to the short ratio stimulus were less variable than those to the high ratio stimulus.

Figures 4 and 5 display (for the wide key box) a similar set of condition changes as seen in Figures 2 and 3. When ratios were increased for Bird #2927, response latencies lengthened initially but returned to their former values after a few sessions. Thus, the ending point for the FR15 baseline was very near the midpoint of the FR3 baseline. When the ratio in one component was lowered to FR3, both latencies initially shortened (a similar induction effect as seen with Bird #571). After 3 sessions the median latencies in the changed component shortened while the median latencies in the unchanged component lengthened (negative contrast). The response latencies of Bird #1277 did not vary in an orderly manner through a series of comparisons when ratio values were FR15 and FR3 or FR15 and FR1. These data are not presented. What developed during these sessions was a strong tendency to peck the stimulus key when it was red (this explains the high relative frequency of trials in which the first peck was to the red stimulus in the first panel of Figure 13).

The data in Figure 5 start with a baseline period of FR15 FR15 which followed a condition in which the red stimulus was associated with an FR1 and the green stimulus with the FR 15 (during this condition there were no systematic differences between latencies so larger ratios were tried). Baseline ratios were increased to FR20 and median latencies increased in both components. Next the ratio in one component was changed from FR20 to FR5. After 5 sessions the latencies in the unchanged component lengthened (negative contrast).
Figure 4. Median response latencies for Subject #2927 (wide key arrangement, high to low ratio changes).
Figure 5. Median response latencies for Subject #1277 (wide key arrangement, high to low ratio changes).
while the latencies in the changed component first shortened then lengthened to a point above baseline. When ratio requirements were reversed for both birds, the long latencies shortened immediately and by the third session the reversal was accomplished. The difference in latencies for Bird #2927 were large and fairly stable. Latencies to the low ratio stimulus were as short as the final sessions in the previous condition. Latencies for bird #1277 were less stable and showed less of a difference than in the preceding condition. Midway through the reversal condition the latencies to the FR20 stimulus shortened to equal the latencies to the FR5 stimulus. The reason for this is unknown. Body weight changes and equipment failures did not occur, nor were there large increases or decreases in stimulus-key responding. This lasted 4 sessions before a difference in response latencies was regained. The final condition change was a return to baseline conditions of high, equal ratios. Latencies for Bird #2927 eventually settled at values higher than the first baseline but lower than the long latencies in the unequal conditions. Response latencies for Bird #1277 became nearly equal in both components, but varied greatly. There was an initial increase before both latencies declined to the approximate level of the short ratio response latencies in the previous condition.

Low to High Ratio Changes

Figures 6 and 7 display the results of two birds in the narrow key box when equal ratios were low (FR3) and one component ratio was
increased. Median response latencies for Bird #4854 were highly variable during the FR3 baseline. They continued to vary in the FR3 FR6 comparison but were almost always similar. Not until FR6 was

Figure 6. Median response latencies for Subject #4854 (narrow key arrangement, low to high ratio changes).
Figure 7. Median response latencies for Subject #3896 (narrow key arrangement, low to high ratio changes).
increased to FR12 did a consistent response latency difference develop. Throughout the condition the latencies fell but those to the FR 3 fell more rapidly. When the FR12 was changed to FR15, response latencies to that stimulus lengthened significantly and became highly variable. When ratios were reversed the latency values reversed after 5 sessions. A second reversal brought about a response latency reversal in only 3 sessions. During this condition the latencies to the FR3 stimulus were shorter than in previous FR3 components. When conditions were equalized again at the low FR3 baseline level, the long latencies shortened rapidly and eventually equaled the latencies to the other stimulus. Response latencies for Bird #3896 were more puzzling. During the initial FR3 FR3 baseline the latencies were fairly similar. When the ratio in one component was increased to FR6 both latencies became shorter for one session followed by a lengthening of both, with the FR3 component latency lengthening by greater degrees. This trend was reversed by increasing the FR6 to FR12. During this FR12 FR3 comparison the lengthening of FR3 latencies halted while the lengthening of FR12 latencies continued to increase to a point then decrease. A small difference between latency values continued (shorter response latencies to the FR3) as both began to fall. It appeared that the step method of changing FR values did not produce good discriminated responding with this bird. When baseline conditions were resumed (FR3 FR3) the downward trend continued. A dramatic ratio increase (FR3 to FR15) quickly produced differential responding. Initially induction occurred and latencies in both components lengthened.
After 2 sessions the response latencies in the FR3 component shortened rapidly while response latencies in the FR15 component remained long and rather unstable. When ratios were reversed, within 4 sessions latencies also reversed. A return to low equal ratios brought both response latencies together at a point well below the initial FR3 FR3 condition.

