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**RATE OF CHANGE IN REINFORCEMENT DENSITY  
AS A PARAMETER OF BEHAVIORAL CONTRAST**

by

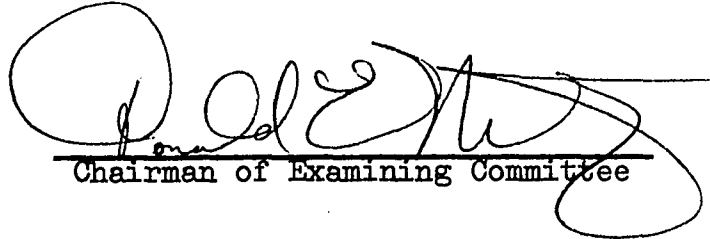
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Abstract

RATE OF CHANGE IN REINFORCEMENT DENSITY  
AS A PARAMETER OF BEHAVIORAL CONTRAST

by

Gerri E. Schwartz

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Two methods of gradually changing one component of a regularly ordered three-ply-mult schedule from VI 1-min. to VI 5-min. were compared with an abrupt change in reinforcement schedule from VI 1-min. to VI 5-min.

In the first experiment, three experimentally naive pigeons were exposed to mult VI 1-min. VI 1-min. VI 1-min. Subsequently, one component (variable component) was gradually changed from VI 1-min. to VI 5-min. in the following sequential series: VI 1, VI 2, VI 3, VI 4, VI 5-min. Each schedule was programmed consecutively for 11 sessions. At the end of this Gradual Manipulation, the programmed schedule in one component of the Baseline schedule was changed from VI 1-min. to VI 5-min. so that VI 1-min. VI 5-min. VI 5-min. was in effect. Significantly greater increases ( $p < .031$ ) in response rate occurred in the constant component (VI 1-min.) where the reinforcement density remained unchanged. A comparison of changes in rates of responding between the VI 1-min.

components that preceded and followed the variable component indicated that for one subject the greatest increase in relative response rate occurred in the preceding component.

In the second experiment, the same three pigeons were exposed to a Baseline Recovery procedure where VI 1-min. VI 1-min. VI 1-min. was in effect. During the Second Abrupt Manipulation, one component was changed from VI 1-min. to VI 5-min. so that VI 1-min. VI 5-min. VI 1-min. was the programmed schedule. For all Ss during the Second Abrupt Manipulation, the mean rate of responding in the variable component decreased and the mean rate in the preceding and following components increased over Baseline Recovery values. Furthermore, for two of three Ss, greater increases occurred in the preceding vs. following values.

In the third experiment, three experimentally naive pigeons were exposed to a mult VI 1-min. VI 1-min. VI 1-min. baseline. During the Cyclical Manipulation, one component (variable component) was changed from VI 1-min. in the following sequence of values: VI 1, VI 1.5, VI 2, VI 3, VI 5-min. Each VI value remained in effect for one session such that at the end of the fifth session, all Ss had been sequentially exposed to each of the five values. This procedure (the Cyclical Manipulation) was in effect for 75 days. Immediately following the Cyclical Manipulation, the birds were exposed to one

session of VI 1-min. VI 1-min. VI 1-min. Thereafter, the component designated as the variable component was abruptly shifted from VI 1-min. to VI 5-min. so that a mult VI 1-min. VI 5-min. VI 1-min. was in effect. Following this Initial Abrupt Manipulation, a Baseline Recovery procedure was reinstated with VI 1-min. VI 1-min. VI 1-min. as the programmed contingency. During the Final Abrupt Manipulation, the variable component was changed from VI 1-min. to VI 5-min. so that the programmed schedule was VI 1-min. VI 5-min. VI 1-min. The Cyclical Manipulation generated an inverted "U-shaped" function in the variable component for all three Ss. No consistent function of the mean rates of responding in the preceding and following components were obtained. In at least one of the two constant components, greater increases in relative response rate occurred in the Initial Abrupt Manipulation than the highest mean rate recorded in the Cyclical Manipulation for each bird. Further analysis indicates that for two of three Ss, the greatest increase occurred in the preceding vs. following components. During the Baseline Recovery procedure, response rates in all components were generally above baseline values. Behavioral contrast was demonstrated by two of three Ss during the Final Abrupt Manipulation.

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In multiple schedules of reinforcement (mult), two or more differentially cued components, each correlated with a single reinforcement schedule, are alternately presented to the organism in a predetermined order. Presumably, rate of responding in each component should be controlled by the schedule that is in effect. However, evidence suggests that in multiple schedules of reinforcement, response rate in one component may be influenced by the consequences of responding in the alternating component (Reynolds, 1961a, 1961b; Terrace, 1966a). In fact, changing the schedule of reinforcement associated with one stimulus condition (variable component) has been shown to produce changes in rates of responding in the alternate stimulus condition (constant component) in which the requirements for reinforcement are unchanged (Reynolds, 1961c; Terrace, 1968). Called an interactive effect by Reynolds (1961a), this phenomenon has been further described in terms of the direction of change in response rates. When rates of responding in the constant component change in the same direction as in the variable component, the effect is labeled induction. When the rate of responding in the constant component changes in the opposite direction as in the variable component, the effect is labeled contrast. The terms "positive" and "negative" are used to further describe rate changes in the variable component: "positive" describes rate increases and "negative" describes

decreases in rates of responding (Hemmes and Eckerman, 1972). For example, if rate of responding in the constant component increases while rate of responding in the variable component decreases, Reynolds (1961a), after Skinner (1938), labeled this interaction as "positive or behavioral contrast".

Recent interest in behavioral contrast can be attributed to the fact that the phenomenon cannot be predicted from traditional theories of conditioning and extinction (Spence, 1936; Hull, 1952). Conventional discrimination paradigms consist of reinforcing responding in the presence of one stimulus, S+, while responding in the presence of a different stimulus, S-, is not reinforced. Habit strength is the tendency of a response to occur in the presence of the stimuli present at the time of reinforcement. Since habit strength was assumed to be equal to the algebraic summation of the effects of reinforcement and extinction, the shape of the gradients of habit strength would seem to be predicted on the basis of their respective excitatory and inhibitory effects on behavior (Spence, 1936; Hull, 1952). Nevertheless, in examining discrimination training in multiple schedules of reinforcement, while extinction produces response decrements in the presence of the stimulus correlated with nonreinforced responding, an increase in rate of responding occurs in the alternated component in which the requirements for reinforce-

ment are unchanged. Therefore, extinction would seem to have both inhibitory and excitatory effects in multiple discrimination training, with the excitation observed in the behavior in an alternated component.

Much research has been directed at determining the single sufficient condition for producing contrast (Terrace, 1963a; Bloomfield, 1967; Reynolds and Limpo, 1968). Two parameters that have been widely explored are response rate and reinforcement frequency in the variable component. However, many experimental procedures designed to examine contrast have frequently confounded the manipulation of reinforcement frequency and its effect on the rate of responding. A reduction in the reinforcement frequency in the variable component is accompanied by a decrease in the rate of responding in that component. It is difficult, therefore, to assess the differential contribution of either of these variables to the resulting rate increase in the constant component.

Whether behavioral contrast is attributed to the effects of the decrease in reinforcement rate or the decrease in response rate in the variable component, a common feature in most studies in this area is that a change is made in the schedule of reinforcement correlated with one component. One parameter that has been relatively neglected in the contrast literature is the rate of change in either discriminative or reinforcing

stimuli. The importance of the rate of change in stimulus conditions in discrimination training has been demonstrated by Terrace (1963a). In the Terrace "fading" procedure, discriminated responding developed when the S+ (red key) and the S- (green key) were initially different with respect to brightness, duration and wavelength. After training started, the duration and brightness of S- was progressively increased until S+ and S- differed only with respect to wavelength. In the "fading" procedure, the key light associated with S- appeared dark and the pigeons did not peck the key. As the "fading" procedure continued, few or no responses were emitted in the presence of S-. Furthermore, Terrace reported that contrast does not appear when a discrimination is learned without "errors".

The present study examined the rate of change in reinforcement density as a parameter of behavioral contrast. Similar to the "fading" procedure, the present study investigated progressive changes in the stimulus conditions of a multiple schedule of reinforcement. However, in the present study, reinforcement density rather than stimulus intensity in the variable component was manipulated. A comparison was made between the effects of abruptly changing the reinforcement frequency in the variable component from VI 1 min. to VI 5 min. (Abrupt Manipulation) vs. the effects of making the same change gradually through a progressive series

of VI values (Gradual Manipulation). In this way, the present study attempts to demonstrate the importance of the rate of change in reinforcement density as a determinant of interactive behavioral phenomena.

