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**EFFECTS OF CUED INTERTRIAL INTERVALS  
ON RESPONSE LATENCY IN PIGEONS**

by

**Franklin Paul Whitley III**

**A Thesis  
Submitted to the  
Faculty of The Graduate College  
in partial fulfillment of the  
requirements for the  
Degree of Master of Arts  
Department of Psychology**

**Western Michigan University  
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EFFECTS OF CUED INTERTRIAL INTERVALS  
ON RESPONSE LATENCY IN PIGEONS

Franklin Paul Whitley III, M.A.

Western Michigan University, 1986

Six White Carneaux pigeons were exposed to fixed-ratio schedule components in a systematic replication of a study by Michael et al. (1981). Separation between median latencies for the two schedule components was demonstrated consistently, reproducing the general features of that research. In a subsequent manipulation, differential stimulus conditions were introduced into the intertrial intervals preceding onset of schedule components in an effort to enhance the likelihood that differential "waiting behaviors" would develop. Two subjects demonstrated a clear decrease in the magnitude of the latency splits following introduction of the cued ITI condition, while other subjects evidenced a similar but less distinct effect. Those results are discussed in terms of a stimulus change analysis of operant latency and are interpreted with reference to Skinner's (1950) conclusions regarding the role of waiting behaviors in latency measures.

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Franklin Paul Whitley III

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**Western Michigan University, 1986**

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## CHAPTER I

### INTRODUCTION

The latency of a response is the interval of time between a stimulus change and an instance of behavior. As a dependent variable, it is a quantitative description of the temporal relation between a stimulus change and the occurrence of a response evoked by that event. Johnston and Pennypacker (1980) have pointed out that latency measures are derived from and directly related to a fundamental property of behavior, that of temporal locus. Furthermore, latency represents a scientifically valid dependent variable in that the relevant dimension (time) is measured in units which are both absolute and standard. The continuity of the temporal dimension also permits the researcher to utilize as sensitive a unit of measurement as is necessary to detect even slight changes in latency as a function of various experimental operations. Latency would appear to have particular heuristic value in stimulus change research, since this dependent variable is more intimately linked to the controlling functional relation between the stimulus change and the response of interest than are other popular behavioral dependent variables (Michael, unpublished). On the basis of these considerations, response latency would appear to constitute a basic datum for a science of behavior.

Response latency is a relatively common dependent variable in experimental analyses of respondent behavior. Because the respondent

relation is defined in terms of a given response form and the antecedent stimulus change which elicits it, latency measures correspond directly with the two events comprising the functional unit of analysis. The practical scientific value of this dependent variable is evidenced by numerous studies which have demonstrated orderly changes in respondent latency as a function of various independent variables. In general, relatively shorter latencies occur under conditions which strengthen or maintain control by the eliciting stimulus change. Conditions which weaken the controlling relation tend to yield longer response latencies.

In the analysis of operant behavior, latency consists of the time interval between a stimulus change and the discriminated operant response evoked by that event, and it would appear to have considerable value as a direct and generally applicable dependent variable. However, the relative number of studies reporting latency as a primary dependent variable suggests that it has not been as widely accepted as a basic datum as have other indices of operant functional relations, such as rate of responding (e.g., Ferster & Skinner, 1957), interresponse time (e.g., Anger, 1973), resistance to response-weakening operations (e.g., Nevin, 1974), or measures of "choice" (e.g., Reynolds, 1963).

It is plausible that many researchers were influenced in this respect by Skinner's (1972) comments on latency as a dependent variable in operant research. Two objections were raised by Skinner in support of his conclusion that operant latency was unsuitable as a



dependent variable in operant research. The first was that operant behavior may occur "in the absence of what is regarded as a relevant stimulus" (p. 73). Latency measures are thus obviated when the behavioral unit of analysis is defined without reference to controlling antecedent stimulation (i.e., the so-called "free operant"). This criticism apparently was directed at the use of latency-type measures in classic runway studies, in which latency typically was defined as the time interval between the animal's release from a starting box and the completion of a maze or runway. Skinner pointed out that such measures are not latencies in the strict sense, since the opening of the starting box is not only a stimulus change correlated with the availability of reinforcement for maze-running behaviors, but is also a necessary condition for the mere opportunity to engage in such behaviors. Furthermore, considerable discriminative control over the animal's behavior is exerted by stimulation encountered during the course of the run which is therefore neither readily identifiable nor directly controlled by the experimenter. This criticism does not apply, however, in the case of discriminative operant behavior, in which onset of relevant antecedent stimulation is explicitly controlled by the experimental procedure.

Skinner's (1972) second criticism of latency was that "this measure does not vary continuously or in an orderly fashion" (p. 74), and thus is insensitive to the effects of major independent variables which have been shown by other indices to control the operant relation in a systematic fashion. In support of this conclusion, Skinner described results from a series of reaction time studies in which

latencies of a pigeon's discriminated keypecking showed no systematic changes as a function of either deprivation or extinction manipulations. Mean latencies approached a minimum value of approximately 0.3 sec during conditioning and modal latencies were essentially unchanged by satiation or during extinction, although the range of latencies increased under the latter condition. The absence of orderly changes in latency as a function of these two major independent variables led Skinner to suggest that operant latency was primarily a function of the development of effective "waiting behaviors" prior to onset of the discriminative stimulus. Thus, in Skinner's view, latency was only indirectly related to variables controlling the operant response of interest.

This latter criticism must be reexamined, however, in view of a number of studies in which operant latency has been shown to vary systematically as a function of several independent variables. Operant latency has been the primary dependent variable in a thematic line of research conducted by Stebbins and his colleagues. Stebbins and Lanson (1961) incorporated the basic features of human reaction time procedures in studying the latency of a discriminated lever-release response in rats. The primary dependent variable was the latency of the release response following onset of a buzzer. Frequency distributions of latencies showed stable modal latencies averaging approximately 200 msec. The basic procedure was refined in a subsequent study (Stebbins & Lanson, 1962). In that study, the effects of continuous reinforcement (CRF) and intermittent reinforcement on latency were assessed. Median latencies increased when the schedule was

changed from CRF to an intermittent schedule in which 36% of responses were followed by reinforcement. Data from one animal exposed to intermediate schedules of 18% and 9% reinforcement indicated an inverse relation between median latency and frequency of reinforcement, and for all subjects the changes in latency produced by intermittent reinforcement schedules were reversed when CRF was reinstated.

Stebbins (1962) also investigated the effects of varying concentrations of sucrose reinforcement on latency in rats. Both median latency and variability of within-session latencies increased when the concentration of sucrose was reduced from 20% to 0% and from 20% to 5%, with a greater increase in those measures occurring with the 20% to 0% shift. On the basis of those data and the results of the previous study, Stebbins concluded that both amount and frequency of reinforcement influenced latency in a similar manner. Decreases in either of those parameters resulted in reproducible and reversible increases in median latency and in the degree of variability of latencies.

Stebbins and Reynolds (1964) further adapted the basic procedure in an investigation of discrimination training and stimulus control in monkeys. Food-deprived monkeys were exposed to a schedule in which the passage of 30 sec without a lever-pressing response resulted in onset of a red keylight. Pressing the response key subsequently produced (after a variable delay) either a cross or a circle superimposed on the red light. Key releases in the presence of the cross ( $S^+$ ) were followed by food presentation, whereas release responses in the presence of the circle ( $S^-$ ) resulted only in termination of the

stimulus complex. Median latencies of key releases after onset of  $S^+$  were shorter than latencies to  $S^-$ , and frequency distributions of latencies evidenced less variability for  $S^+$  than for  $S^-$ . In a subsequent experiment (Stebbins & Miller, 1964), median latency was employed as the dependent variable in a procedure for deriving stimulus generalization gradients with monkeys. The procedure employed in that investigation was adapted in later studies which generated equal loudness contours in monkeys (see Moody, Stebbins, & Iglauer, 1971; Stebbins, 1966).

A number of studies have reported orderly relations between various independent variable parameters and latency of pigeons' keypeck responses. Ferster and Skinner (1957) found that the duration of the postreinforcement pause (prp) lengthened as the number of responses in fixed-ratio contingencies was increased. (The prp is a form of latency measure, since it is the time interval between offset of the preceding reinforcement event and the first response in the succeeding response sequence.) A similar relation was reported by Felton and Lyon (1966) and by Powell (1968). In both of those studies, response rate failed to change as systematically with ratio requirement as did prp length. The relation between prp duration and ratio requirement was investigated further by Neuringer and Schneider (1968). Pigeons responded under either fixed-ratio (FR) or fixed-interval (FI) schedules for the duration of the experiment. Response-produced blackouts of varying durations were introduced into both schedules to examine the relative contributions of number of responses in the ratio and the delay to reinforcement necessitated by higher ratios.

For the FR subjects, the effect of the blackouts was to increase the time between reinforcements while the response requirement remained constant. Interreinforcement time for the FI birds remained constant as the blackouts reduced responding during the interval. Postreinforcement pauses lengthened with increasing blackout duration only for the FR subjects. The authors concluded that it was the increased interval between reinforcements, and not the number of responses in the ratio, that accounted for the lengthening of prp with increases in ratio size.

Schuster (1959) reported a latency "contrast effect" in pigeons' keypecking as a result of changes in ratio requirements in multiple schedules of food reinforcement. When the ratio requirement in one component of a multiple fixed-ratio (mult FR 20 FR 20) schedule was increased, latencies in the unchanged component decreased. An increase in latencies was observed in the unaltered component when the other component's ratio requirement was reduced. Those results are significant in that the effect on latency was consistent with reports of behavioral contrast in which rate of responding was employed as the dependent variable (e.g., Reynolds, 1961).

Other latency studies employing pigeons as subjects have investigated the relation between antecedent discriminative stimulation and keypecking as a function of various reinforcement parameters. Powell (1969) exposed pigeons to fixed-ratio schedules of grain reinforcement and alternated between 4 sec and 2.5 sec durations of grain access. When completed ratios resulted in 4 sec grain access, the prp

was consistently shorter than when reinforcement duration was 2.5 sec. Differences in prp between the two reinforcement durations were diminished when the ratio requirement was reduced but increased again when higher ratios were reinstated.

The effect of differing probabilities of reinforcement on latency was investigated by Graf, Bullock, and Bitterman (1964, Experiment II). Pigeons responded under a multiple schedule in which responding in one component was followed by reinforcement on 70% of the trials, while only 30% of the other component presentations resulted in reinforcement. When the response requirement was a single peck in both components, no difference in mean log latencies between the two conditions was observed. However, when the response requirement was increased to FR 10 or FR 20, latencies were longer in the 30% reinforcement probability component than in the 70% component. In a subsequent phase of the experiment, Graf et al. demonstrated that lower latencies occurred in the component with the higher probability of reinforcement even when the absolute frequencies of reinforcement in the two components were equal. Crossman (1968) investigated the effect of reinforcement probability by exposing pigeons to alternating FR 10 and FR 100 components. By decreasing the frequency of reinforcement for FR 10, the prp prior to FR 100 responding was reduced while pausing before FR 10 responding lengthened.

A thematic series of studies conducted by Michael et al. (1981) provided further demonstrations of orderly changes in latency of pigeons' keypecking under multiple schedules of food reinforcement.

In those studies, pigeons were exposed to a mult FR FR schedule in which the two reinforcement components differed with respect to either ratio requirement, probability of reinforcement, or duration (amount) of reinforcement. Shorter median latencies consistently occurred in the component having the lower ratio requirement, the greater probability of reinforcement, or the longer duration of reinforcement. Furthermore, the latency contrast effect reported by Schuster (1959) was replicated with all three of those independent variables. Latencies in the less favorable component generally tended to be more variable than did those in the relatively more favorable condition, and decreased when the other component was deleted from the schedule. Separation of median latencies was maintained when the 5 sec inter-trial interval (ITI) was variable as well as fixed in duration. However, increasing the duration of the ITI from 5 sec to 20 sec attenuated existing splits in latencies. Those general results were reversible and replicable both within and across subjects.

The general interpretation of those results is that response latency provides, at least within the procedures and parameters employed in the studies cited, a rather sensitive dependent variable, demonstrating systematically replicable and orderly changes in median latency as a function of three schedule variables. Although those data seemingly contradict Skinner's (1950) conclusion that latency measures do not change in an orderly fashion, his suggestion that operant latency is at least partly a function of effective preliminary (or "waiting") behaviors has not been directly addressed. An analysis in terms

of that interpretation would suggest that the contingencies correlated with a particular discriminative stimulus might exert control over the organism's preparatory behavior during the time period preceding that stimulus change. Effective waiting behaviors during the ITI presumably would permit the organism to respond with shorter latency upon presentation of the discriminative stimulus.

Skinner's reaction time data had suggested that effective waiting behaviors are established relatively early in the course of conditioning and that latencies thus approached a minimum value beyond which they are insensitive to or do not systematically covary with such operations as extinction or satiation manipulations. The implication is that effective waiting behaviors are controlled in an "all-or-none" fashion, but it is possible that those behaviors are themselves functionally related to the same independent variables that control the response of interest. An alternative statement of the waiting behavior interpretation would propose that the effectiveness of the subjects' waiting behavior might be systematically related to schedule variables. More favorable contingencies (involving, for example, a lesser response requirement, greater reinforcement probability, or greater amount of reinforcement) might be expected to control more effective preliminary behaviors during the ITI than would contingencies constituting relatively less favorable conditions.