Figures 8 and 9 display (for the wide key box) similar condition changes as seen in Figures 6 and 7. The decision as to which stimulus would be associated with the high or low ratios was made according to the bird's responding during baseline conditions. If there was a tendency to respond faster in the presence of a particular color when ratios were equal, that color was chosen for the higher ratio. This method was intended to correct for individual bias and was used for all eight birds in the experiment.

Bird #132 began with highly variable response latencies but variability decreased as the experiment advanced. The bias of shorter latencies to the green stimulus was not overcome until the ratio in that component was increased to FR24 while the other remained at FR3. After 4 sessions the response latencies in green lengthened significantly (initially the latency collection bins went only as high as 4.6 seconds, thus points on the graph above 4.6 seconds have brackets indicating that these values are simply "greater than 4.6") while latencies in the FR3 (red) component remained about the same. It took 7 sessions after ratios were reversed before the response latency values reversed. Differences between latencies were less than in the previous condition. With equal conditions (FR3 FR3)
Figure 8. Median response latencies for Subject #132 (wide key arrangement, low to high ratio changes).
Figure 9. Median response latencies for Subject #9602 (wide key arrangement, low to high ratio changes).
Response latencies in both components shortened and in the end became very similar at a level about .5 seconds below their previous baseline.

Response latencies for Bird #9602 were shorter to the red stimulus when ratios were equal. It wasn't until 13 sessions into the FR24 FR3 comparison that they became more stable with longer latencies to the red (FR24) stimulus. When ratios were reversed, latencies in both components reversed for one session then reversed again for 6 sessions (almost reaching their previous levels) before finally reversing again and remaining apart (FR24 producing long, highly variable response latencies and FR3 producing shorter more stable ones). When ratios were returned to FR3 FR3, response latencies became shorter and similarly variable in both components.

Stimulus-key Responding

Figures 10 through 17 depict the relative frequency of trials in which the first response of the trial was to the stimulus key. The points were calculated by dividing the number of trials in which the first response was to the stimulus key by the total number of trials (with that stimulus) in which a response was made. Figures 10 through 13 are for the narrow key box and Figures 14 through 17 are for the wide key box.

All birds (except #2717) eventually responded to the stimulus key in varying proportions according to the ratios associated with each component. On the average more trials with first pecks to the
stimulus key occurred in the narrow key box. Stimulus-key pecks that were the first peck of the trial developed later in the wide key box and were usually enhanced by a stimulus/ratio reversal. Also in this box, equal ratios (both high and low) produced less trials with first pecks to the stimulus key. The same cannot be said for the narrow key box. Bird #3896 had high proportions of trials with initial stimulus-key pecks throughout most of the conditions. When conditions involved unequal ratios, the proportion of trials with a first peck to the stimulus key was lowered during the high ratio stimulus.

When Figures 10 through 17 are compared to Figures 2 through 9 relations between stimulus-key responding and constant-key latencies can be seen. In conditions with unequal ratios, the stimulus associated with the short ratio drew a higher proportion of initial pecks during a trial then the other stimulus. However, latencies to the constant key were generally shorter in this component than in the component with the long ratio. Stimulus-key pecking took longer to develop in the wide key box and it was less variable. The proportion of trials in which the first peck was to the stimulus key was a dependent variable that varied inversely with median latencies to the constant key.
Figure 10. Relative frequency of trials with a first response to the stimulus key for Subject #571, narrow key arrangement.
Figure 11. Relative frequency of trials with a first response to the stimulus key for Subject #2717, narrow key arrangement.
Figure 12. Relative frequency of trials with a first response to the stimulus key for Subject #4854, narrow key arrangement.
Figure 13. Relative frequency of trials with a first response to the stimulus key for Subject #3896, narrow key arrangement.
Figure 14. Relative frequency of trials with a first response to the stimulus key for Subject #2927, wide key arrangement.
Figure 15. Relative frequency of trials with a first response to the stimulus key for Subject #1277, wide key arrangement.
Figure 16. Relative frequency of trials with a first response to the stimulus key for Subject #132, wide key arrangement.
Figure 17. Relative frequency of trials with a first response to the stimulus key for Subject #9602, wide key arrangement.
DISCUSSION

In general, the results show response latency to be sensitive to operant control. When one response ratio of a two component multiple FR schedule was increased, median response latencies during that component were longer than median response latencies in the shorter ratio component. When component ratios were reversed, response latency values reversed along with the ratios. The two-key procedure attenuated the difference between component median latencies. In general, the short latencies were longer than those reported in the one-key procedure (Hesse, Michael, Whitley, Nuzzo & Sundberg, 1984; Nuzzo, 1984).