#### Parameters of Contrast

Previous research in this area has explored the manipulation of reinforcement frequency and its effects on the rate of responding in the variable component. Contrast effects have been attributed to 1) relative rate of reinforcement in the constant component, 2) response suppression in the variable component, 3) increases in nonreinforced responding in the variable component, and 4) the "emotional" effects of punishment, extinction and time-out procedures in the variable component. The following is a summary of some of the major empirical findings and theoretical implications.

Relative rate of reinforcement in the variable component. Decreasing reinforcement frequency in the variable component necessarily produces a change in the relative reinforcement rate in the constant component. Reynolds (1961a) suggested that this change in relative rate of reinforcement is a sufficient condition to produce contrast. Specifically, in a mult VI 3-min. VI 3-min. schedule, one component (variable component) was changed to either extinction (EXT) or to time-out (TO) conditions. In both mult VI EXT and mult VI TO schedules, response rate in the constant component increased

over baseline values. Although contrast did occur under these conditions, changes in the reinforcement frequency and the rate of responding in the variable component were confounded. Both the rate of reinforcement and the rate of responding were reduced. In a second procedure, Reynolds (1961a) changed the variable component of the mult VI 3-min. VI 3-min. to a "schedule of reinforcement for not responding" (DRO). The parameters of the mult VI 3-min. DRO 50-sec. produced the same reinforcement frequencies in the constant and variable components. Concurrently, a decrease in response rate occurred in the DRO component (variable component). No contrast resulted from this manipulation and Reynolds concluded that the absence of reinforcement rather than the low rate of responding in the variable component created a necessary condition for contrast. However, an alternate conclusion may be advanced from Reynolds' DRO study. Differential reinforcement of behaviors other than key pecking increase behaviors incompatible with key pecking, i.e., pausing. Perhaps contrast did not occur because of induced changes in response patterns that were incompatible with rate increases in the constant VI component.

In another study, Reynolds (1961b) examined different values of relative frequency of reinforcement in a series of mult VI FR schedules. The procedure consisted of two series of multiple schedules in

which the first component was a VI schedule and the second component was a fixed-ratio (FR) component. In the first series, the VI 3-min. schedule was alternated with either FR 75, FR 150, or an extinction component. In the second series, FR 150 was alternated with either VI 1.5, VI 3, VI 6-min., or extinction. The results indicated that the magnitude of contrast was proportional to the relative frequency of reinforcement in the constant component. However, changes in the reinforcement frequency and rate of responding in the variable component were confounded. Thus, no conclusive evidence is provided for the relative reinforcement explanation of contrast.

In a related study, Shettleworth and Nevin (1965) examined reduction in magnitude of reinforcement as a possible cause of contrast. Pigeons were trained on a mult VI 2-min. VI 2-min. schedule in which the duration of access to grain was varied independently in the two components. No contrast effect was obtained. This indicates that although changes in the relative frequency of reinforcement has been shown to produce contrast (Reynolds, 1961a, 1961b), the reduction of magnitude of reinforcement was not a sufficient parameter.

Response suppression in the variable component.

Brethower and Reynolds (1962) reinforced pigeons on a mult VI 3-min. VI 3-min. schedule of reinforcement. A punishment contingency was added to the variable com-

ponent of the schedule such that electric shock followed each response emitted in the presence of one of the stimuli. When punishment was introduced, the rate of punished responding decreased and the rate of unpunished responding increased as a function of shock intensity. Further analysis indicated that as the rate of responding in the punishment-correlated component decreased, so did the rate of reinforcement. Thus, response suppression and reduction of reinforcement frequency in the variable component were confounded in this study. Brethower and Reynolds (1962) did not attribute contrast to the response suppression in the variable component. Instead, the authors concluded that contrast occurred as an effect of punishment.

Reynolds and Limpo (1968) examined the effects of response suppression in multiple schedules using a schedule that differentially reinforced low rates of responding (DRL). After a steady state of performance was obtained on a mult DRL 35-sec. DRL 35-sec. schedule, a clock was added to the variable component such that one of a series of visual stimuli was illuminated for each of seven consecutive 5-sec. periods during every interresponse time. The "DRL with clock" contingency resulted in response rate decrements and therefore reinforcement rate increments in that component. Concurrently, the rate of responding in the component without the added stimuli increased, even though this

increase resulted in less frequent reinforcement. This finding necessitates a reconsideration of the previous suggestion by Reynolds (1961a) that an increase in relative frequency of reinforcement was a primary cause of contrast. To rescue the relative reinforcement interpretation of contrast, the authors speculated that contrast in the constant component was produced by the presence of the stimuli associated with nonreinforcement (DRL with clock) rather than response suppression.

Increases in nonreinforced responding in the variable component. Discrimination training consists of reinforcing responding under one stimulus condition, S+, and not reinforcing responding under another stimulus condition, S-. As discrimination training progresses, the amount of reinforced responding increases as the amount of nonreinforced responding decreases. A "fading" procedure for discrimination training with a minimum of nonreinforced responding has been developed by Terrace (1963a) and is described above.

In an additional study, Terrace examined "errorless" transfer from the original red-green discrimination to a discrimination between vertical and horizontal lines (1963b). This was done by initially superimposing the vertical and horizontal lines on the red and green backgrounds, and subsequently "fading out" the red and green backgrounds. Results showed that behavioral contrast was related to the occurrence of

errors during the acquisition of the vertical-horizontal discrimination. This would seem to support Terrace's notion that nonreinforced responding is a sufficient condition to produce contrast. Conflicting evidence was reported by Reynolds (1961a) who studied discrimination training without an extinction procedure. This experiment was similar to Terrace's errorless discrimination procedure in that discrimination occurred without responding to the S-. This was accomplished by using a time-out (TO) procedure under which the illumination of the houselights and the keylights in the pigeons' chamber was discontinued. Because contrast was obtained under this procedure, Reynolds concluded that extinction in the presence of one stimulus was not a necessary condition for the occurrence of contrast. Terrace counterargued that because pigeons rarely respond in total darkness, TO discrimination training is different from the "errorless" discrimination training reported in his experiments. Furthermore, he suggested that the increase in response rate in TO procedure could be attributed to the "aversiveness" of TO procedures. The status of an appeal to "aversiveness" as a determinant of contrast is discussed in the following section.

"Emotional" effects of punishment, extinction, and TO procedures. To support the notion that response suppression is the sufficient determinant of contrast,

Terrace (1963a, 1966a) has advanced the hypothesis that contrast is due to "emotional" effects of responding during punishment, extinction, and TO procedures. This "emotional" effect is similar to the frustration effect first described by Amsel (1962). Following a nonreinforced trial in a goal box, there was an increase in running speed down the runway. This has been attributed to the motivational consequences of frustration. Accordingly, Terrace concluded that responding in either punishment, extinction, or TO conditions arouses "aversive motivational variables" which are similar to the frustration effects described by Amsel. These "emotional" effects are manifested by the increase in response rate in the constant component. Once the "emotional" effects are adapted out, as with extended training, the contrast effects disappear (Terrace, 1966). The salient feature of this hypothesis rests in the terms "aversive" and "emotional or frustrative" responses. Empirical evidence to support an explanation of contrast based on the "emotional" effects of response suppression would seem to depend on the operational definitions and concurrent measurement of these variables. One approach to this problem has been the use of the concurrent chain procedure (Autor, 1960) in which relative preference and hence relative aversiveness can be measured in a choice procedure. It is also possible that the "emotional" effects and the increase

in response rate could be merely correlated rather than functionally related.

#### Properties of Contrast

In addition to the research on the determinants of contrast, some studies have investigated other properties of this phenomena such as 1) the dynamics of responding under contrast procedures (Gamzu and Schwartz, 1973; Keller, 1973; Rachlin, 1973), and 2) the temporal characteristics of this multiple schedule interaction (Bloomfield, 1967; Nevin and Shettleworth, 1965).

Dynamics of responding. When food-deprived pigeons are repeatedly exposed to a brief illumination of a key immediately followed by access to food, they will begin to peck the illuminated key. This phenomenon has been termed autoshaping (Brown and Jenkins, 1968), and has been applied to the analysis of behavioral contrast by Gamzu and Schwartz (1973) and Keller (1973). Gamzu and Schwartz (1973) suggested that two classes of responding occur in the constant component during positive contrast. In their study, they provided noncontingent food reinforcement to pigeons in both components of a multiple schedule. Little or no pecking occurred when the rate of free food presentation in the two components was equal. When reinforcement rate in the two components was different, the pigeons pecked the key in the component associated with a higher reinforcement rate and infrequently or not at all in the other component.