The possible role of waiting behaviors in the Michael et al. data is not clear. Components in the basic procedure were presented in a randomized sequence, and stimulus conditions in the ITI were



not experimentally differentiated with respect to the upcoming schedule component. Thus, while the differences between schedule components might have sustained differential waiting behaviors, the development of such control was precluded by the manner in which component presentations were sequenced and by the fact that ITI conditions were "nonpredictive" of the upcoming FR contingencies.

The current study was an effort to examine the influence of differential ITI conditions on median latencies. By experimentally introducing distinctly different stimulus conditions into the ITI preceding each of the two reinforcement components, waiting behaviors might become differentiated with respect to the correlated contingencies. A distinctive stimulus change correlated with one of the two schedule components was introduced into the mult FR FR schedule and effects on median latencies were assessed in terms of previous latency values under identical schedule parameters with nondifferential ITI conditions. The first phase of the experiment thus constituted a direct replication of the procedure employed by Michael et al. This phase was followed by manipulations involving "cued" intertrial intervals.

## CHAPTER II

### METHOD

#### Subjects

Six White Carneaux pigeon hens were maintained at  $80\% \pm 15$  g of their free-feeding body weights. Grit and water were continuously available in the home cages, and supplementary feedings were provided immediately following daily experimental sessions as necessary to maintain subjects at their proper running weights.

Birds P1788, P2872, and P5855 previously had served as subjects in an undergraduate laboratory course and had been exposed to reinforcement schedules identical to those constituting the baseline conditions of the present research and to some parametric manipulations of those conditions. The remaining three subjects (P9544, P9957, and P10694) were experimentally naive prior to this study.

#### Apparatus

Each of three operant conditioning chambers was equipped with a three-key Lehigh Valley Electronics pigeon intelligence panel. The center key, 2.5 cm in diameter, was located on the midline of the panel 26 cm above the chamber floor and could be transilluminated by an Industrial Electronics Engineers, Inc., one-plane readout projector mounted behind the key. Pecks on the center key having a force greater than 0.2 N activated recording and control equipment located in an

adjacent room. Two side keys, positioned 6.5 cm on either side of the center key, were not used and remained dark during experimental sessions. A 6 cm x 5 cm opening beneath the center key and 12.5 cm above the chamber floor permitted access to mixed grains when a food hopper was activated. The chamber was illuminated by a 7.5 W houselight located 7 cm above the center key. Each chamber was enclosed in a sound-attenuating compartment with masking noise provided by a ventilation fan located in the upper rear wall of the chamber.

All scheduled experimental events and data recording were controlled by a PDP-8-f computer (Digital Equipment Corporation, Maynard, MA) using SUPERSKED software and interfacing (State Systems, Inc., Kalamazoo, MI).

### Procedure

#### Pretraining

Subjects P1788, P2872, and P5855 had been hand-shaped to peck a lighted center key before serving as subjects in a previous study. P9544, P9957, and P10694 were shaped to peck either a red or green keylight. Following several reinforced pecks, the keylight color was alternated between red and green until pecks readily occurred to both colors. The multiple fixed-ratio (mult FR FR) schedule employed in this study was then introduced.

#### Condition 1: Equivalent Schedule Components

The basic schedule replicated that employed by Michael et al.

and consisted of a multiple schedule in which ratio requirement, probability of reinforcement, and duration of reinforcement availability could be manipulated. Experimental contingencies are diagrammed in Figure 1. At the start of each session, the houselight was illuminated and all keys were dark. If no pecks on the center key occurred for

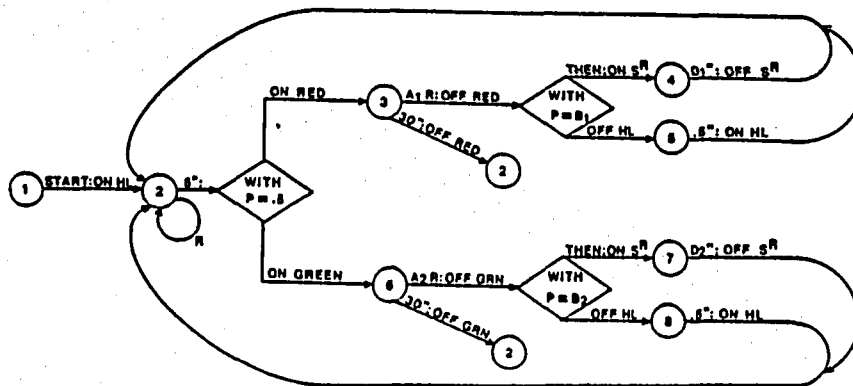


Figure 1. Diagram of Basic (Noncued) Mult FR FR Schedule.

5 sec, the center key was transilluminated either red or green, with the two colors equiprobable. Completion of the ratio requirement for that component resulted in offset of the keylight and either hopper presentation or a 0.5 sec offset of the houselight. Probability of reinforcement and duration of grain access were controlled according to the programmed contingencies in effect for each schedule component. The parameters in each component can be represented according to the format  $FR/p(S^R)/duration$  (for example, mult FR 15/0.9/4 sec). Failure to complete the response requirement within 30 sec following onset of the keylight resulted in darkening of the center key and 0.5 sec

offset of the houselight. Each component was followed by a 5 sec ITI during which the key remained dark. Any response on the center key during the ITI postponed presentation of the subsequent component by 5 sec. Pecks on the two side keys had no scheduled consequences at any time. Sessions were conducted daily, and each session was terminated after presentation of 64 trials or delivery of 50 reinforcements, whichever occurred first.

All subjects were initially exposed to a mult FR 3 FR 3 schedule with reinforcement probability of 0.9 and 4 sec grain access in both components (mult FR 3/0.9/4 sec FR 3/0.9/4 sec). Ratio requirements in both red and green components then were increased simultaneously from FR 3 to FR 15 (mult FR 15/0.9/4 sec FR 15/0.9/4 sec). The purpose of this phase of the study was to assess median latencies during equivalent component contingencies.

#### Condition 2: Differential Noncued Schedule Components

In this phase each bird was exposed to a schedule in which the two reinforcement components differed with respect to either ratio requirement, probability of reinforcement, or duration of reinforcement. Differential contingencies for birds P1788 and P9544 were duration based. Reinforcement duration was increased to 6 sec in one component and reduced to 2 sec in the other condition (mult FR 15/0.9/6 sec FR 15/0.9/2 sec). Different ratio requirements were in effect for P2872 and P9957. The fixed-ratio was decreased to FR 3 in one component and maintained at FR 15 in the other (mult FR 3/0.9/4 sec FR 15/0.9/4 sec). Subjects P5855 and P10694 were exposed to a

schedule involving a probability-based difference between the two components. Reinforcement probability was reduced from 0.9 to 0.3 in one of the components, then increased to 0.5 (mult FR 15/0.9/4 sec FR 15/0.5/4 sec). This latter change permitted a reduction in the supplementary feedings required to maintain these two subjects at their proper running weights.

For reasons to be discussed in the Results section, the experimental history of bird P10694 in Condition 2 differed from that of the other subjects. Following the schedule manipulations previously described for this subject, ratio requirements in both components were reduced to FR 5, followed by an increase to FR 15 in the lower-probability component and an increment from 0.9 to 1.0 reinforcement probability in the other condition. Thus, differential contingencies for P10694 for the remainder of the study were both ratio- and probability-based (mult FR 3/1.0/4 sec FR 15/0.5/4 sec).

The correlation of keylight color with schedule contingencies for each bird was based on the subject's data from Condition 1. Michael et al. (1981) found that shorter median latencies occurred in the more favorable component (i.e., the component involving the lower ratio requirement, the greater probability of reinforcement, or the longer duration of reinforcement). For each subject in the current study, if latencies in Condition 1 were consistently longer in the presence of either red or green, then that color was correlated with the more favorable contingency in Condition 2. Birds P2872 and P9957 evidenced markedly longer latencies in the presence of the red keylight in the

previous condition, and thus red was correlated with the lower ratio requirement in Condition 2. Slightly longer latencies occurred in the red component for birds P5855 and P10694 under equivalent schedule contingencies. For these subjects the red keylight was correlated with the greater probability of reinforcement. No consistent differences between latencies in the two components were observed for birds P1788 and P9544 in Condition 1. The longer reinforcement duration was correlated with red for P1788 and with green for P9544.

### Condition 3: Differential Schedule Components with Cued ITIs

During the first two conditions of the study, red and green components were preceded by identical ITI stimuli in the experimental chamber. The response keys were dark and constant houselight illumination was provided. As shown in Figure 2, a cued ITI feature was

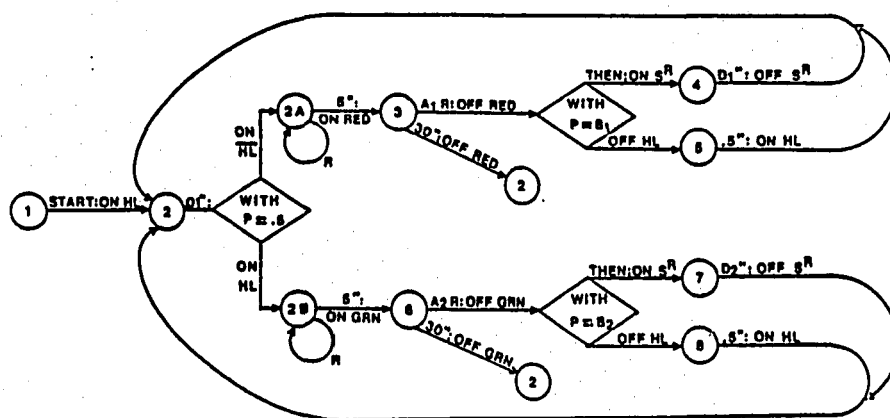


Figure 2. Diagram of Cued ITI Mult FR FR Schedule.

added to the existing mult FR FR procedure. As in the preceding conditions, red and green components were presented in a randomized sequence. However, in Condition 3, the houselight flickered off and on at the rate of approximately twice per second during all ITIs preceding one of the two components. Chamber illumination remained steady during ITIs preceding the other component. Thus houselight illumination (flickering or constant) in the cued ITI procedure was reliably correlated with the subsequent stimulus change and component contingencies.

This form of cuing the ITIs was based on two considerations. Observations of subjects in the first two conditions of the study indicated that some birds would move about the chamber or look away from the darkened key during the ITI. Basing the differentiation of ITI conditions on houselight illumination appeared to increase the likelihood that subjects would be affected by this form of cuing regardless of body position or head orientation. In addition, localization of a distinctive visual stimulus on the response key prior to onset of the discriminative stimulus was avoided in an effort to reduce the possibility that autoshaped keypecks (Brown & Jenkins, 1968) might develop and summate with previously developed ratio performances. The addition of such pecks might be especially likely to affect response latency measures in a manner which would tend to obscure possibly subtle effects of cuing on existing performances.

For birds P9544, P2872, and P9957 the flickering houselight preceded presentations of the more favorable component. For the remain-



ing subjects, the relatively less favorable component was preceded by that ITI stimulus condition.

#### Condition 4: Differential Schedule Components with Noncued Reversal

Differential cuing of ITIs was eliminated for five of the subjects by reintroducing the noncued procedure employed in Condition 2. For bird P9957, noncued conditions in this phase of the study involved flickering houselight illumination during ITIs preceding both red and green component presentations. The stimulus change introduced as a cue in Condition 3 was therefore retained in the noncued reversal for this subject, although it was no longer differentially correlated with the upcoming schedule component.

This alternative noncued procedure also was employed with bird P2872. Following exposure to the original noncued schedule conditions, this subject was exposed again to the cued ITI procedure. The noncued procedure described for P9957 was then presented, followed by a return to the original noncued procedure in which houselight flicker was completely eliminated.

#### Data Analysis

Computer-recorded session data included the response latency for each component presentation. A frequency distribution of latencies in each of the two components was generated for each session and provided the basis for deriving within-session median latencies for each component. The temporal intervals defining that distribution are

shown in Table 1. Latencies of less than 0.25 sec comprised the first bin, and the next interval was assigned a range of 0.05 sec. The remainder of the distribution was generated by successively multiplying each bin's duration by 1.2 to yield the duration of the succeeding interval.

Median latencies in red and green components were plotted across sessions for each bird on a semilogarithmic chart (Schmid & Schmid, 1979). Logarithmic scaling portrays relative changes in the dependent variable more clearly than does an arithmetic scale. Semilogarithmic plotting is thus especially well suited for the current application, since even slight absolute changes in latencies of brief duration would be of interest.

Table 1

## Interval Values for Latency Frequency Distributions

Interval (sec)	Duration (sec)
<.25	0.24
0.25-0.29	0.05
0.30-0.35	0.06
0.36-0.42	0.07
0.43-0.51	0.09
0.52-0.61	0.10
0.62-0.73	0.12
0.74-0.88	0.15
0.89-1.06	0.18
1.07-1.27	0.21
1.28-1.53	0.26
1.54-1.84	0.31
1.85-2.21	0.37
2.22-2.66	0.45
2.67-3.19	0.53
3.20-3.83	0.64
3.84-4.60	0.77
>4.60	----

## CHAPTER III

### RESULTS

#### Equivalent Schedule Components

When the two components of the multiple schedule were equivalent in terms of ratio requirement, probability of reinforcement, and duration of reinforcement access, median latencies in those components were relatively undifferentiated. Latencies under those schedule conditions are displayed for each subject in Figures 3 through 8.