Response latencies to the stimulus key were generally very short. Stimulus-key responses were infrequent (on the average less than one per trial). They usually occurred as the first response in the trial.

Those stimuli associated with lower ratio requirements produced more stimulus-key pecks than those associated with higher ratio requirements. The respondent dependent variable (the relative number of trials where the first response of the trial was to the stimulus-key) showed sensitivity to ratio size (or perhaps some temporal aspect directly correlated with ratio size). When ratios were equal there were near equal numbers of first peck trials to both stimulus-key colors. When ratios were unequal there were fewer first peck trials in the high ratio color and more first peck trials in the low ratio color.
Stimulus-key pecking was less in the wide key box. Also, the initial development of differential latencies both after baseline and after condition reversals required more sessions in that box.

Constant-key Response Latencies in Terms of Behavioral Contrast

The majority of experiments using the two-key procedure were designed to study operant and respondent contributions to behavioral contrast. The usual behavioral contrast procedure involves a multiple VI schedule with visual, localized stimuli appearing on the response key. With equal VI components, equal rates of responding occur to each stimulus. When one component is changed to a lower or higher rate of reinforcement, responding in the other, unchanged component also changes but in the opposite direction (contrast). An increase in responding in the unchanged component when the relative rate of reinforcement decreases in the changed component is positive contrast. Negative contrast is a decrease in responding in the unchanged component when the reinforcement rate is increased in the changed component. When reinforcement rates are equal again, responding returns to previous levels. This return to baseline (rather than an additional condition change such as the reversals in the present experiment) is required by some (Schwartz, 1975; Mackintosh, 1974a) to adequately demonstrate contrast. Contrast effects have been heavily researched in the past 20 years (see Williams, 1983 for a review). The present experiment (although not designed to study contrast) displayed multiple schedule component interactions that resemble behavioral contrast. Taking into
consideration the dependent variable (response latency) and the reinforcement schedules (fixed ratios), an analogy can be drawn to the typical contrast experiment. When the ratios were both high and one was subsequently lowered (analogous to equal VIs and one VI being lowered) latencies in the unchanged component increased (analogous to response rates decreasing in the unchanged VI). Mackintosh (1974b) reported similar negative contrast effects with response latency and VI schedules but failed to find positive contrast. Schuster (1959) found both positive and negative contrast with response latency using fixed ratios. The present experiment found negative contrast (Figures 2 through 5, high ratio to low ratio changes) but no positive contrast (Figures 6 through 9, low ratio to high ratio changes). The explanation could be the step-by-step method of increasing ratios rather than the one large step change as used in the high to low changes. This step-by-step method was used to insure continued responding. To better study contrast effects with response latency, a different design (a return to equal conditions after each manipulation and sudden, large ratio changes) would be more revealing.

Analysis of Stimulus-key Responding

Gamzu and Schwartz (1973), using pigeons, multiple response-independent schedules of food delivery and localized visual stimuli, demonstrated that an experimenter-programmed response-reinforcer relationship was not necessary to produce
differential rates of key pecking. When stimuli on the response key "signaled" different schedules of response-independent food presentation, higher rates of key pecking developed to the stimulus associated with higher rates of food delivery. When each component stimulus was associated with equal amounts of food delivery, key pecking was less. They emphasized the differential association of stimuli and food delivery as the important condition.

Response-dependent schedules of food delivery in which discriminative stimuli were located on a key other than the response key (two-key procedure) produced more stimulus-key responding in unequal reinforcement conditions than in equal ones (Schwartz, 1975; Spealman, 1976). When local rate of stimulus-key responding was measured, higher rates were found in the initial portion of the component (Schwartz, Hamilton & Silberberg, 1975; Schwartz, 1978).

The measures of responding in the present experiment analogous to response rate measures used in the above mentioned response-independent and two-key procedures were the average rate of stimulus-key pecking per trial and the relative frequency of trials in which the first peck was to the stimulus key. There was less stimulus-key pecking and fewer first peck trials to those stimuli associated with higher ratio components when alternated with lower ratio components. Thus, stimulus-key pecking with FR schedules followed a similar pattern as in VI schedules, both in number and in location (the stimulus-key pecking was infrequent when compared to the constant-key pecking and most of the stimulus-key pecks occurred as the first peck in a trial).
How can one interpret these similar findings? Given that the two-key procedure separates stimulus-reinforcer relations from response-reinforcer relations, analysis of stimulus-key responding is aided by research involving response-independent food delivery.