In a suggestion influenced by the autoshaping phenomenon, the authors speculated that contrast consists of two classes of responses: instrumental responding to the schedule of reinforcement and "extra" responses due to the relation of the signal of the key light and reinforcement.

In a related study, Keller (1973) examined multiple schedules of reinforcement in a two-key pigeon chamber. Pecking on one key, the instrumental key, produced reinforcement according to a two-ply-mult schedule. However, no change in color to signal the two different components occurred in this key. The two components were differentially cued by changes in the color of the other key, the signal key. Pecking on the signal key had no scheduled consequences. Considering pecking that occurred only on the schedule key, no behavioral contrast was demonstrated; however, frequent pecking on the signal key occurred during the component with the higher rate of reinforcement. In typical multiple schedules, one key, programmed with the reinforcement contingencies, signals the component in effect. In Keller's study, if the number of responses on the signal and instrumental key were summed, positive contrast would have been observed.

The notion that contrast occurs as a function of responding to a signal for reinforcement has been extended by Rachlin (1973). He speculated that transient

effects result from the alternation of two schedules of different reinforcement frequency. Moreover, these transient effects are thought to occur at the point of transition from one component to the other. A transition from a low to a high density would excite responding; conversely, a transition from a high to a low density would decrease responding. Since short components would sample the maximal effects of a transition between schedules, Rachlin predicts that in a multiple schedule with the two components differing in reinforcement frequency, the shorter the duration of the component, the more rapid the alternation of the components and thus the greater the contrast effect. To test this notion, Rachlin exposed pigeons to a multiple schedule consisting of two alternating components, Component A and Component B. A VI 2-min. reinforcement schedule was programmed during Component A. During Component B, a VI 15-sec. free-food presentation was superimposed on a VI 2-min. schedule. The rates of responding in Component A and Component B were compared in two groups of pigeons under either an 8-sec. alternation of components or an 8-min. alternation of components. The results indicated that pigeons under the 8-sec. alternation of components pecked more in Component B, whereas pigeons responding during the 8-min. alternation of components pecked slightly more in Component A. Further analysis of responding recorded during the 8-min. alternation revealed

that at the beginning of Component B (a transition from low to high density), responding was elevated, whereas at the beginning of Component A (a transition from high to low density), responding was suppressed. These contrast effects dissipated within the duration of the component and the final steady-state responding was higher in Component A. These findings support Rachlin's contention that contrast is the result of "autoshaped" responses which occur as a function of the transition from stimuli signaling one density of reinforcement to stimuli signaling another density of reinforcement.

Temporal characteristics of contrast. In addition to the dynamic properties of the responses that occur in multiple schedule interaction, some studies (Nevin and Shettleworth, 1966; Bloomfield, 1967) have systematically investigated the temporal characteristics of this multiple schedule interaction. In one such study, Nevin and Shettleworth (1966) exposed pigeons to a 3-component multiple schedule (three-ply-mult schedule) with the constant component fixed at VI 5 min. The other two components were variable components in which extinction and a greater frequency VI value were respectively programmed. Each cycle within an experimental session consisted of an alternation of the variable and constant components. When the preceding component (variable component) was the greater frequency VI value, response rate in the constant component was ini-

tially low and increased with time. If the preceding variable component was extinction, response rate in the constant component was initially high and decreased with time. Rate changes within a constant component were labeled transient contrast effects. These were distinguished from sustained contrast effects, described as rate changes which occurred across successive schedule cycles.

In a similar study, Bloomfield (1967) found that contrast effects persisted through the training and re-training of a successive discrimination. In his study, mult VI VI and mult VI EXT were alternated daily for 40 days, with 20 presentations of each multiple schedule. In this procedure, responding under VI in mult VI EXT schedule was found to be higher than mult VI VI, even though these two multiple schedules were alternately presented several times. This was labeled a permanent contrast effect. An increase in response rate which appeared in the beginning of the VI period but declined during the experimental session was called transient contrast effects. Bloomfield's definition of transient contrast effects coincides with the transient effects first described by Nevin and Shettleworth (1966).

Permanent contrast effects were re-examined by Terrace (1966b), who used Bloomfield's procedure of the alternation of fixed length components of S+ and S-. The basic paradigm was modified by the addition of a

correction procedure such that each response to S- delayed the termination of the component for 30 seconds. Results reveal that with the correction procedure, response rate initially increased and then decreased across sessions to a value greater than baseline. The contrast effects were therefore said to disappear. A further difference in the procedures used by Bloomfield and Terrace was the number of sessions of discrimination training. Bloomfield continued training for 17 sessions, whereas Terrace extended training to 60 sessions. Terrace's findings indicate that with both the correction procedure and extended training, contrast effects disappear.

In summary, previous research in behavioral contrast has examined relative frequency of reinforcement (Reynolds, 1961a), response suppression (Terrace, 1966a), and increases in nonreinforced responding in the variable component (Terrace, 1963a) as determinants of contrast. In an alternate explanation, the occurrence of contrast has been attributed to the "emotional" effects of punishment, extinction, and time-out procedures (Terrace, 1966a). More recent explanations of the phenomenon have appealed to the dynamic properties of behavioral contrast (Gamzu and Schwartz, 1973; Keller, 1973), as well as to the effects of the alternation of components in a multiple schedule (Rachlin, 1973). However, no single explanation can account for all multiple

schedule interactions. Other variables such as the number of responses per reinforcement, the overall frequency of reinforcement per session, and the rate and magnitude of change in the schedule, have been relatively neglected in the experimental analysis of interactive behavioral phenomena.

The present study investigates gradual and abrupt changes in reinforcement frequency in the variable component, and examines their relations to behavioral contrast.

## Experiment 1

### Method

#### Subjects

Three experimentally naive, mature, white Garneaux male pigeons were maintained at  $80\% \pm 15$  gm. of ad libitum body weight. They were housed in separate cages in an animal vivarium and had continuous access to water.

#### Apparatus

The experimental chamber was a standard two-key Lehigh Valley operant test chamber for pigeons. Its interior measurements are 38 by 29 by 35 cm. Two keys, separated by a distance of 13 cm. from the center of one key to the other, were mounted 27 cm. above the floor of the chamber. The right key was transilluminated with either red, green, or white light. A response in excess of 20 gm. was required for switch closure. The left key was inoperative and remained dark throughout the experiment. A houselight was centrally located above the keys and was illuminated continuously during sessions. The reinforcement was 3.5-sec. access to mixed grain (50% Kaffir, 40% vetch, 10% hemp), presented in a lighted hopper. During reinforcement presentation, the key lights were turned off. Water was continuously available to the birds during experimental sessions. The test chamber was housed in a sound attenuation chamber and a ventilation fan and

white noise masked most extraneous sounds. Experimental contingencies were programmed by a series of relays, timers and counters. Key pecking in each component was recorded on counters and a cumulative recorder.

#### General Procedure

After magazine training and shaping to key peck, all three Ss were exposed sequentially to the following experimental conditions: Baseline, Gradual Manipulation (Procedure 1), Abrupt Manipulation (Procedure 2). All Ss were exposed to one experimental session per day, seven days a week. Occasionally, supplementary feedings were required to maintain the birds at 80% body weight. These were provided immediately following the test sessions. The experimental procedures for this experiment are summarized in Table 1.

Baseline. Three pigeons were exposed to a three-component multiple schedule of reinforcement, mult VI 1-min. VI 1-min. VI 1-min., for 90 days. Each component in the mult schedule was 3 min. in duration and was differentially cued by either green, red or white key lights. Every session was 54 min. in duration and consisted of six regularly ordered presentations of three 3-min. components in the sequence of key lights noted above. Reinforcements were programmed on a VI 1-min. schedule in which the momentary probability of reinforcement is constant (Catania and Reynolds, 1963). When a reinforcer was programmed but not delivered

TABLE 1  
 Sequence of Experimental Conditions  
 EXPERIMENT 1

Subjects	Condition	Contingency	Number of Sessions
B2,B5,B7	Baseline	VI 1 VI 1 VI 1	90
	Gradual Manipulation: Procedure 1	VI 1 VI 1 VI 1	11
		VI 1 VI 2 VI 1	11
		VI 1 VI 3 VI 1	11
		VI 1 VI 4 VI 1	11
		VI 1 VI 5 VI 1	11
	Abrupt Manipulation: Procedure 2	VI 1 VI 5 VI 5	11

during the presentation of one component, it was cancelled for all successive components.