When the ratio requirement in both components was FR 3, five of six subjects evidenced no consistent splits between red and green latencies and within-session differences between the two values were generally less than 0.1 sec. Subject P9544 (see Figure 4) responded with consistently shorter median latency in the red component, although the magnitude of that difference decreased across the latter sessions of Condition 1.

Simultaneously increasing the response requirement to FR 15 in both components produced an increase in latencies within the first few sessions of those schedule conditions. Median latencies remained undifferentiated for four subjects, although separations in red and green latencies occur at points in the records of all six birds. Subjects P9957 and P10694 (Figures 6 and 8) responded with shorter latencies in the green component in the latter sessions of this condition.

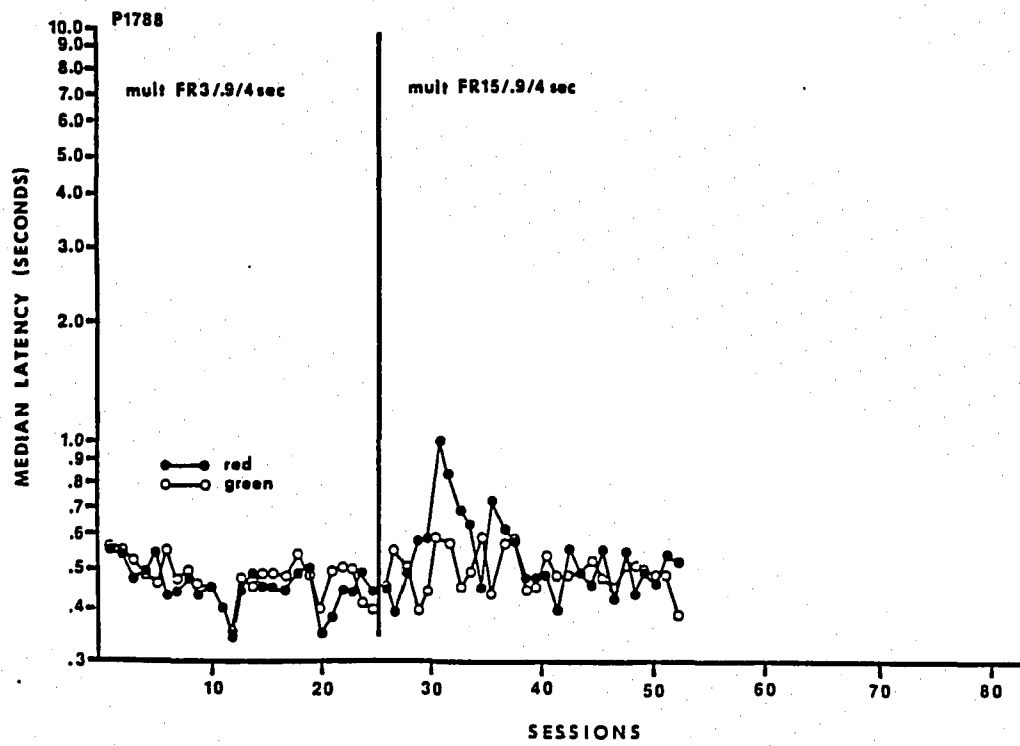


Figure 3. Median Latencies for P1788 in Condition 1 (Equivalent Schedule Components).

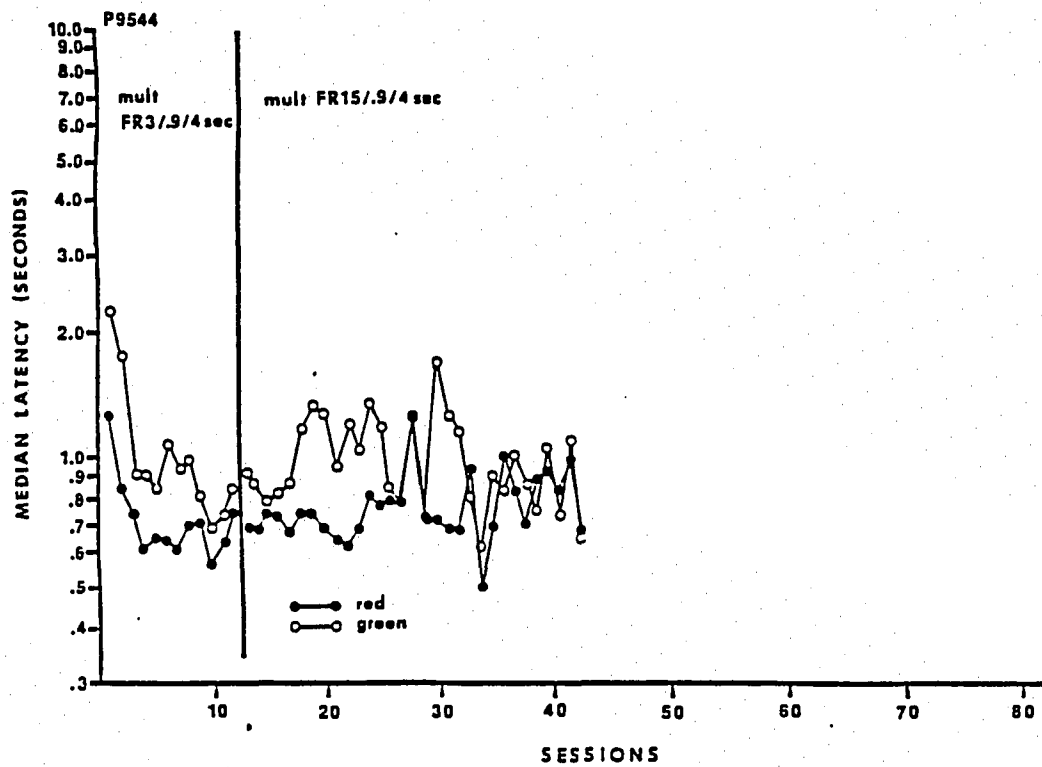


Figure 4. Median Latencies for P9544 in Condition 1 (Equivalent Schedule Components).

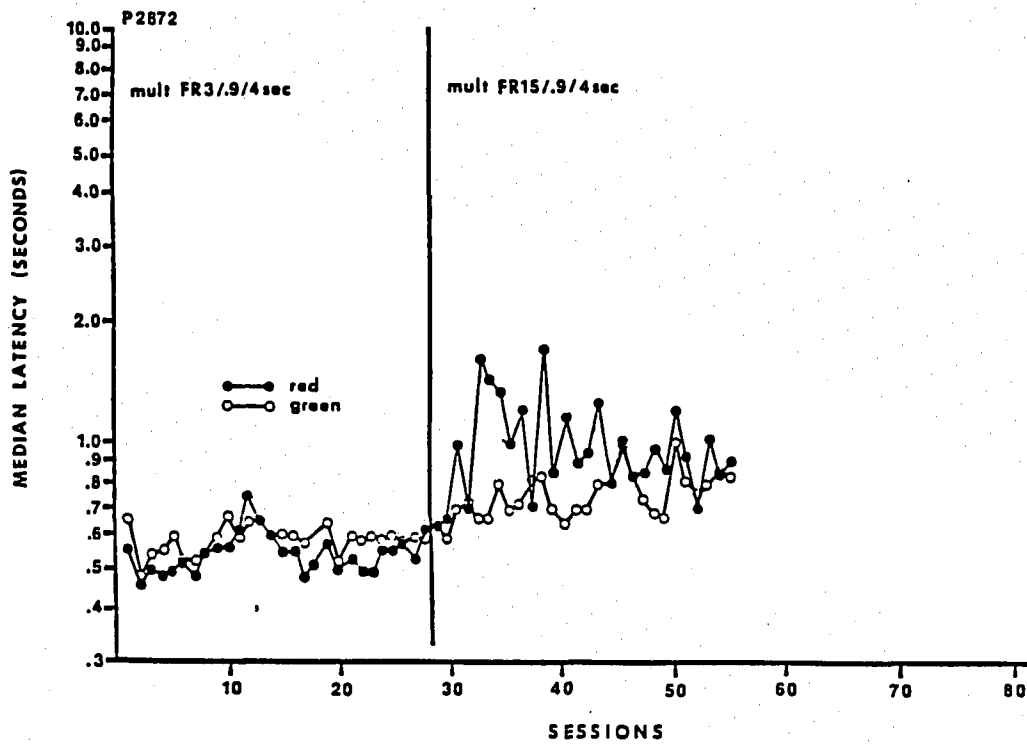


Figure 5. Median Latencies for P2872 in Condition 1 (Equivalent Schedule Components).

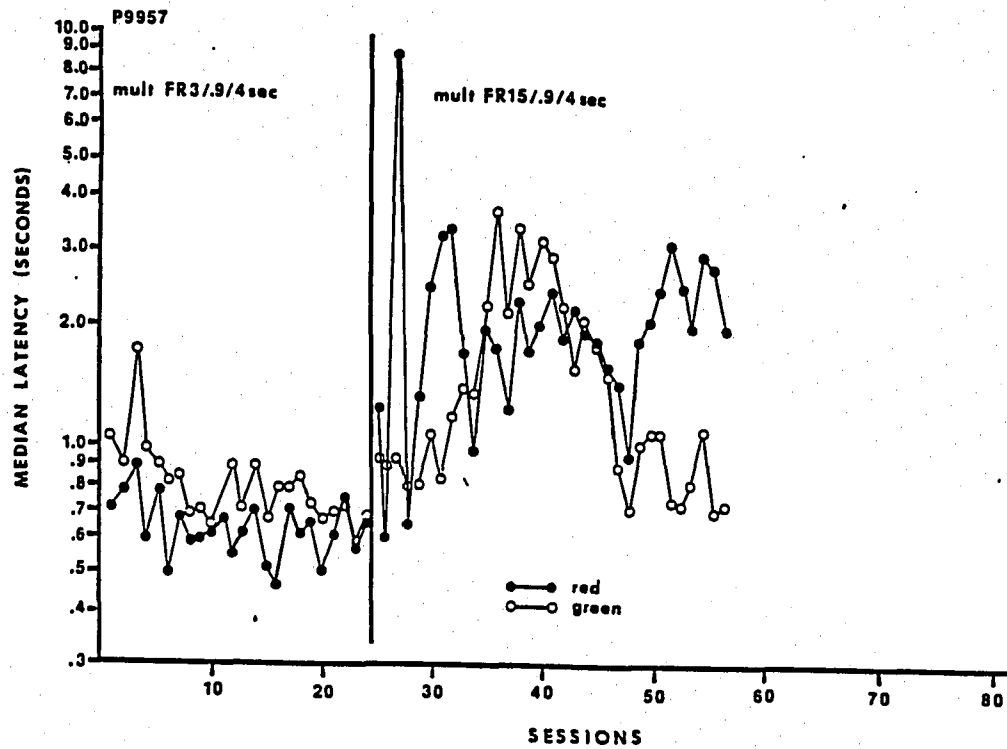


Figure 6. Median Latencies for P9957 in Condition 1 (Equivalent Schedule Components).



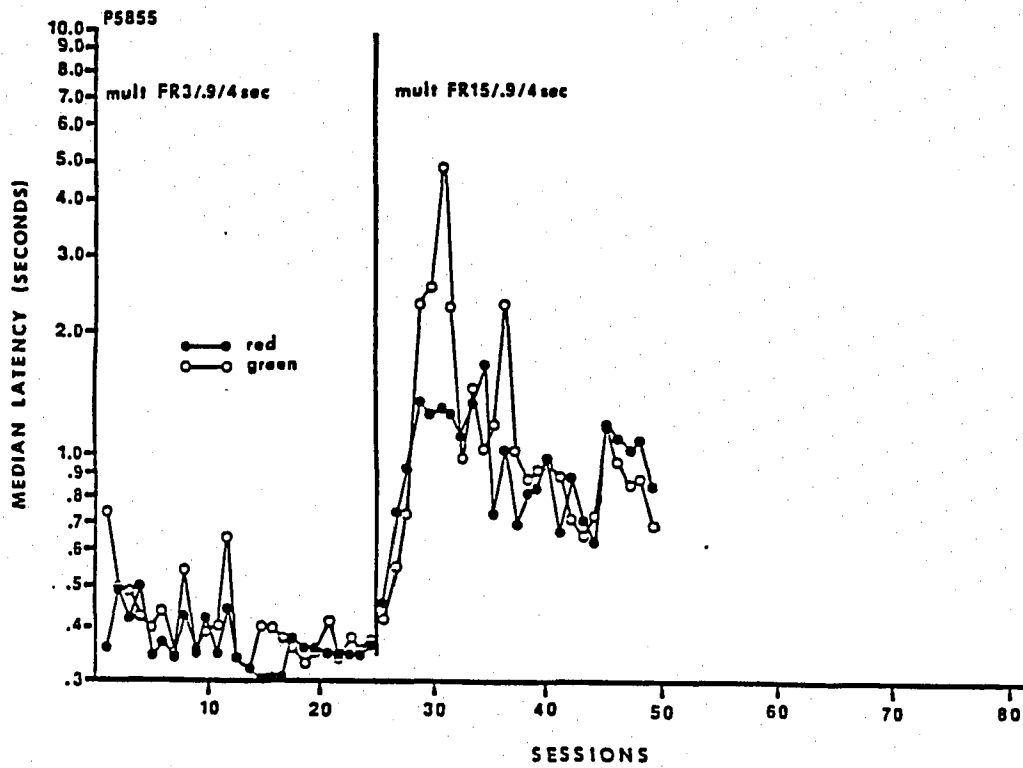


Figure 7. Median Latencies for P5855 in Condition 1 (Equivalent Schedule Components).