Temporal factors relating stimulus periods, food delivery and intertrial interval periods are critical to the development of key pecking on response-independent schedules of food delivery (Balsam & Gibbon, 1981). Brief stimulus illuminations, followed by immediate food presentations, separated by relatively long intertrial intervals quickly produce pecking toward the stimulus. When intertrial interval lengths are shortened, more trials are required to produce pecking (Terrace, Gibbon, Farrell, & Baldock, 1975). A critical factor appears to be the amount of time the animal waits between food presentations. Long waits resulted in fewer trials to the first peck while shorter waits required more trials. At the heart of these findings is the notion that the eliciting effectiveness of the trial stimulus is directly related to the "improvement in the average delay to reinforcement in the signal compared with the average delay overall or in the background" (Gibbon & Balsam, 1981). With long intertrial intervals, stimulus onsets represented a significant reduction in time to food delivery while shorter intertrial intervals produced a less observable reduction.

This delay-reduction analysis is appropriate to stimulus-key pecking in both multiple VI schedules and multiple FR schedules. With VI components, onset of stimuli associated with shorter VIIs represents a greater decrease in time to reinforcement than onset of
stimuli associated with longer VIs or EXT. Likewise, in the multiple FR schedule with a 5 s ITI between components, onset of the stimulus represents a decrease in the delay to reinforcement. In the presence of one stimulus, completion of a FR3 (taking on the average about 1.5 - 2.0 s) produced reinforcement. In the presence of the other stimulus, completion of a FR15 (taking on the average about 5 - 7.5 s) produced reinforcement. From the bird's perspective, onset of reinforcement occurred every 6.5 to 12.5 s depending on which stimulus was present when pecking the constant key. When the short ratio stimulus appeared, reinforcement followed constant-key pecking after about 1.5 to 2.0 s (a significant improvement for the bird who has been waiting the last 5 s in the ITI). However, when the long ratio stimulus appeared, reinforcement followed constant-key pecking after about 5 - 7.5 s (not as much of an improvement as with the short ratio stimulus since reinforcement was still 5 - 7.5 s away). In this case the short ratio stimulus would be a more powerful elicitor of pecking and perhaps the long ratio stimulus functioned more as an inhibitor.

A related hypothesis was offered by Nuzzo, (1984) when explaining differences in response latencies in a single-key procedure where ITI lengths were manipulated. The effect of interest was the attenuation of initial response latency differences (maintained by different ratios or different time delays) when the intertrial interval was lengthened. The explanation considered only the operant relationships in the procedure. Since the discriminative stimuli appeared on the same key as the food producing responses,
stimulus-reinforcer relationships were probably as much a part of the effect as response-reinforcer relationships. The shortening of the high ratio (or longer time delay) response latencies with the longer ITIs could be a result of the increased eliciting effectiveness of the stimulus produced by the increased waiting time during the longer ITIs. This respondent control would compete with the operant control that caused the response latencies to be long in the first place.

Given the context of the present experiment and the two-key procedure, if ITI length were increased and stimulus durations (related to different FR sizes) were held constant, an increase in signal-key pecking to both stimuli would be predicted. This prediction is based on the temporal changes in the situation increasing the average waiting time to food during the experiment without proportionally increasing the waiting time to food during the trial stimulus. This "relative waiting time hypothesis" (Jenkins, Barnes & Barrera, 1981), asserts in this case, that both trial stimuli become more "excitatory" relative to background stimuli and thus produce more stimulus-key pecking.

The two-key procedure uses spatial differences to separate stimulus-reinforcer from response-reinforcer control. Given the importance of temporal parameters in both operant and respondent control, separation by temporal means should be possible. Such a "temporal separation procedure" was reported by Brown, Hemmes, Coleman, Hassin, & Goldhammer (1982) and Marcucella (1981). It involved a single key and a multiple schedule with four components, arranged as two pairs. The first component of each pair was
associated with a different stimulus (usually a red or green keylight). The duration of this component was between 4 and 8 s and responses to the key had no effect (but were counted). With the offset of the colored component came the onset of a white keylight (the same in both pairs). In the presence of this stimulus, key-pecking was reinforced on different interval schedules. The white stimulus duration was 30 s. Manipulations were changes in reinforcement conditions during the second (white) stimulus, signaled by the first (red or green) stimulus. Pecks to red or green were considered the product of the stimulus-reinforcer relationship (similar to the stimulus-key pecks of the two-key procedure) and pecks to white were considered response-reinforcer products (similar to the constant-key pecks). Rate of response to all stimuli (figured separately) was the dependent variable. Of primary concern was the rate of first component responding when delay and probability of reinforcement were varied in Component 2. They found delay to reinforcement to be a powerful determinant of first component responding. Rate of responding in Component 1 varied inversely with delay to reinforcement in Component 2. These results support the temporal differences explanation of differential responding to the stimulus-key in the present experiment.
Stimulus-key and Constant-key Influences on Response Latency