Gradual manipulation: Procedure 1. One component, cued by the red key light, was designated as the variable component. In the variable component, the density of reinforcement was systematically reduced by changing the schedule of reinforcement from VI 1-min. to VI 5-min. in the following sequence: VI 1, VI 2, VI 3, VI 4, VI 5-min. Each reinforcement schedule was in effect for 11 consecutive sessions, such that at the end of 55 days, all Ss had been exposed to each of the five VI values. Throughout the experiment, the remaining two components were designated as constant components. The constant components were further designated as the preceding (green key light) and the following (white key light) components according to their immediate sequential relationship to the variable component. The density of reinforcement in the preceding component and following component remained fixed at VI 1 min.

Abrupt manipulation: Procedure 2. In this procedure, the mult VI 1-min. VI 5-min. VI 1-min. was abruptly shifted to mult VI 1-min. VI 5-min. VI 5-min., with the abrupt shift from VI 1-min. to VI 5-min. occurring in the following constant component (white key light). This procedure was in effect for 11 days and immediately followed the final day of mult VI 1-min. VI 1-min. VI 5-min. under Procedure 1.

### Results

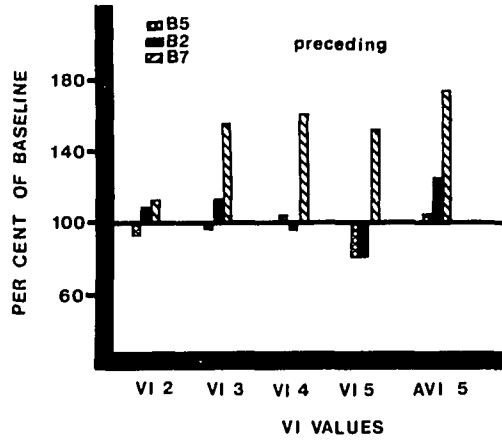
In Experiment 1, the relative rates of responding in each component during the Gradual Manipulation (Procedure 1) and the Abrupt Manipulation (Procedure 2) are reported for each subject. The relative response rates for each bird in each component were computed as a percent change from the mean rate of the last ten sessions of Baseline recorded in Experiment 1. This measure, the relative rate of responding, will be used in subsequent experimental analyses. The changes in absolute response rate and relative response rate in this and the subsequent experiments co-varied. The absolute rates of responding during the last ten days of Baseline are included in Appendix A.

Initially, each change in the reinforcement schedule produced a great amount of variability ( $\pm 42\%$  of baseline) in the preceding, variable and following components. This variability in rate of responding declined as a function of training.

#### Preceding Component

The preceding component remained fixed at VI 1-min. throughout the Gradual and Abrupt Manipulations. The mean relative response rate in the preceding component across the 5th through the 11th session under each experimental manipulation that followed Baseline is presented in Figure 1. As shown in Figure 1, for all three birds the greatest increase over baseline values oc-

Figure 1. Mean relative response rate in the preceding component across the 5th through the 11th session under Gradual (Procedure 1: VI 2, VI 3, VI 4, VI 5) and Abrupt (Procedure 2: A VI 5) Manipulations. Relative rates of responding were computed as a percent change from the mean rate of the last ten sessions of Baseline recorded during Experiment 1. The abscissa represents the reinforcement schedules programmed during the Gradual and Abrupt Manipulations. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

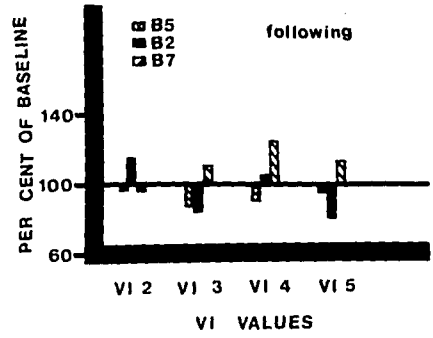


curred during the Abrupt Manipulation. A sign test indicated that this effect was significant ( $p < .031$ ) for all three subjects. In general, as the reinforcement frequency in the variable component decreased, relative response rate in the preceding component increased to a highest value, and then progressively decreased for the remaining VI values. For Bird B2, the highest value occurred when the variable component was VI 3-min. For birds B5 and B7, the highest value occurred when the variable component was VI 4-min.

#### Following Component

The following component was VI 1-min. during the Gradual Manipulation. During the Abrupt Manipulation, this component was shifted from VI 1-min. to VI 5-min. The mean relative response rate in the following component across the 5th through the 11th session under the Gradual Manipulation is presented in Figure 2. The mean relative response rate for B2 alternately increased and decreased around baseline values. For B5, the mean relative response rate in the following component ranged between baseline and below baseline values during the Gradual Manipulation. The lowest value occurred when the variable component was VI 3-min. During the Gradual Manipulation, for B7 the mean rate increased until VI 4-min. was programmed in the variable component. When VI 5-min. was programmed in the variable component, the mean rate decreased.

Figure 2. Mean relative response rate in the following component across the 5th through the 11th session under the Gradual Manipulation (Procedure 1). Relative rates of responding were computed as a percent change from mean rate of the last ten sessions of Baseline recorded during Experiment 1. The abscissa represents the reinforcement schedules programmed in the Gradual Manipulation. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.



### Variable Component

Reinforcement frequency in the variable component was decreased from VI 1-min. to VI 5-min. during the Gradual Manipulation. Figure 3 shows the mean relative response rate in the variable component across the 5th through the 11th session under each experimental manipulation following Baseline. As shown in Figure 3, for B2 and B7 the mean rate of responding progressively decreased from above baseline to below baseline values as the reinforcement frequency in this component decreased. An opposite trend was demonstrated by B5. As the reinforcement frequency in the variable component decreased, the mean rate of responding increased with each mean rate occurring below baseline values. During the Abrupt Manipulation, the schedule in the following component was shifted from VI 1-min. to VI 5-min. Therefore, the relative frequency of reinforcement in the variable component was effectively increased. The lowest mean response rate in the variable component for B2 and B7 occurred during the Abrupt Manipulation.

Data generated by each bird during the individual sessions following Baseline can be seen in Figures 4, 5 and 6. The trend of increases in relative response rate in the preceding component reported in Figure 1 may again be seen for all three subjects, with some individual differences occurring in individual sessions. Although the mean data showed greater increases in the

Figure 3. Mean relative response rate in the variable component across the 5th through the 11th session under the Gradual (Procedure 1: VI 2, VI 3, VI 4, VI 5) and Abrupt (Procedure 2: A VI 5) Manipulations. Relative response rates were computed as a percent change from the mean rate of the last ten sessions of baseline recorded during Experiment 1. The abscissa represents the reinforcement schedules programmed in the Gradual and Abrupt Manipulations. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

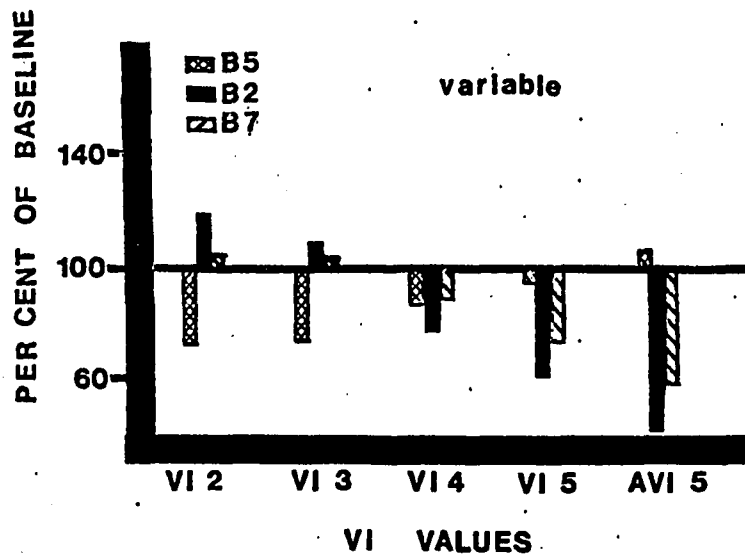


Figure 4. Relative response rate for Bird B2 in preceding, variable and following components under Gradual (Procedure 1: VI 2, VI 3, VI 4, VI 5) and Abrupt (Procedure 2: A VI 5) Manipulations. Relative rates of responding were computed as a percent change from the mean rate of the last ten sessions of baseline recorded in Experiment 1. The abscissa represents the successive sessions during the Gradual and Abrupt Manipulations. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