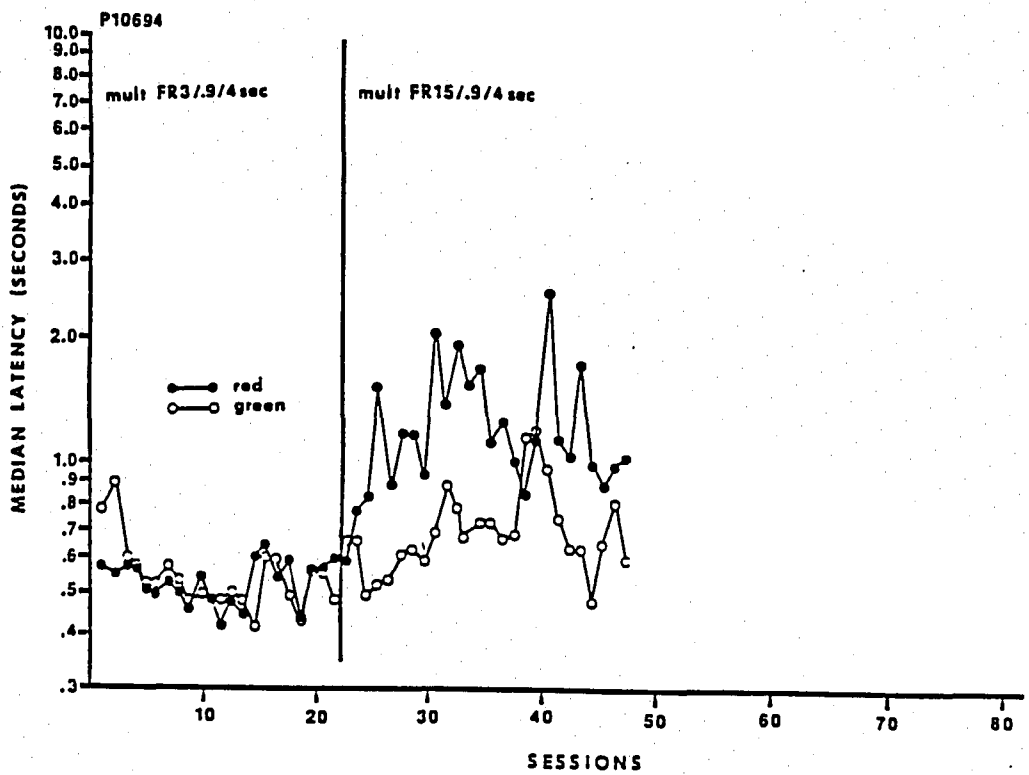


Figure 8. Median Latencies for P10694 in Condition 1 (Equivalent Schedule Components).

### Differential Schedule Components

Introducing differential contingencies into the multiple schedule in Condition 2 produced clear separations between red and green median latencies. Shorter latencies occurred in the component with the lower ratio requirement, the higher probability of reinforcement, or the longer duration of reinforcement (i.e., the more favorable schedule).

Subjects P1788 and P9544 were exposed to schedules differing in duration of reinforcement. P1788 (see Figure 9) exhibited a separation

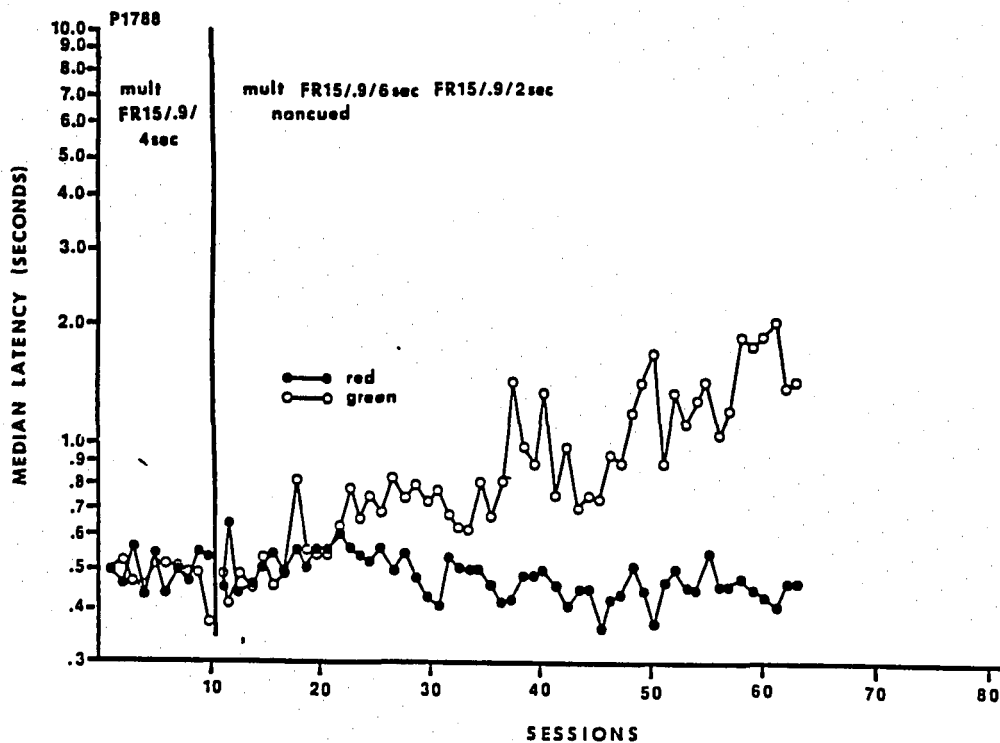


Figure 9. Median Latencies for P1788 for Last 10 Sessions of Condition 1 and for Condition 2 (Differential Noncued Schedule Components: Red = FR 15/0.9/6 sec, Green = FR 15/0.9/2 sec).

between latencies following several sessions in this condition. Latencies increased in the green component (correlated with the shorter duration of reinforcement) and gradually decreased in the more favorable component as the split developed. The duration-based split in latencies for P9544 (see Figure 10) emerged in the first sessions of

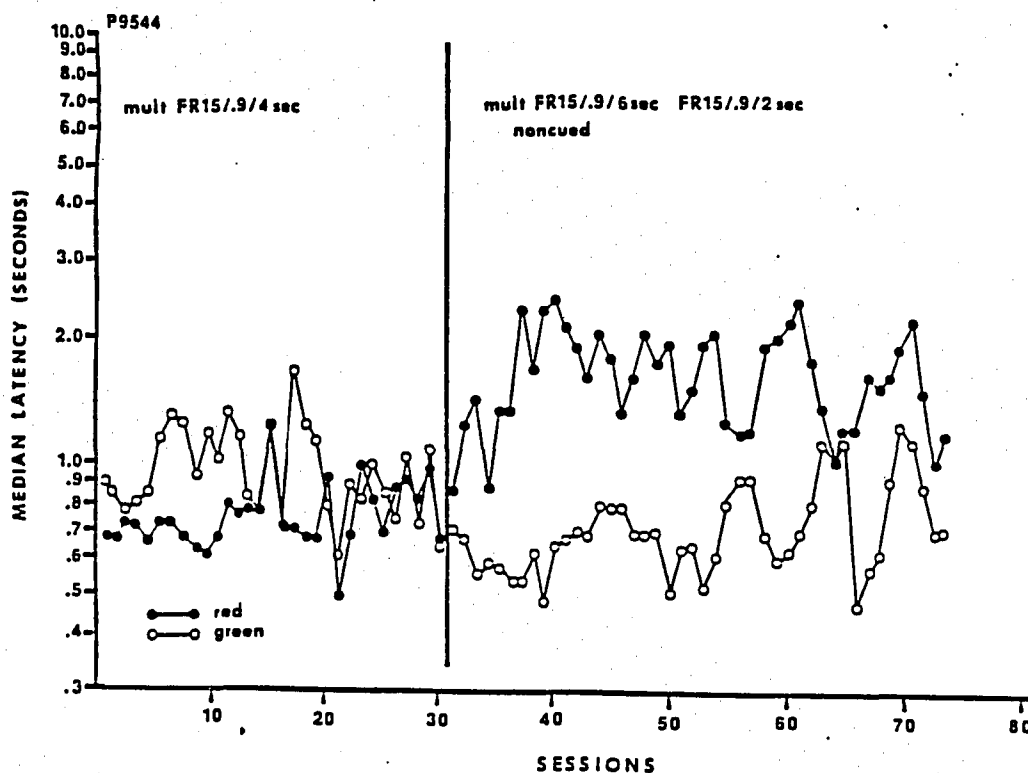


Figure 10. Median Latencies for P9544 for Last 10 Sessions of Condition 1 and for Condition 2 (Differential Noncued Schedule Components: Red = FR 15/0.9/2 sec, Green = FR 15/0.9/6 sec).

Condition 2. Median latencies in the red (2 sec reinforcement) component increased while latencies in green decreased.

Ratio-based split conditions for P2872 and P9957 were introduced in Condition 2 by decreasing the response requirement in one component from FR 15 to FR 3. Those data are presented in Figures 11 and 12. Both subjects exhibited an immediate and sizable decrease in latencies under the FR 3 condition, accompanied by a sharp increase in the unchanged FR 15 component. This latter effect reproduced the apparent contrast-type phenomenon reported by Michael et al. (1981) and by Schuster (1959).

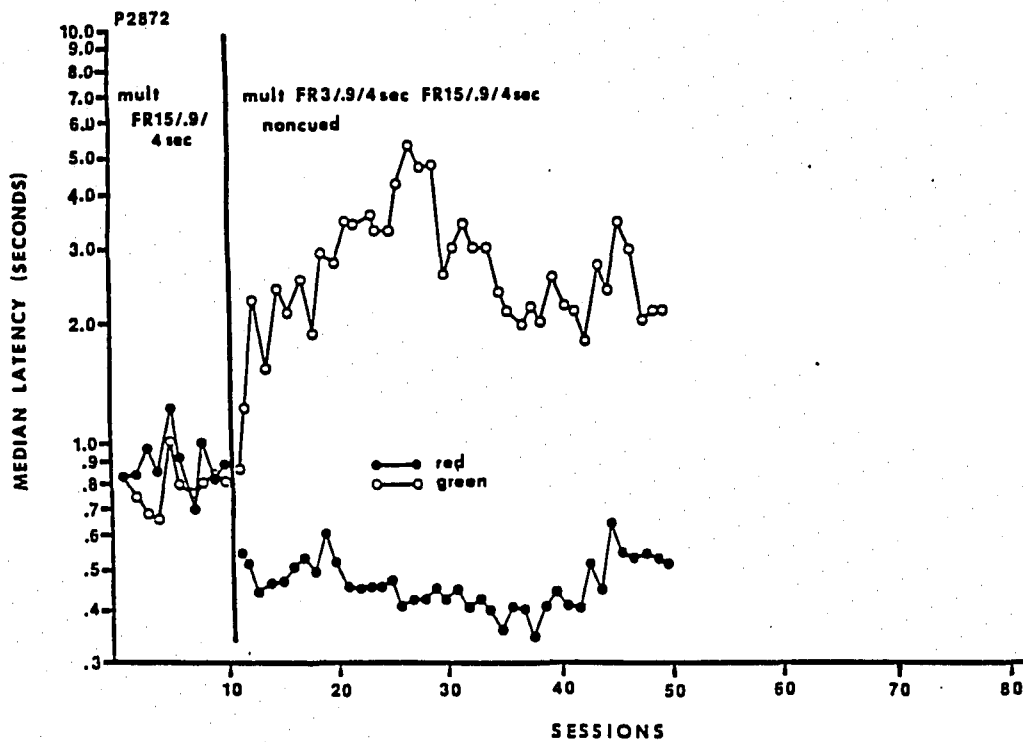


Figure 11. Median Latencies for P2872 for Last 10 Sessions of Condition 1 and for Condition 2 (Differential Noncued Schedule Components: Red = FR 3/0.9/4 sec, Green = FR 15/0.9/4 sec).