Previous two-key experiments involved placement of the keys between 6.4 cm and 10 cm center to center. The arrangement of the keys in the present experiment were similar to this in the narrow key box but nearly twice as wide in the wide key box. Wide key placement decreased stimulus-key pecking for possibly two reasons. First, to peck the stimulus key then peck the constant key required about a three step shift in body position. The time taken for this shift delayed reinforcement in general and insured a delay between stimulus-key pecking and reinforcement for constant-key pecking. Adventitious reinforcement for stimulus-key pecking was therefore removed (a form of change-over-delay not programmed by the experimenter). Second, many of the birds positioned themselves between the two keys. At stimulus onset they would move quickly to the constant key. In the process, head movements and "air pecks" were directed toward the stimulus key but contact was not made. This form of "sign tracking" is common in auto-shaping experiments (see Hearst & Jenkins, 1974). With narrow key placement these movements are more likely to contact the key since the bird is close to both keys. This is not the case with the wide key placement.

Discriminations took longer to develop and reversals required more sessions in the wide key box. When pecking the constant key, the stimulus key was on but could not be seen easily by the bird. Thus, reinforcement differences were not as contiguous with the discriminative stimuli as with the narrow key placement. In that box
many birds tilted their heads while pecking the constant key, providing a better view of the stimulus key. Offset of the stimulus-key color along with the sound of the food magazine was the immediate consequence of a completed ratio. The constant key never changed. Reinforcement conditions were closer in time to the relevant stimulus in the narrow key box than in the wide key box, thus discriminations developed a little faster.

With a two-key procedure, orientation responses to the stimulus key compete with responses to the constant key. When response latency is used as the dependent variable this competition is especially critical. Stimulus changes which draw the bird away from the response key must contribute to the lengthening of response latencies to that key. The reaction-time procedure was designed to have the opposite effect, to bring the organism as close to the response manipulandum as possible and shorten response latency times. Thus, absolute response latencies from the two procedures would be expected to be quite different. For similar reasons, single-key procedures and two-key procedures would be expected to produce different absolute values of response latency. In the single-key procedure, stimulus-reinforcer relationships draw the bird's pecks to the same key as the response-reinforcer relationships. In the case of the stimulus associated with the lower ratio, short latencies are accomplished with the aid of the "elicitation" function of the stimulus onset. With the other stimulus, this relationship is weaker and contributes less to producing a fast response. This notion is supported by the longer, low ratio response latencies in the current
study as compared to the Hesse et. al (1984) and Nuzzo (1984) single-key procedure. Of critical importance here is the strength of operant control in competition with respondent control. Even when birds oriented toward the stimulus key and sometimes pecked the stimulus associated with the low ratio, they still (on the average) had shorter constant-key response latencies when compared to the constant-key response latencies in the other component. The competing respondent control lessened the difference between operant response latencies but did not eliminate it.

Five out of eight birds had ending baseline response latencies shorter than the initial baseline. Extended training on the multiple FR schedule appears to facilitate faster responding. Improvements in response efficiency are usually brought about by practice with highly repetitive movements. Also, fixed ratio schedules tend to cause upward shifts in rate of responding. The explanation being the direct relationship between the rate of response and rate of reinforcement in such schedules. Since latency is a subcomponent of the usual average response rate measure in multiple schedules (or any schedule with a distinctive stimulus onset) it would be expected to shorten as response rates increase. The present results confirm this expectation.

Conclusion

The results and interpretations of the present study point to the importance of considering all possible controlling relations in a
situation. Response latency can be the product of both respondent and operant variables. Control by the operant characteristics appears to be sufficient to produce reliable differences when ratios are manipulated. Also, when a two-key procedure is used with a multiple schedule involving fixed ratio components, pecking develops to the stimulus key in a similar manner as when variable interval components are used.


Stebbins, W. C., & Miller, J. F. (1964). Reaction time as a
function of stimulus intensity for the monkey. *Journal of the Experimental Analysis of Behavior, 7*, 309-312.