preceding ———  
variable - - - - -  
following ······

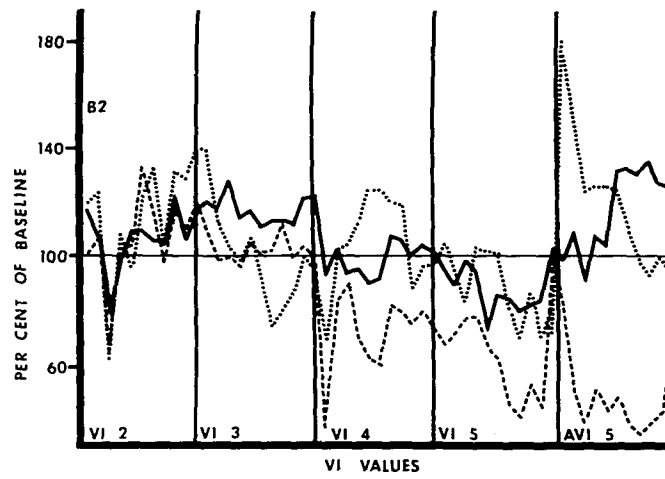
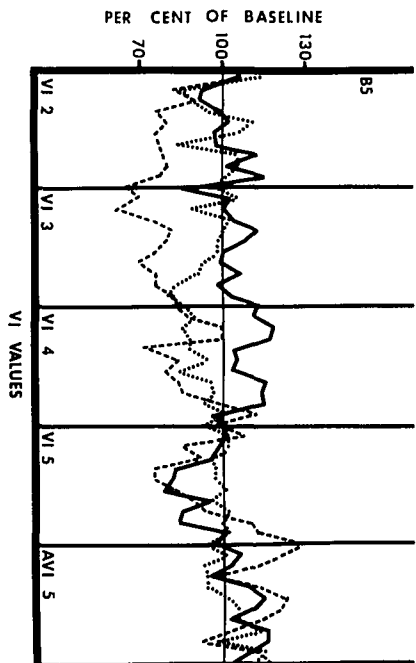


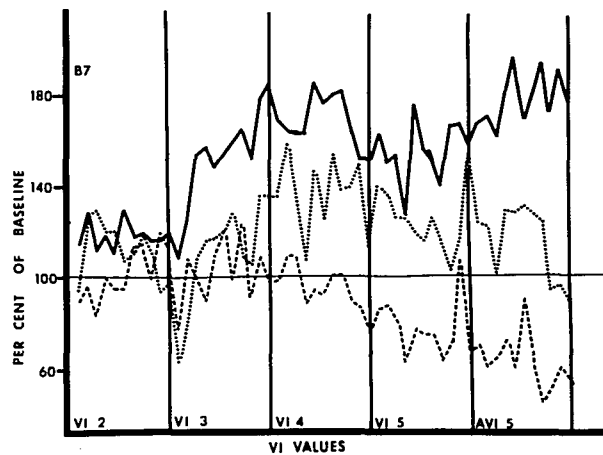
Figure 5. Relative response rate for Bird B5 in preceding, variable and following components under the Gradual (Procedure 1: VI 2, VI 3, VI 4, VI 5) and Abrupt (Procedure 2: A VI 5) Manipulations. Relative rates of responding were computed as a percent change from the mean rate of the last ten sessions of Baseline recorded during Experiment 1. The abscissa represents the successive sessions during the Gradual and Abrupt Manipulations. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.



preceding ———  
 variable - - - - -  
 following .....

Figure 6. Relative response rate for B7 in preceding, variable and following component under Gradual (Procedure 1: VI 2, VI 3, VI 4, VI 5) and Abrupt (Procedure 2: A VI 5) Manipulations. Relative rates of responding were computed as a percent change from the mean rate of the last ten sessions of Baseline recorded during Experiment 1. The abscissa represents the successive session during the Gradual and Abrupt Manipulations. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

preceding —————  
variable - - - - -  
following ······



Abrupt vs. Gradual Manipulation, for B5 the highest value in the preceding component was actually obtained during the Gradual Manipulation.

As shown in Figure 4, it appears as though the Abrupt Manipulation resulted in initially high relative response rates in the following component that decreased as a function of training in B2. Conversely, for B5, presented in Figure 5, the relative rates of responding in the following component increased over sessions. The relative response rates in the following component for B7 is shown in Figure 6. For this subject, during the Gradual Manipulation, the relative response rate generally increased to high values until VI 4-min. was programmed in the variable component. When VI 5-min. was programmed in the variable component, generally the response rate in the following component decreased for the remaining sessions. One exception, as shown in Figure 6, was the final session of the Gradual Manipulation in which the relative response rate in the following component was markedly higher than most previous sessions. During the Abrupt Manipulation, the relative response rates in the following component initially increased and then subsequently decreased below baseline values for this bird. One additional finding observed from a comparison of changes in rates of responding between the following and preceding component is that for B7 the greatest increase in relative response rate oc-

curred in the preceding component. No consistent tendency was observed for the other birds.

As reinforcement frequency in the variable component decreased to VI 3-min., for B2 and B7, shown in Figure 4 and Figure 6 respectively, the relative response rate in this component fluctuated around the baseline value. Subsequent experimental conditions produced decreases in response rate in the variable component by these subjects. As shown in Figure 5, for B5, as the reinforcement frequency in the variable component decreased, the relative response rate in this component decreased under VI 1-min. and VI 3-min.; thereafter, the response rate increased for the remaining manipulations.

## Experiment 2

### Method

#### Subjects

Three pigeons from Experiment 1 served as subjects. Previous reinforcement history is detailed in the procedures of Experiment 1.

#### Apparatus

The apparatus used was the same as that described in Experiment 1.

#### General Procedure

All three Ss were sequentially exposed to two additional conditions: Baseline Recovery (Procedure 3) and Second Abrupt Manipulation (Procedure 4). As in Experiment 1, each session was 54 min. in duration and consisted of six regularly ordered presentations of three 3-min. components in the following sequence of key lights: green, red and white. Reinforcement consisted of 3.5-sec. access to mixed grain. All Ss were run on one experimental session per day, seven days a week. Occasionally, supplementary feedings were required to maintain the birds at 80% body weight. These were provided immediately following the test sessions. The experimental procedures for this experiment are summarized in Table 2.

Baseline Recovery: Procedure 3. At the end of the Abrupt Manipulation (Procedure 2), the schedule in effect was mult VI 1-min. VI 5-min. During Baseline

TABLE 2

## Sequence of Experimental Conditions

## EXPERIMENT 2

Subjects	Condition	Contingency	Number of Sessions
B2,B5,B7	Baseline Recovery: Procedure 3	VI 1 VI 1 VI 1	31
	Second Abrupt Mani- pulation: Procedure 4	VI 1 VI 5 VI 1	35

Recovery, each S was run on mult VI 1-min. VI 1-min. VI 1-min. for 31 days. The equipment malfunctioned during session 19 for bird B7, such that the reinforcement hopper was inoperative for an unknown portion of the session.

Second Abrupt Manipulation: Procedure 4. The two components for each bird which had the most similar value in absolute response rate for the last ten days of Baseline Recovery (Procedure 3) were designated as constant components. For birds B5 and B7, the redesignated preceding and following components were previously classified in Experiment 1 as the variable (VI 5-min.) and following (VI 1-min.) components, respectively. Using the same rule for reclassification, for B2 the redesignated preceding and following components were previously classified in Experiment 1 as the following (VI 1-min.) and variable (VI 5-min.) components, respectively. The preceding and following components remained fixed at VI 1-min. during this procedure. For each S, the remaining component was designated as the variable component. The variable component had been previously designated in Experiment 1 as the following component for birds B5 and B7, and the preceding component in B2, respectively. The schedule programmed in the variable component was VI 5-min. Construction in the lab generated unusually high noise levels which may have disturbed the bird B2 while sessions 6 and 8 were

were being run. To summarize, a three-ply-mult schedule, with two VI 1-min. components and one VI 5-min. component was programmed during the Second Abrupt Manipulation. This procedure was in effect for 35 days.

### Results

In Experiment 2, relative response rates in each component were computed as a percent change from the mean of the last ten sessions of Baseline recorded in Experiment 1.