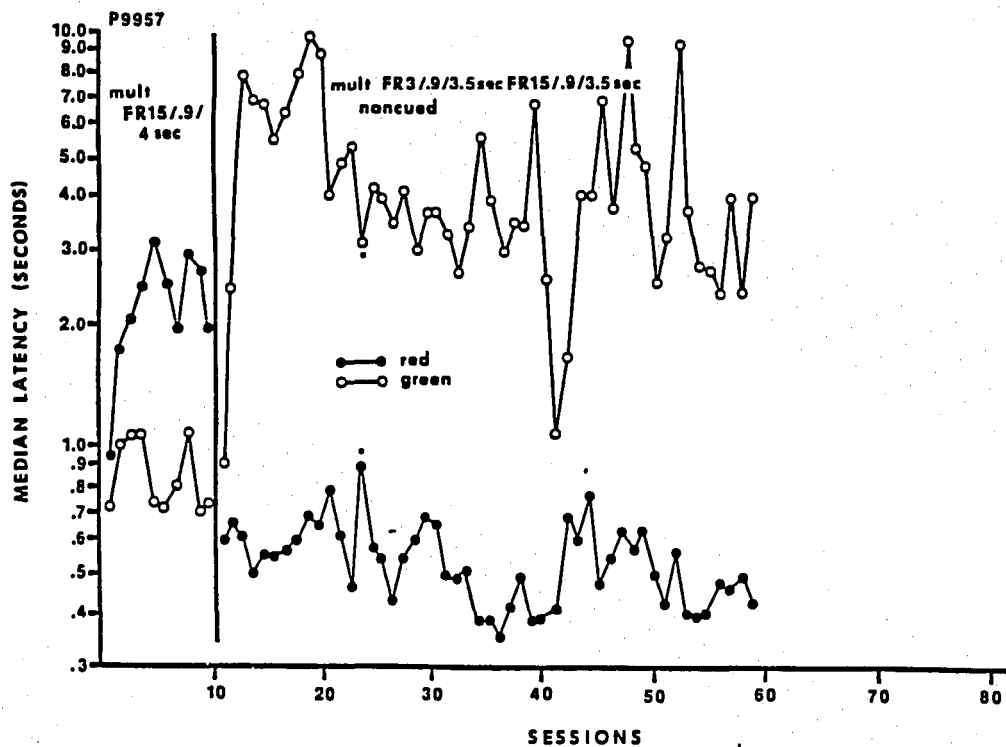


Figure 12. Median Latencies for P9957 for Last 10 Sessions of Condition 1 and for Condition 2 (Differential Noncued Schedule Components: Red = FR 3/0.9/3.5 sec, Green = FR 15/0.9/3.5 sec).

Probability-based splits in red and green components were exhibited by subjects P5855 (see Figure 13) and P10694 (Figure 14). When the probability of reinforcement in one component was reduced from 0.9 to 0.3, latencies in that component lengthened while those in the constant schedule condition decreased. The effect on latencies in the unchanged probability component constitutes a contrast-type phenomenon similar to that demonstrated by subjects exposed to ratio-based split conditions.

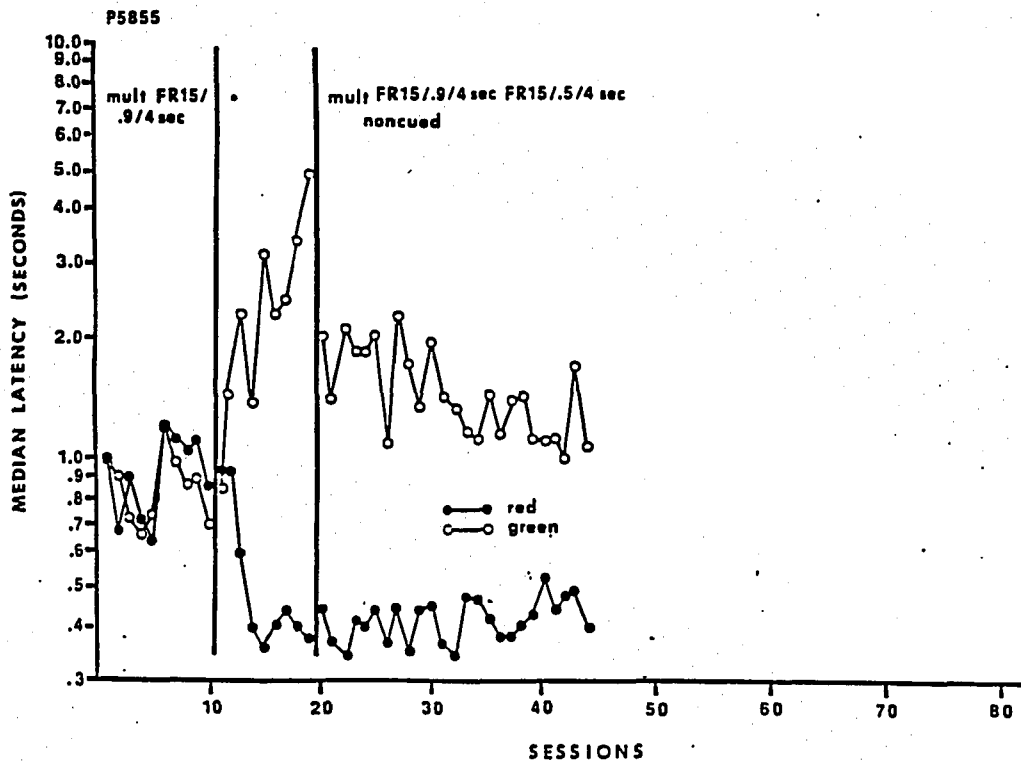


Figure 13. Median Latencies for P5855 for Last 10 Sessions of Condition 1 and for Condition 2 (Differential Noncued Schedule Components: Red = FR 15/0.9/4 sec, Green = FR 15/0.5/4 sec. The \* denotes nine sessions in which reinforcement probability in green was 0.3).

The reinforcement probability in the less favorable component was increased from 0.3 to 0.5 for P5855 after nine sessions and for P10694 after seven sessions. As shown in Figure 13, latencies in that component decreased as a result of this manipulation for P5855 and a clear separation between red and green latencies was maintained for the remainder of Condition 2. The probability-based split for P10694 deteriorated under those schedule parameters, however, and a subsequent reduction from FR 15 to FR 5 in both components failed to

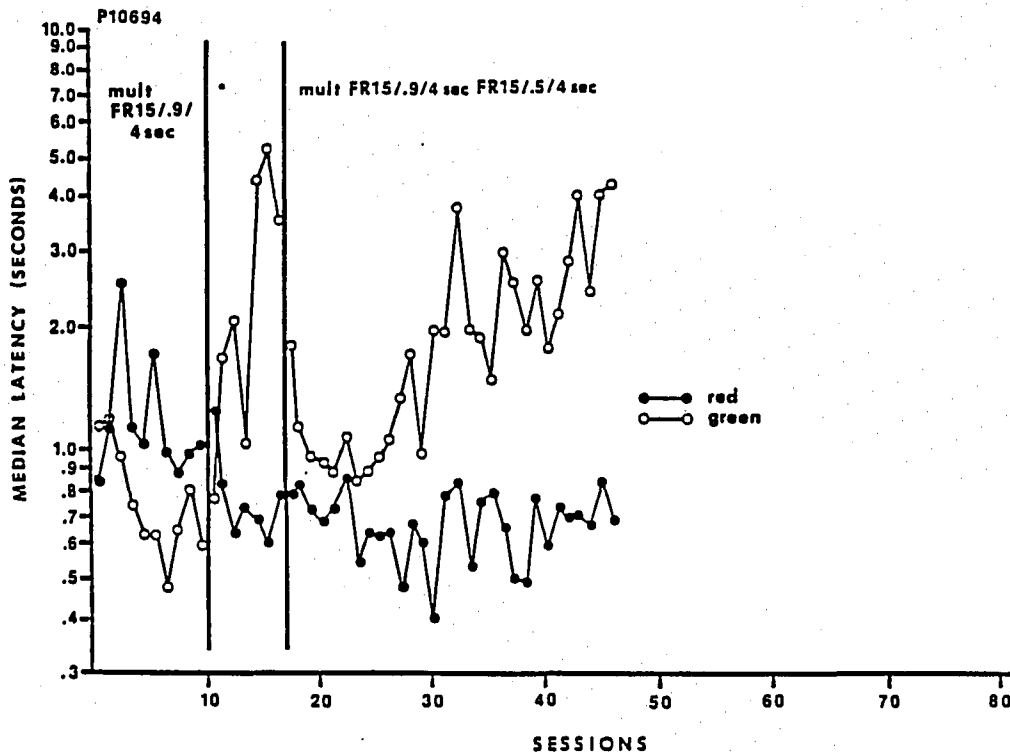


Figure 14. Median Latencies for P10694 for Last 10 Sessions of Condition 1 and for First Phase of Condition 2 (Differential Noncued Schedule Components: Red = FR 15/0.9/4 sec, Green = FR 15/0.5/4 sec. The \* denotes seven sessions in which reinforcement probability in green was 0.3).

maintain a consistent probability-based separation between red and green latencies for this subject (see Figure 15). A sizable split in latencies was produced, however, when the two components differed in both ratio requirement and reinforcement probability. That schedule (mult FR 3/1.0/4 sec FR 15/0.5/4 sec) remained in effect for P10694 for the remainder of the study.



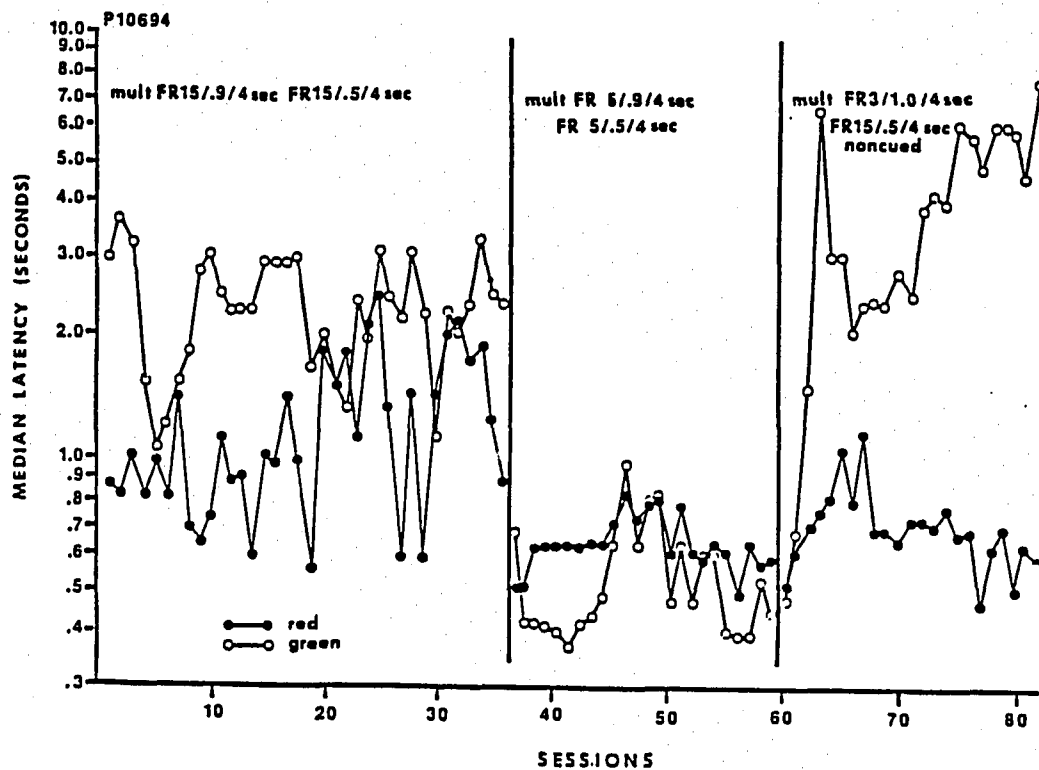


Figure 15. Median Latencies for P10694 for Second Phase of Condition 2 (Differential Noncued Schedule Components: 1) Red = FR 15/0.9/4 sec, Green = FR 15/0.5/4 sec; 2) Red = FR 5/0.9/4 sec, Green = FR 5/0.5/4 sec; 3) Red = FR 3/1.0/4 sec, Green = FR 15/0.5/4 sec).

Condition 2 resulted in consistent separations between red and green latencies for all subjects, with shorter latencies occurring in the relatively more favorable reinforcement component. Those splits in latency constituted the baseline performances for assessing the effects of cued ITIs in Condition 3.

### Cued Intertrial Intervals

Condition 3 involved the addition of a cued ITI procedure to the mult FR FR schedule in effect for each subject in Condition 2. Chamber illumination (constant or flickering houselight) during each ITI was correlated with the upcoming schedule component (red or green).

The general effect of the cued ITI condition was a reduction in the magnitude of latency splits relative to the size of the splits generated under noncued schedule conditions. With four subjects (P1788, P2872, P9957, and P10694) this reduction involved a decrease in median latencies for the less favorable component. Splits were diminished with P9544 and P5855 by an increase in latencies for the more favorable component as well.

Introduction of the cued ITI procedure for P1788 (see Figure 16) resulted in a reversal in the gradual upward trend in green latencies across the latter sessions of Condition 2 and an overall decrease in those latencies relative to the noncued condition. Latencies in the more favorable component remained relatively stable and appeared unaffected by the cued procedure. When cued ITIs were withdrawn in a reversal to noncued schedule conditions, latencies in the green component increased and a latency split comparable in magnitude to that in the earlier exposure to noncued conditions was maintained.

The duration-based split for P9544 (Figure 17) was essentially lost under cued ITI conditions. Latencies in the more favorable (green) component lengthened while those in the other component de-

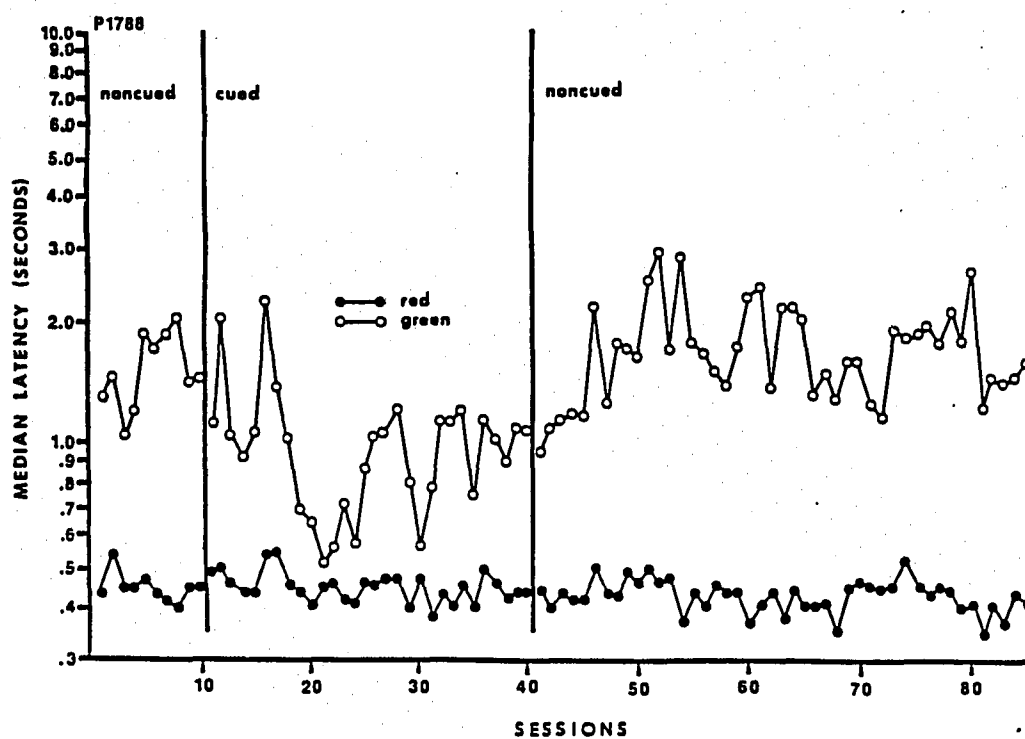


Figure 16. Median Latencies for P1788 for Last 10 Sessions of Condition 2 (Noncued Schedule Components), for Condition 3 (Cued Schedule Components), and for Condition 4 (Noncued Reversal). (Red = FR 15/0.9/6 sec, Green = FR 15/0.9/2 sec).

creased for several sessions but subsequently increased, demonstrating a greater range of variability than in the noncued condition. When the noncued reversal was implemented, latencies in the more favorable component decreased and those in the other component increased to values greater than in this bird's previous exposure to noncued conditions (see Figure 18).

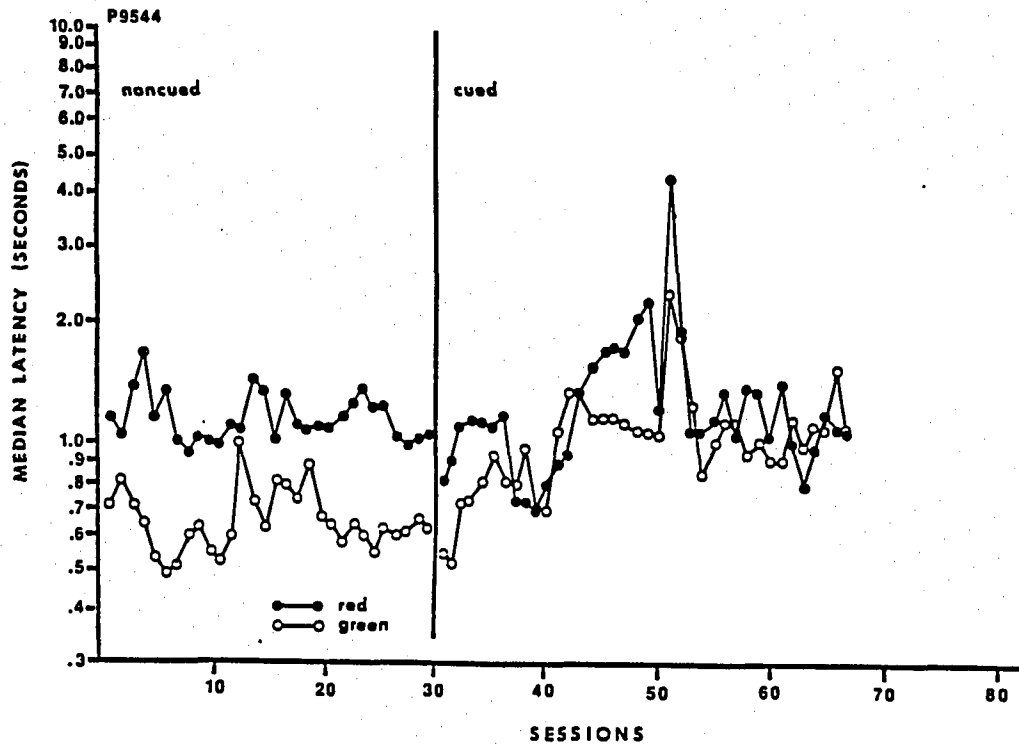


Figure 17. Median Latencies for P9544 for Last 30 Sessions of Condition 2 (Noncued Schedule Components) and for Condition 3 (Cued Schedule Components). (Red = FR 15/0.9/2 sec, Green = FR 15/0.9/6 sec).

The ratio-based latency split for P2872 was reduced within several sessions of exposure to the cued ITI condition. As shown in Figure 19, latencies in the green (less favorable) component decreased to values less than the range of green latencies in the noncued condition. A very slight increase occurred in latencies for the more favorable red component. Both of those effects were reversed when the cued feature of the procedure was withdrawn in Condition 4. P2872 was exposed to the cued procedure a second time (see Figure 20), and

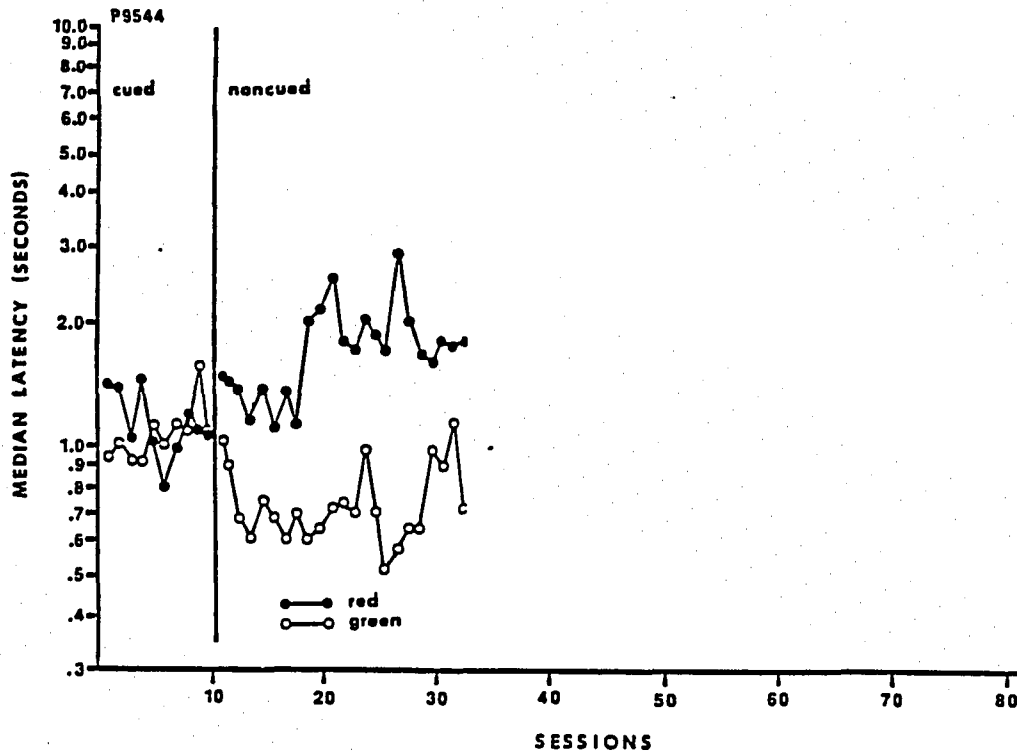


Figure 18. Median Latencies for P9544 for Last 10 Sessions of Condition 3 (Cued Schedule Components) and for Condition 4 (Noncued Reversal). (Red = FR 15/0.9/2 sec, Green = FR 15/0.9/6 sec).

again the ratio-based split with this subject was diminished by a decrease in the less favorable component's latencies. When differential ITI stimulus conditions were removed by introducing flickering house-light illumination into all ITIs, latencies in green increased. Although the magnitude of the split in this condition was comparable to the split under the earlier noncued conditions, a further increase in green latencies enhanced the separation when steady houselight illumination was reinstated for P2872.

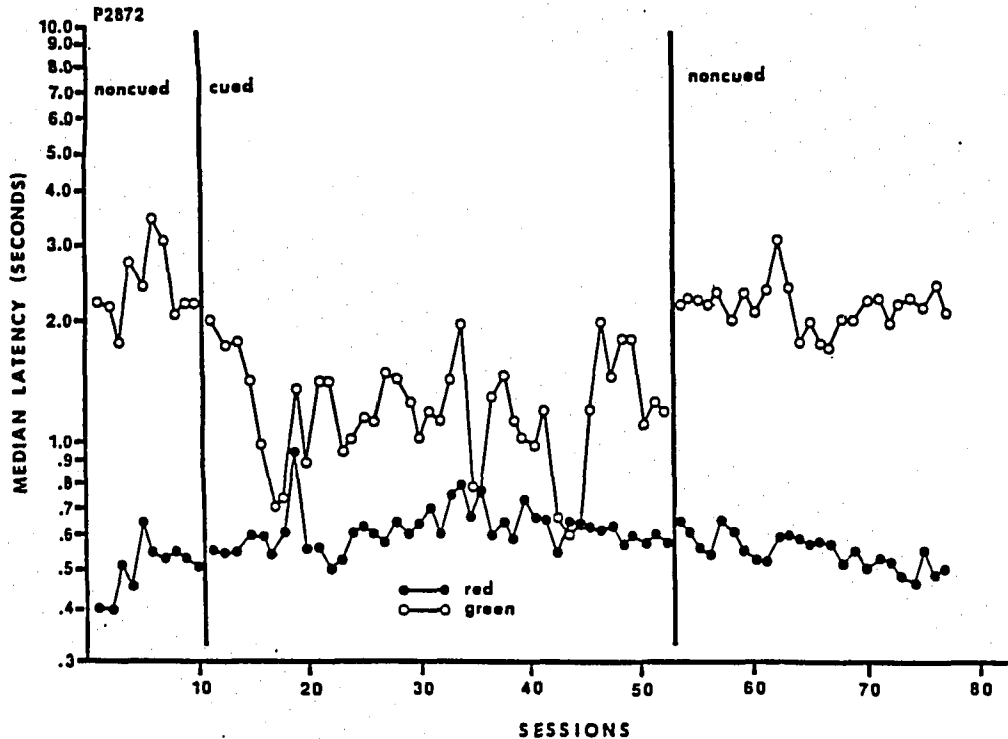


Figure 19. Median Latencies for P2872 for Last 10 Sessions of Condition 2 (Noncued Schedule Components), for Condition 3 (Cued Schedule Components), and for Condition 4 (Noncued Reversal). (Red = FR 3/0.9/4 sec, Green = FR 15/0.9/4 sec).

The effect of cuing for P9957 (see Figure 21) was less pronounced. Although latencies in the less favorable component varied over a relatively broad range, a general declining trend is evident across this condition. Latencies in red appeared unaffected by the cued ITI procedure, and the general impression is that the ratio-based split in latencies for P9957 was slightly reduced in magnitude under the cued condition relative to that generated under noncued schedule components.