#### Baseline Recovery (Procedure 3)

Figures 7, 8 and 9 show the relative rates of responding in each component during Baseline Recovery (Procedure 3) and Second Abrupt Manipulation (Procedure 4) of Experiment 2. The component names used in the figures represent the reclassification described above. Similar trends occurred in all three birds. Although there are individual differences among subjects, generally, during Baseline Recovery the rates of responding in all components was greater than during the original Baseline procedure (Experiment 1). For B2, as shown in Figure 7, the relative response rate in the preceding and following components increased from below baseline to above baseline values until session 14. Concurrently, the relative rate of responding in the variable component decreased progressively until session 7, and then continuously increased until session 14. After session 14, response rate in all components decreased. This

Figure 7. Relative response rate for B2 in each component during all sessions of Baseline Recovery (Procedure 3) and Second Abrupt Manipulation (Procedure 4). Relative response rates were computed as a percent change from the mean rate of the last ten sessions of baseline during Experiment 1. The abscissa represents the successive sessions of Procedure 3 and Procedure 4. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.



Figure 8. Relative response rate for B5 in each component during all sessions of Baseline Recovery (Procedure 3) and Second Abrupt Manipulation (Procedure 4). Relative response rates were computed as a percent change from the mean of the last ten sessions of baseline recorded in Experiment 1. The abscissa represents the successive sessions of Procedure 3 and Procedure 4. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

preceding ———  
variable - - - - -  
following .....  
B5

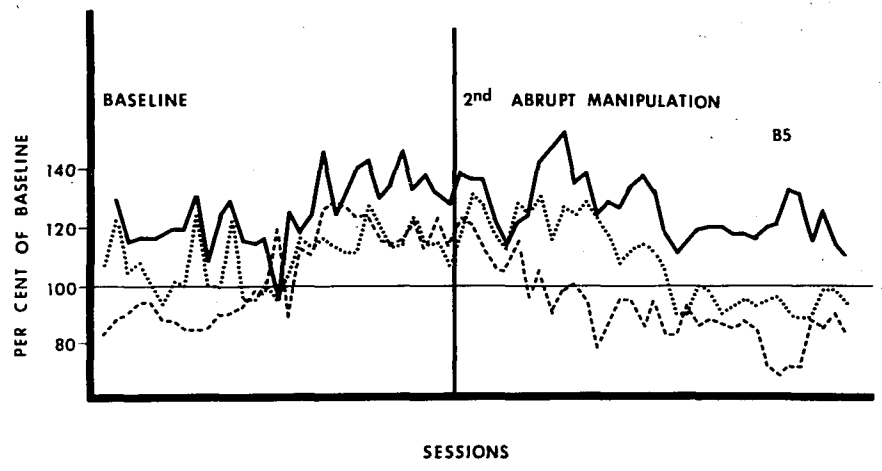
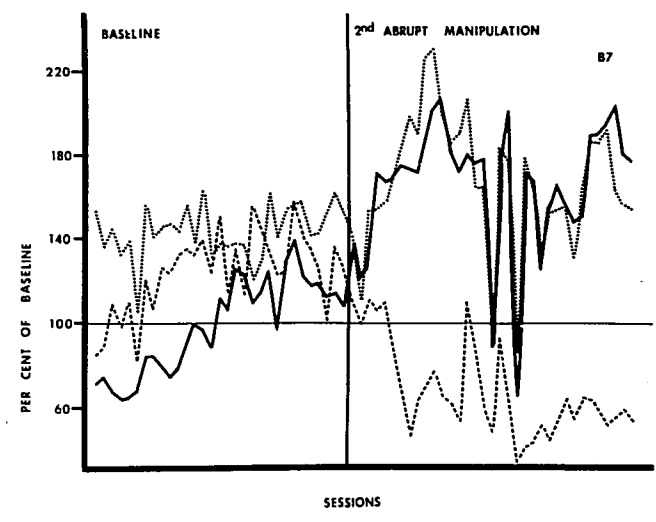


Figure 9. Relative response rate for B7 in each component during all sessions of Baseline Recovery (Procedure 3) and Second Abrupt Manipulation (Procedure 4). Relative response rates were computed as a percent change from the mean rate of the last ten sessions of baseline recorded during Experiment 1. The abscissa represents the sessions of Procedure 3 and Procedure 4. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

preceding —————  
variable - - - - -  
following .....



decline is most prominent in sessions 19 and 20 and the equipment malfunction during session 19 may have contributed to this decrease in response rate. In subsequent sessions, the rate of responding generally increased so that during the terminal session in Baseline Recovery (Procedure 3), the response rate in each component was elevated from the original baseline (Experiment 1) values.

Figure 8 shows the rate of responding in each component under Baseline Recovery recorded for B5. Response rate in the variable component increased from below baseline to above baseline values. The rate of responding in the preceding and following components that were initially above baseline values appear to increase as a function of training.

Figure 9 shows the rate of responding in each component under Baseline Recovery recorded for B7. The rates of responding in the preceding and variable components that were initially below baseline values continually increased so that in terminal sessions of this procedure, the response rate in both components were greater than baseline values recorded in Experiment 1. It appears as though the rate of responding in the preceding component varied around a level approximately 45% of baseline value. For all birds, the variability in response rate in the terminal sessions of Baseline Recovery was not greater than the mean rate  $\pm$  15% of the

of the last five days.

To summarize, during Baseline Recovery, generally, the rates of responding in all components was greater than during the original Baseline Procedure (Experiment 1).

#### Second Abrupt Manipulation (Procedure 4)

For B2, as shown in Figure 7, the rate of responding in all components initially decreased below baseline values in all components. The general trend observed in the terminal sessions of this procedure is that the response rate in the variable component decreased and response rate in the following and preceding components increased as a function of the number of sessions. This general trend is also characteristic of the performance of B7, presented in Figure 9, during the Second Abrupt Manipulation. As shown in Figure 8, for B5, response rate in the preceding and following component initially increased and subsequently decreased as a function of the number of sessions during the Second Abrupt Manipulation. In the variable component, the response rate generally decreased during the sessions.

A comparison between changes in rates of responding in all components under Baseline Recovery (Procedure 3) and Second Abrupt Manipulation (Procedure 4) is shown in Table 3. The data reported for each bird in Baseline Recovery represent the mean percent of baseline response rate in each component for the last ten

TABLE 3

Response Rate in each Component under Baseline Recovery  
and Second Abrupt Manipulation

Subject	Mean percent of baseline response rate			Procedure
	Preceding	Variable	Following	
B2	110	108	100	Baseline Recovery
	109	74	91	Second Abrupt Shift (first 10 sessions)
	141	86	133	Second Abrupt Shift (second 10 sessions)
B5	130	117	115	Baseline Recovery
	134	107	123	Second Abrupt Shift
B7	118	133	153	Baseline Recovery
	161	87	169	Second Abrupt Shift

sessions. Similarly, the data reported for B5 and B7 in the Second Abrupt Manipulation (Procedure 4) represent the mean percent of baseline response rate in each component for the first ten sessions. For B2, the mean data are reported for the first ten sessions and the second ten sessions during the second Abrupt Procedure (Procedure 4). As shown in Table 3, for B2 the mean percent of baseline response rate in all components during the first ten sessions decreased from the values recorded during this procedure; however, response rates recorded during the second ten sessions are consistent with the trend observed in the other birds. For all subjects during the Second Abrupt Manipulation, the mean rate in the variable component decreased and the mean rate in the preceding and following components increased over Baseline Recovery values. Further analysis of response rates show differences between the increases in the two constant components. For B2 and B7, greater increases occurred in the preceding vs. following components. For B5, greatest increases occurred in the following component.

## Experiment 3

### Method

#### Subjects

Three experimentally naive, mature, white, Carneaux male pigeons were maintained at  $80\% \pm 15$  gm. of ad libitum body weight. They were housed in separate cages in an animal vivarium and had continuous access to water.

#### Apparatus

The apparatus used was the same as that described in Experiment 1.

#### General Procedure

After magazine training and shaping to key peck, all three Ss were exposed sequentially to the following experimental conditions: Baseline Cyclical Manipulation (Procedure 5), Initial Abrupt Manipulation (Procedure 6), Baseline Recovery (Procedure 7), and Final Abrupt Manipulation (Procedure 8).

Baseline. Three pigeons were run on a three-ply-mult schedule of reinforcement, mult VI 1-min. VI 1-min., for 65 days. Each component in the mult schedule was of 3-min. duration and was differentially cued by either green, red or white key lights. Each session was 54 min. in duration and consisted of six regularly ordered presentations of the three components in the sequence of key lights noted above. Reinforcement consisted of 3.5-sec. access to mixed grain. All Ss were exposed to one experimental session per day, seven days a week. Occa-

sionally, supplementary feedings were required to maintain the birds at 80% body weight. These were provided immediately following the test sessions. The experimental procedures for this experiment are summarized in Table 4.