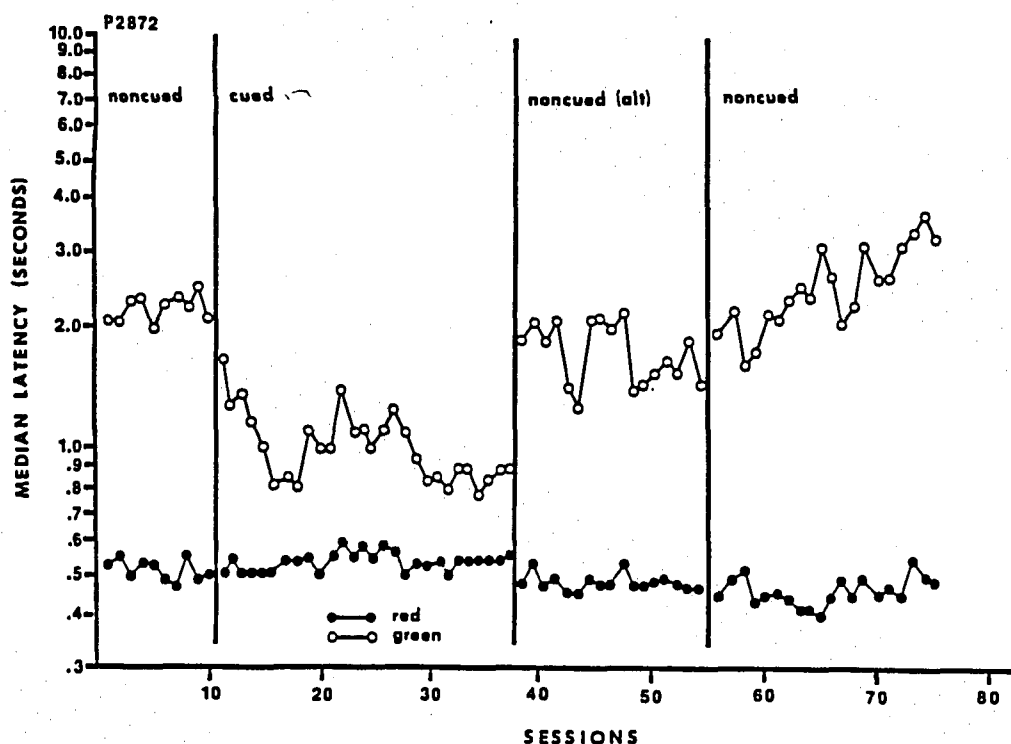


Figure 20. Median Latencies for P2872 for Last 10 Sessions of Condition 4 (Noncued Reversal), for Condition 3 (Cued Schedule Components), and for Condition 4 (Alternate Noncued Procedure and Noncued Schedule Components). (Red = FR 3/0.9/4 sec, Green = FR 15/0.9/4 sec).

The performance of P5855 in Condition 2 was marked by a rather broad range of variability for latencies in the less favorable component (see Figure 22). Those latencies evidenced even greater variability for a number of sessions under the cued ITI procedure as red component latencies lengthened. Relative to Condition 2, latencies in the less favorable component varied within a lower range and those of the more favorable component lengthened. Both of those changes contributed to a reduction in the size of the split for P5855. When

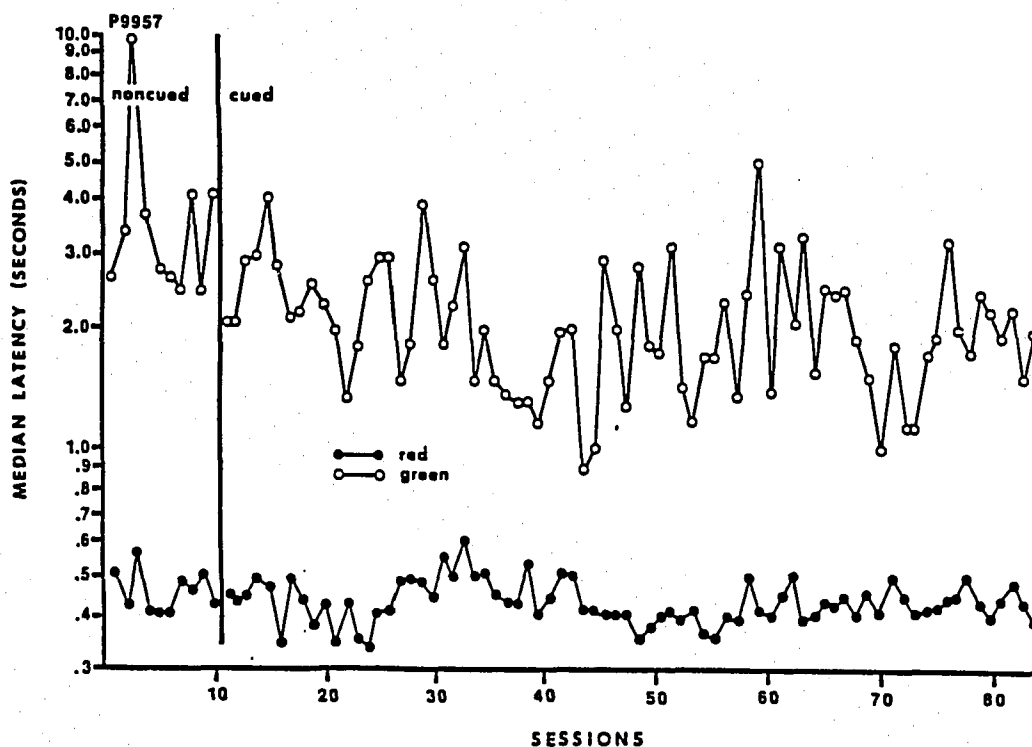


Figure 21. Median Latencies for P9957 for Last 10 Sessions of Condition 2 (Noncued Schedule Components) and for Condition 3 (Cued Schedule Components). (Red = FR 3/0.9/3.5 sec, Green = FR 15/0.9/3.5 sec).

the cued feature was withdrawn from the schedule in Condition 4, the size of the split increased (see Figure 23). Green latencies lengthened and eventually exceeded the values reached under the earlier noncued condition, while latencies in the more favorable component decreased slightly.

A reduction in latencies in the less favorable component also occurred with P10694 (see Figure 24). That effect resulted in a decrease in the magnitude of the split maintained by ratio and reinforcement probability differences between red and green.



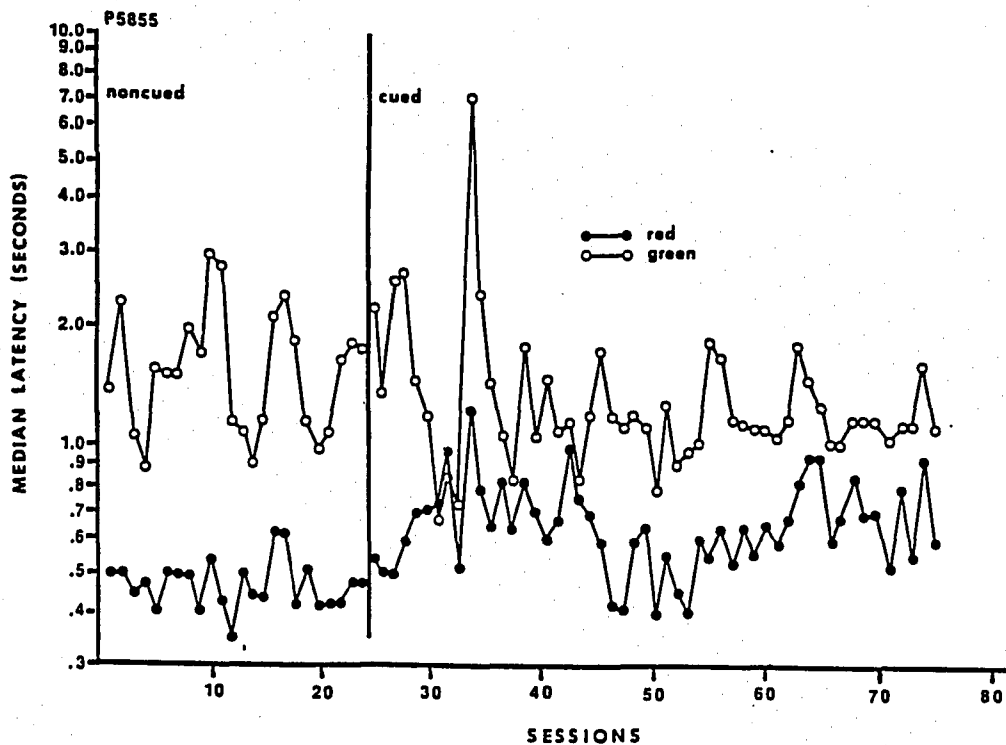


Figure 22. Median Latencies for P5855 for Last Sessions of Condition 2 (Noncued Schedule Components) and for Condition 3 (Cued Schedule Components). (Red = FR 15/0.9/4 sec, Green = FR 15/0.5/4 sec).

In summary, cued ITIs diminished existing schedule-based separations between red and green component latencies for all subjects. With four subjects, the split was attenuated primarily as a result of shortened latencies in the less favorable reinforcement component. The split increased when the cued aspect of the procedure was withdrawn for all four subjects exposed to this manipulation. Latencies in the more favorable component were generally unaffected by the cued procedure, although two subjects evidenced increases in latencies.

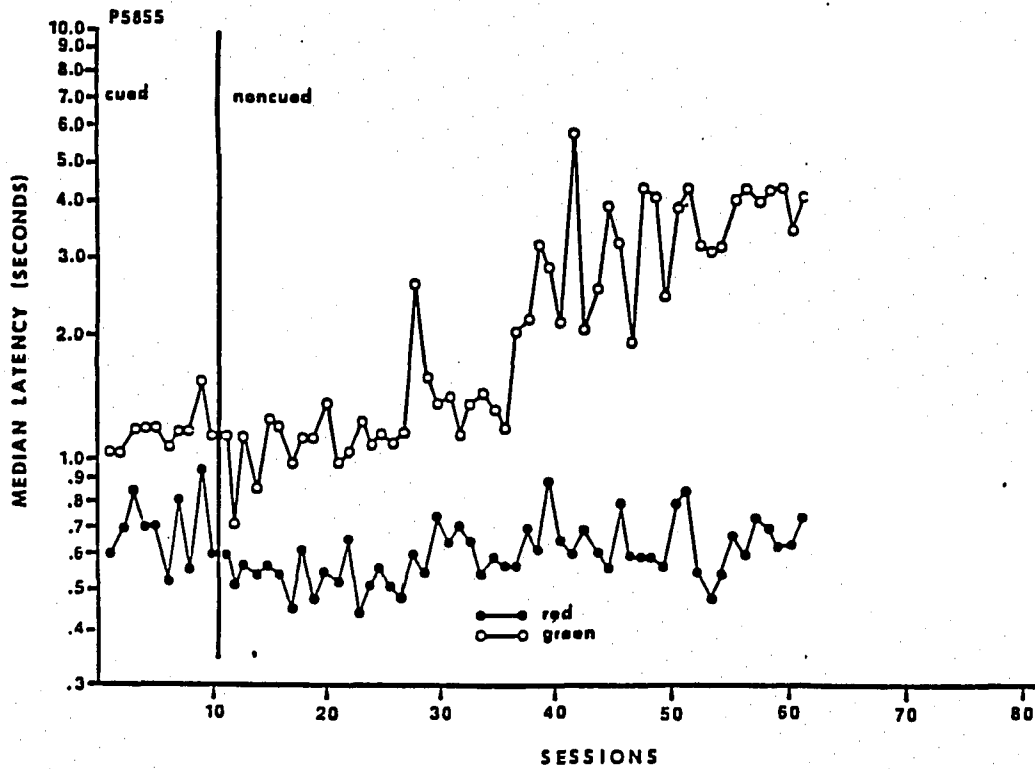


Figure 23. Median Latencies for P5855 for Last 10 Sessions of Condition 3 (Cued Schedule Components) and for Condition 4 (Noncued Reversal). (Red = FR 15/0.9/4 sec, Green = FR 15/0.5/4 sec).

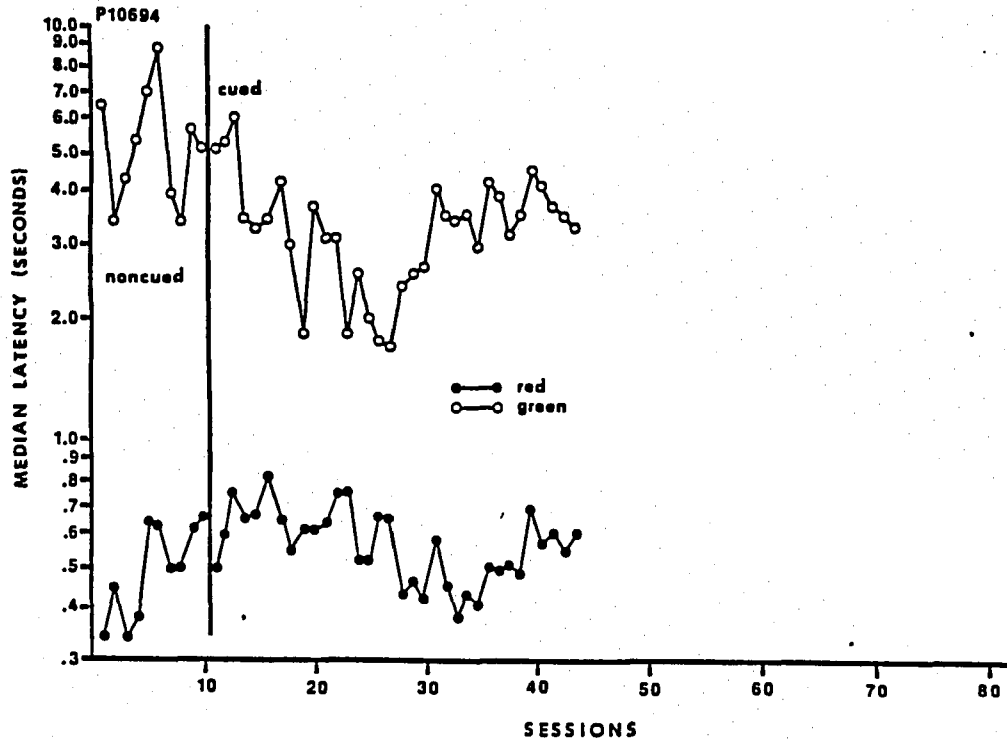


Figure 24. Median Latencies for P10694 for Last 10 Sessions of Condition 2 (Noncued Schedule Components) and for Condition 3 (Cued Schedule Components). (Red = FR 3/1.0/4 sec, Green = FR 15/0.5/4 sec).