Cyclical Manipulation: Procedure 5. The two components for each bird which had the most similar values in absolute rate of responding for the last ten days of Baseline were designated as constant components. The constant components were VI 1-min. during this procedure. The remaining component was designated as the variable component. The experimental procedure consisted of a systematic reduction in reinforcement frequency in the variable component, from the highest value to the lowest value, in the following cyclical sequence of values: VI 1, VI 1.5, VI 2, VI 3, VI 5-min. Each VI value remained in effect for one session, such that at the end of the 5th session, all the Ss had been sequentially exposed to each of the five VI values. Each cycle in the Cyclical Manipulation consisted of one exposure to each of the five programmed VI values in the sequence of values as noted above. Thus, VI 1-min. immediately followed VI 5-min. of the preceding cycle. This procedure was in effect for 75 days and included 15 cycles.

Initial Abrupt Manipulation: Procedure 6. Immediately following Procedure 5, the birds were exposed

TABLE 4  
Sequence of Experimental Conditions  
EXPERIMENT 3

Subjects	Condition	Contingency	Number of Sessions
B3, B8, B9	Baseline	VI 1 VI 1 VI 1	65
	Cyclical Manipulation: Procedure 5	VI 1 VI 1 VI 1	1
		VI 1 VI 1 VI 1.5	1
		VI 1 VI 1 VI 2	1
		VI 1 VI 1 VI 3	1
		VI 1 VI 1 VI 5	1
		5 per cycle for 15 cycles	
	75 total		
	Initial Abrupt Manipulation: Procedure 6	VI 1 VI 1 VI 1	1
		VI 1 VI 1 VI 5	20
B3, B8	Baseline Recovery: Procedure 7	VI 1 VI 1 VI 1	18
B9	Baseline Recovery: Procedure 7	VI 1 VI 1 VI 1	19
B3, B8, B9	Final Abrupt Manipulation: Procedure 8	VI 1 VI 1 VI 5	16

to one session of mult VI 1-min. VI 1-min. VI 1-min. Thereafter, the component previously designated as the variable component was abruptly shifted from VI 1-min. to VI 5-min. The two remaining components, the constant components, remained at VI 1-min. so that the programmed schedule was a three-ply-mult schedule, with one VI 5-min. component (variable component) and two VI 1-min. components (constant components). This schedule remained in effect for 20 days.

Baseline Recovery: Procedure 7. Following Procedure 6, the variable component was shifted from VI 5-min. to VI 1-min. so that the programmed schedule was now mult VI 1-min. VI 1-min. VI 1-min. The reinforcement contingency was in effect until variability of response rate in each consecutive session was not greater than 10% of the mean of the last five sessions. This procedure remained in effect for 18 days for birds B3 and B8, and for 19 days for bird B9.

Final Abrupt Manipulation: Procedure 8. Similar to Procedure 6, in this procedure the previously designated variable component was abruptly shifted from VI 1-min. to VI 5-min. The two remaining components, the constant components, were VI 1-min., such that a three-ply-mult schedule, with one VI 5-min. component (variable component) and two VI 1-min. components (constant components), was the programmed contingency for 16 days.

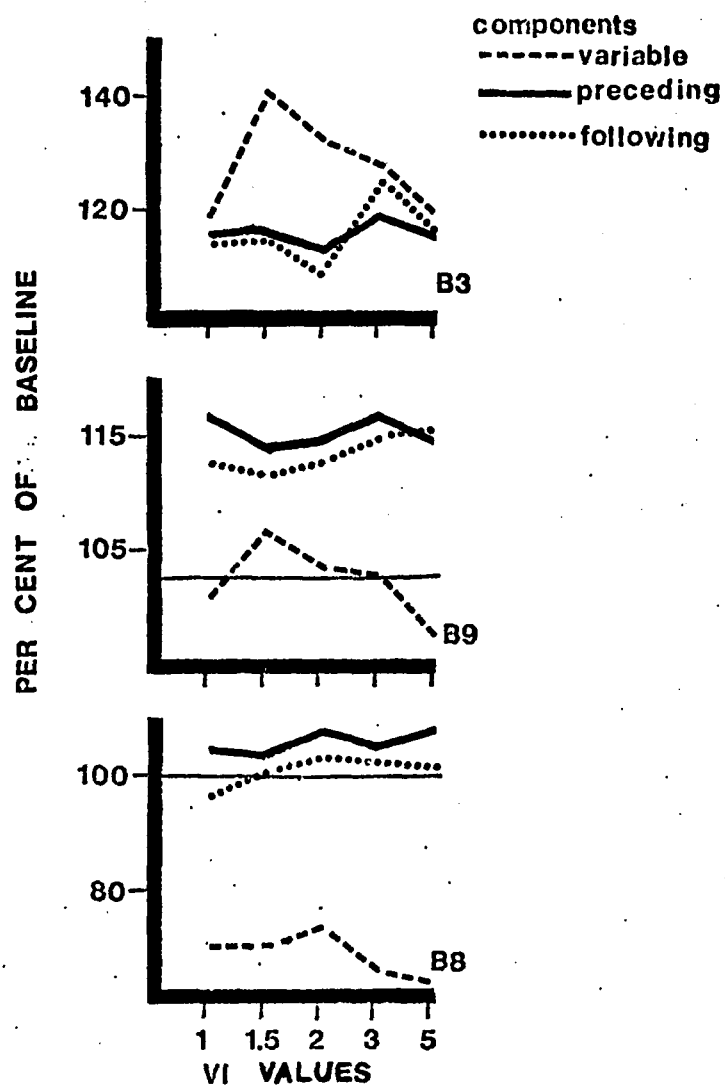
## Results

In Experiment 3, the relative rates of responding in each component during the Cyclical (Procedure 5), Initial Abrupt (Procedure 6), Baseline Recovery (Procedure 7) and Final Abrupt (Procedure 8) Manipulations are reported for each subject. The relative response rates for each bird in each component were computed as a percent change from the mean rate of the last ten sessions of Baseline, recorded in Experiment 3. This measure, the relative rate of responding, will be used in the experimental analyses. The changes in absolute response rate and relative response rate in this and subsequent experiments co-varied. The absolute rates of responding during the last ten days of Baseline are included in Appendix B.

### Cyclical Manipulation (Procedure 5)

The Cyclical Manipulation consisted of a systematic reduction in the reinforcement frequency in the variable component, from the highest value to the lowest value, in the following cyclical sequence of values: VI 1, VI 1.5, VI 2, VI 3, VI 5-min. Each cycle consisted of one exposure to each of the five programmed VI values, in the sequence of values noted above. The preceding and following components were VI 1-min. during this procedure. The mean relative response rate for the last six cycles of this manipulation are represented in Figure 10. For all birds, the mean response rate in the vari-

Figure 10. Mean relative response rate for the last six cycles of 15 cycles during Cyclical Manipulation (Procedure 5). Relative response rates are computed as a percent change from the mean of the last ten sessions of Baseline in Experiment 3. Each abscissa represents the VI values programmed in the variable component and the ordinates show the percent of baseline response rate. Note that there are different scales in the ordinates for the three birds. The horizontal line represents 100% of baseline response rate.



able component approximated an inverted "U-shaped" function. The mean rates of responding in the preceding and following components, for each subject, are similarly characterized as nonmonotonic functions. For B8 and B9, the relative rate of responding in the preceding and following components was higher than the relative response rate in the variable component. Conversely, for B3, relative rate of responding in the variable component was greater than the relative response rates in the preceding and following components.

The relative response rate in each component for the individual session of the last eight cycles under the Cyclical Manipulation (Procedure 5) are reported for each subject in Figures 11, 12 and 13. These figures show trends comparable to those shown in Figure 10 in that the relative response rates in the variable components are characterized by inverted "U-shaped" functions. No systematic functions in either the preceding or following components seems to emerge from this analysis.