## CHAPTER IV

### DISCUSSION

The first phase of the current study constituted a direct replication of the Michael et al. (1981) research and reproduced the general features of those data. Median latencies in two components of a multiple schedule diverged when those components differed in ratio requirement, probability of reinforcement, or duration of reinforcement. Shorter median latencies consistently occurred under the relatively more favorable reinforcement conditions. In addition, the apparent contrast effect noted by Schuster (1959) and by Michael et al. was reproduced in the current investigation. Such data, as well as that from other studies in which latency has been sensitive to and has changed systematically with schedule parameters, are in apparent contradiction with Skinner's (1950) data and conclusions.

This discrepancy may result in part from technological and procedural differences in latency studies. Skinner (1983) has pointed out that his latency research had "crudely measured a pigeon's reaction time" (p. 383), and it is possible that more precise measurement of response latency afforded by computer-based experimental programming permitted more accurate detection of slight but orderly changes in the dependent variable than did Skinner's apparatus. Furthermore, Michael et al. and the current study utilized median latency as the primary dependent variable. That measure was derived from a frequency

distribution of latencies whose ranges (or temporal "bins") comprised a geometric progression rather than a simple arithmetic progression. In contrast, Skinner's dependent variable was modal latency from distributions based on invariate 0.1 sec bins. Such a measure would appear to be less sensitive to very slight relative changes in latency than would median latency.

Enhanced sensitivity of the dependent variable is not, however, the only plausible basis for the discrepancy between Skinner's data and that of Michael et al. and the current investigation. In the latter studies and in the study by Schuster (1959), multiple schedules with two reinforcement components were employed and latency was found to be sensitive to various schedule parameters under those schedules. Skinner, however, examined latencies in a single reinforcement component and concluded from those data that latency was not sensitive to independent variable manipulations. The implication of those differences in procedure and results is that latency of responding to onset of the discriminative stimulus in a given component of the multiple schedule is determined in part by the reinforcement conditions in other schedule components. The occurrence of a contrast-type effect on latencies in an unchanged component when variables are altered in the other component supports that interpretation, as do data from the Michael et al. research in which a decrease in latencies under the less favorable component was demonstrated when the more favorable component was deleted from the multiple schedule.

An additional procedural consideration is the possibility that

fixed-ratio reinforcement contingencies may serve to enhance the sensitivity of latency as a dependent variable. Michael et al. found that median latency was relatively more sensitive to differences in probability or duration of reinforcement when the response requirement was FR 15 than when it was FR 3 in both components. When the higher ratio was employed, the observed split in median latencies generated by a given difference in probability or duration of reinforcement was more pronounced than the separation occurring under the lower ratio requirement.

The nature of ratio schedules might be expected to support a relatively direct relation between reinforcement schedule parameters and response latency. Under FR schedules the onset of reinforcement is less delayed in relation to the onset of responding when responses occur with short interresponse times (IRTs) than when responses are separated by longer IRTs. Shorter latency of responding to onset of the discriminative stimulus also would contribute to relatively more immediate delivery under ratio schedules. Temporal-based contingencies such as fixed-interval schedules lack this direct relation between either latency of responding or IRT length. Latency might therefore be a more orderly or sensitive dependent variable when the temporal distribution of responses directly affects the delay to reinforcement delivery (see Fantino, 1977).

Despite these methodological differences, however, the data from Michael et al. and the reproduction of those effects in the current study are not easily reconciled with Skinner's conclusion that latency

is simply a function of effective "waiting behavior" prior to onset of the  $S^D$ . Although differential reinforcement parameters in the two schedule components reliably produced separations of median latencies, the possibility that consistent differences in median latencies could be attributed to the emergence of correlated differential waiting behaviors is untenable. Such behaviors could not have developed in the noncued conditions since the stimulus conditions during all ITIs were identical and red and green components were presented in a randomized sequence. Median latencies instead appeared to correspond with the relative "values" of the discriminative stimuli, with the term "value" serving as a summary statement of the independent variables inhering in that stimulus condition (e.g., probability of reinforcement, duration or amount of reinforcement, response "effort" required to effect reinforcement, delay to reinforcement, etc.).

A plausible interpretation of the basic latency data is directly implied by a stimulus change analysis of behavioral consequences (e.g., Premack, 1959; Baum, 1973; Michael, 1975). In those analyses, reinforcement is described in terms of the change from pre-reinforcement conditions to onset of the reinforcement event. Such a transition constitutes an improvement in stimulus conditions, the magnitude of which consists in the degree of difference between the values of the pre- and post-change components of that transition.

A stimulus change analysis of the current procedure requires that a value be described for each component of the mult FR FR schedule. Intertrial interval stimulus conditions ( $S^{ITI}$ ) consisted of a

period of time (5 sec if no response occurred) in which the houselight was on and the keylight off and during which the probability of reinforcement following a keypeck was zero, i.e., extinction conditions. Those variables constitute the post-change condition in terminating the previous trial and the pre-change condition involved in onset of the subsequent  $S^D$ . To the extent that the value of  $S^{ITI}$  was influenced by the stimulus conditions with which it was temporally contiguous, the contributions of red and green component values would be comparable since  $S^{ITI}$  was followed and preceded by red and green components with equal frequency.

The change from ITI to onset of the  $S^D$  represented a change from extinction to reinforcement conditions. When equivalent reinforcement conditions were in effect for red and green components, the values of the two  $S^D$ s were also equivalent. Thus the degree of "improvement" was the same for onset of red and green. Under those conditions (as in Condition 1 of the current investigation) median latencies in the two components were either comparable in value or were not systematically related to the relative values of the two components.

The relative values of the two reinforcement conditions were altered, however, when differential reinforcement contingencies were introduced. If stimulus conditions during the more favorable component are designated  $S^>$ , then  $S^>$  was always correlated with the lesser ratio, the higher probability of reinforcement, or the greater duration of reinforcement. The relatively less favorable stimulus condition can be represented as  $S^<$ . Because  $S^>$  has a greater value than  $S^<$ , the



transition from  $S^{ITI}$  to  $S^>$  thus represented a greater magnitude of stimulus change (i.e., a greater improvement in conditions) than did the change from  $S^{ITI}$  to  $S^<$ . Shorter median latencies consistently occurred following onset of  $S^>$  or, in other words, following the greater degree of change from ITI conditions.

An extension of the stimulus change analysis of latency splits under multiple fixed-ratio schedules can be offered in interpreting the effects observed when cued ITIs were introduced. The general effect consisted of a decrement in the magnitude of the split generated under noncued conditions, with the split being essentially eliminated in the case of subject P9544 and especially marked and replicable with P2872. Other subjects, however, demonstrated less marked effects.

In the context of the stimulus change analysis, a convergence of red and green latencies in the cued condition would suggest that the degree of change from  $S^{ITI}$  to  $S^>$  in that condition was less than when nondifferential ITI conditions were in effect and that the cued change to  $S^<$  was greater than in the noncued phase. Because reinforcement parameters and stimulus conditions in  $S^>$  and  $S^<$  were unaltered across noncued and cued phases of the study, any increase or decrease in the magnitude of stimulus change effected by introduction of the cued procedure would appear to involve the value of the ITI condition relative to its value during the noncued phase.

In both the noncued and cued conditions,  $S^{ITI}$  consisted of a 5 sec extinction period. But to the extent that the value of  $S^{ITI}$  was influenced by its correlation with temporally contiguous conditions,

introduction of the cued procedure would be expected to differentiate the values of the two ITI conditions relative to the value of  $S^{ITI}$  in the noncued phase. In the noncued condition,  $S^{ITI}$  was followed by  $S>$  and  $S<$  with equal probability. In the cued phase, however, each of two distinctive  $S^{ITI}$ s was invariably correlated with only one of the reinforcement components.

The implications of this change in correlation between ITI stimulus and reinforcement component can be examined in terms of the degree to which ITI conditions were correlated with the more favorable reinforcement component. In the noncued condition,  $S^{ITI}$  was correlated with the more favorable component ( $S>$ ) with a probability of 0.5. In the cued procedure, one ITI stimulus condition was correlated with  $S>$  with a probability of 1.0, while for the other ITI stimulus this correlation was 0. Thus the ITI condition preceding  $S>$  (designated  $S^{ITI>}$ ) would be expected to have a slightly greater value than did  $S^{ITI}$  in the noncued procedure, while the condition preceding  $S<$  ( $S^{ITI<}$ ) would have a value slightly less than  $S^{ITI}$ .

A rank ordering of ITI stimulus values in the noncued and cued conditions would yield  $S^{ITI>} > S^{ITI} > S^{ITI<}$ . Incorporating those relative values into the stimulus changes inhering in the transitions from the ITI to the two reinforcement components, then

$$\begin{array}{l} S^{ITI} \rightarrow S> > S^{ITI>} \rightarrow S> \quad \text{and} \\ S^{ITI} \rightarrow S< < S^{ITI<} \rightarrow S< \end{array}$$

If median latencies are, in general, inversely related to the

magnitude of change in stimulus value from ITI to reinforcement conditions (i.e., the greater the magnitude of this change, the shorter the latency of responding), then latencies to  $S>$  might be expected to increase when cued ITIs are introduced while latencies to  $S<$  might tend to decrease.

The fact that introduction of the cued procedure in the current study yielded relatively slight effects with most subjects is of interest. If the stimulus change analysis proposed above is correct, then the values of differential ITI conditions would be altered only in their correlation with temporally contiguous schedule components. Relative to the other factors determining the value of the ITI (i.e., a zero probability of reinforcement following keypecking and a duration of 5 sec), any change in correlation with differential reinforcement components might be expected to contribute only slightly to a differentiation of ITI stimulus values. In addition, all birds were subjected to extended exposure to noncued conditions, and this may have mitigated the effect of exposure to the cued ITI procedure. These considerations suggest that a replication of the cued procedure in which other ITI variables, such as its duration or a nonzero probability of noncontingent reinforcement, are manipulated might extend the proposed analysis. Such replications might also involve less extended exposure to the noncued baseline phase to reduce the possibility of stimulus "blocking" by the original ITI conditions (see Mackintosh, 1977, for a discussion of this phenomenon). Another variation would be to introduce cued conditions prior to subjects' first exposure to noncued conditions.

The current procedure does not permit a careful examination of the extent to which introduction of the cued ITI condition might have contributed to the development of autoshaped keypeck responses. The use of flickering versus steady houselight illumination as the basis for differentiating ITI conditions was based partly on an effort to procedurally reduce the likelihood that autoshaped keypecks would be generated by the introduction of the cued condition. It is possible that this feature was not entirely successful in that regard, however, and the decreases in median latencies for the less favorable component demonstrated by several subjects under cued conditions might be the result of additional short-latency autoshaped responses to effect a reduced median latency. The results of an investigation by Hesse (1984/1985), employing a two-key procedure to more clearly identify any autoshaped contribution to keypeck latencies, lend credence to the possibility that such a contribution is involved under differential schedule components. However, it is not clear how autoshaping would be involved in observed increases in latency to S<sup>></sup> for P9544 and P5855 when cued conditions were introduced. A systematic replication of the current study employing Hesse's procedure instead of the single-key arrangement involved in this investigation would permit more explicit investigation of the autoshaping influence.

As was mentioned previously, it is possible that the latency effects reported by Michael et al. and reproduced in the current investigation were influenced by the use of fixed-ratio schedules. Schlinger (1985) has examined this issue more directly and has proposed an

analysis of those latency data in terms of pre-ratio pausing under fixed-ratio procedures.

Despite these interpretive and methodological considerations, however, the current data nonetheless appear to be inconsistent with Skinner's (1950) "waiting behavior" interpretation of his latency data. A straightforward implication of that analysis would be that the introduction of cued ITI conditions in the current mult FR FR schedule would be such as to permit the development of more clearly differentiated preparatory behaviors during the ITI. Should that occur, latency splits generated under noncued conditions might be expected to diverge further under cued conditions. None of the six subjects in the present investigation demonstrated an enhanced split between red and green latencies when cued ITI conditions were in effect, and informal observations of ITI behaviors revealed no clearly discernible change when cued conditions were introduced. Under both conditions, subjects tended to remain close to the response key and to maintain orientation toward and in proximity to the darkened key prior to onset of the discriminative stimulus. Further studies of keypeck latencies might profitably incorporate more precise measurement of head orientation and position to determine whether slight changes in this aspect of effective "waiting behaviors" might occur as a result of procedural changes.

The results of the current study are inconclusive in several respects, but do suggest further lines of investigation in the analysis of operant response latency and cued ITIs. A preliminary endeavor

might involve efforts to reproduce the current results employing different methods of cuing the ITIs, such as presenting the two reinforcement components in simple alternation or in blocks of trials. A two-key arrangement such as that employed by Hesse might better enable isolation of an autoshaping contribution to the cued ITI data.

Despite those issues, however, several variables and interactions have been implicated in the analysis of response latency in pigeons which suggest further lines of investigation in terms of a stimulus change interpretation of those data. Elaboration of such an interpretation through additional research into operant response latency might have implications for the molecular analysis of other behavioral phenomena, especially in the analysis of stimulus control.

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