Table 5 shows the mean number of responses emitted by each subject during the first within-session presentation of the variable component during cycles 8-14 and the mean number of responses during all variable component presentations during cycles 8-14. Equipment malfunction during cycle 15 prevented the calculation of the number of responses emitted by each subject during

Figure 11. Relative response rate for B3 for cycles 8 through 15 of the Cyclical Manipulation (Procedure 5). Relative response rates are computed as a percent change from the last ten sessions of Baseline recorded in Experiment 3. Columns represent the variable, preceding and following components. Rows represent the specified cycle of Procedure 5. The abscissas in the graphs are the programmed values in the variable component. The ordinate scale represents the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

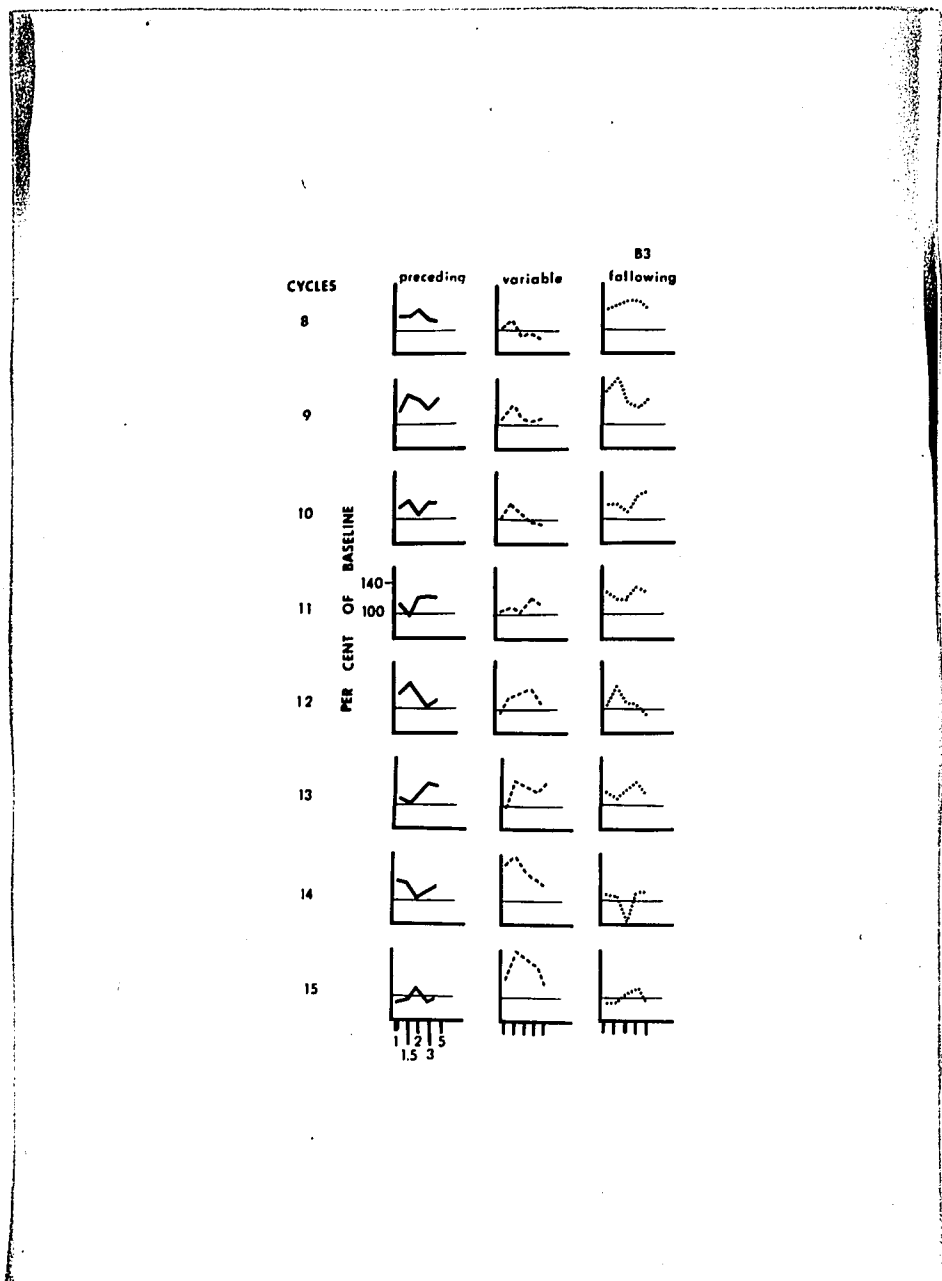


Figure 12. Relative response rate for B8 for cycles 8 through 15 of the Cyclical Manipulation (Procedure 5). Relative response rates are computed as a percent change from the last ten sessions of Baseline recorded in Experiment 3. Columns represent the variable, preceding and following components. Rows represent the specified cycle of Procedure 5. The abscissas in the graphs are the programmed values in the variable component. The ordinate scale represents the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

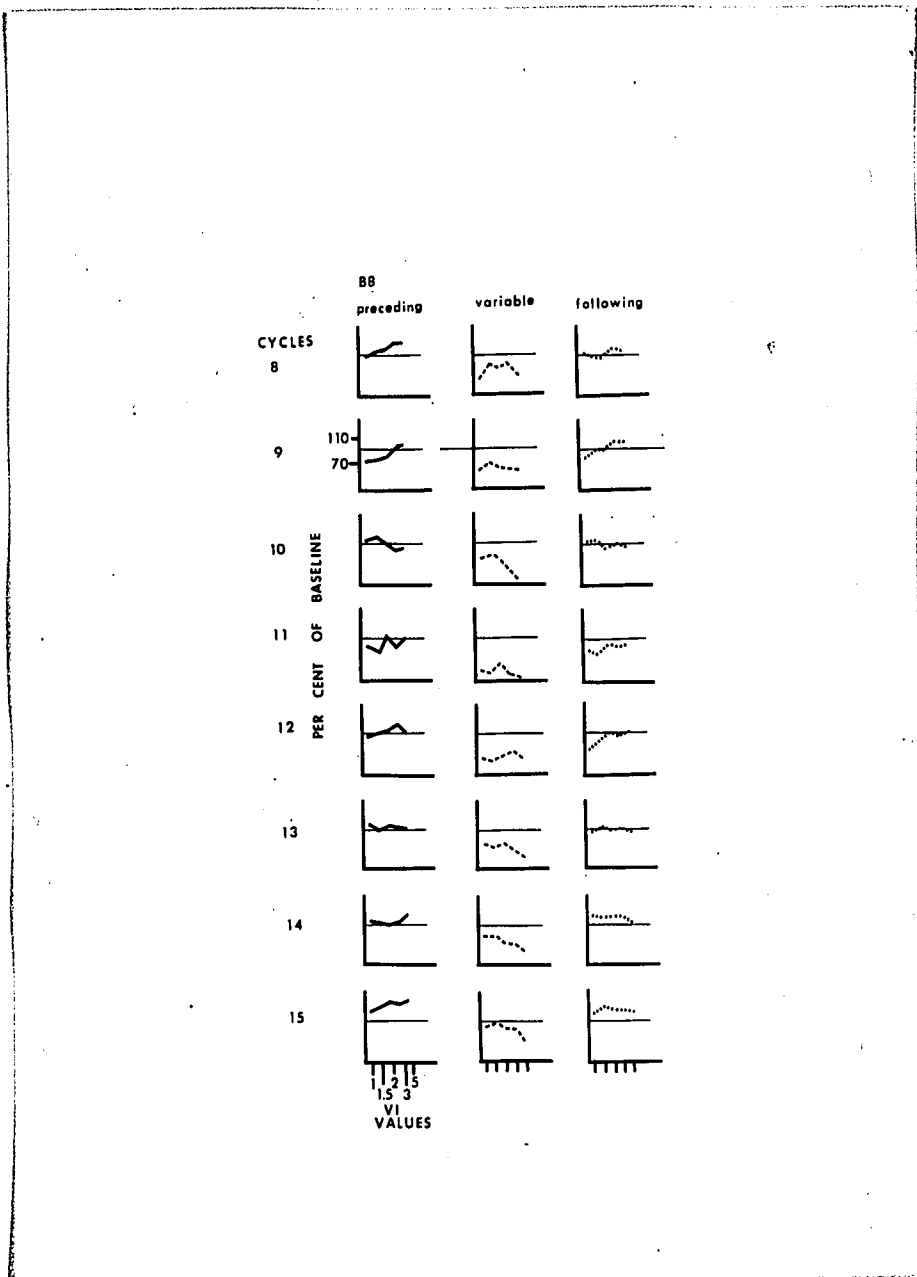


Figure 13. Relative response rate for B9 for cycles 8 through 15 of the Cyclical Manipulation (Procedure 5). Relative response rates are computed as a percent change from the last ten sessions of Baseline recorded in Experiment 3. Columns represent the preceding, variable and following components. Rows represent the specified cycle of Procedure 5. The abscissas in the graphs are the programmed values in the variable component. The ordinate scale represents the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

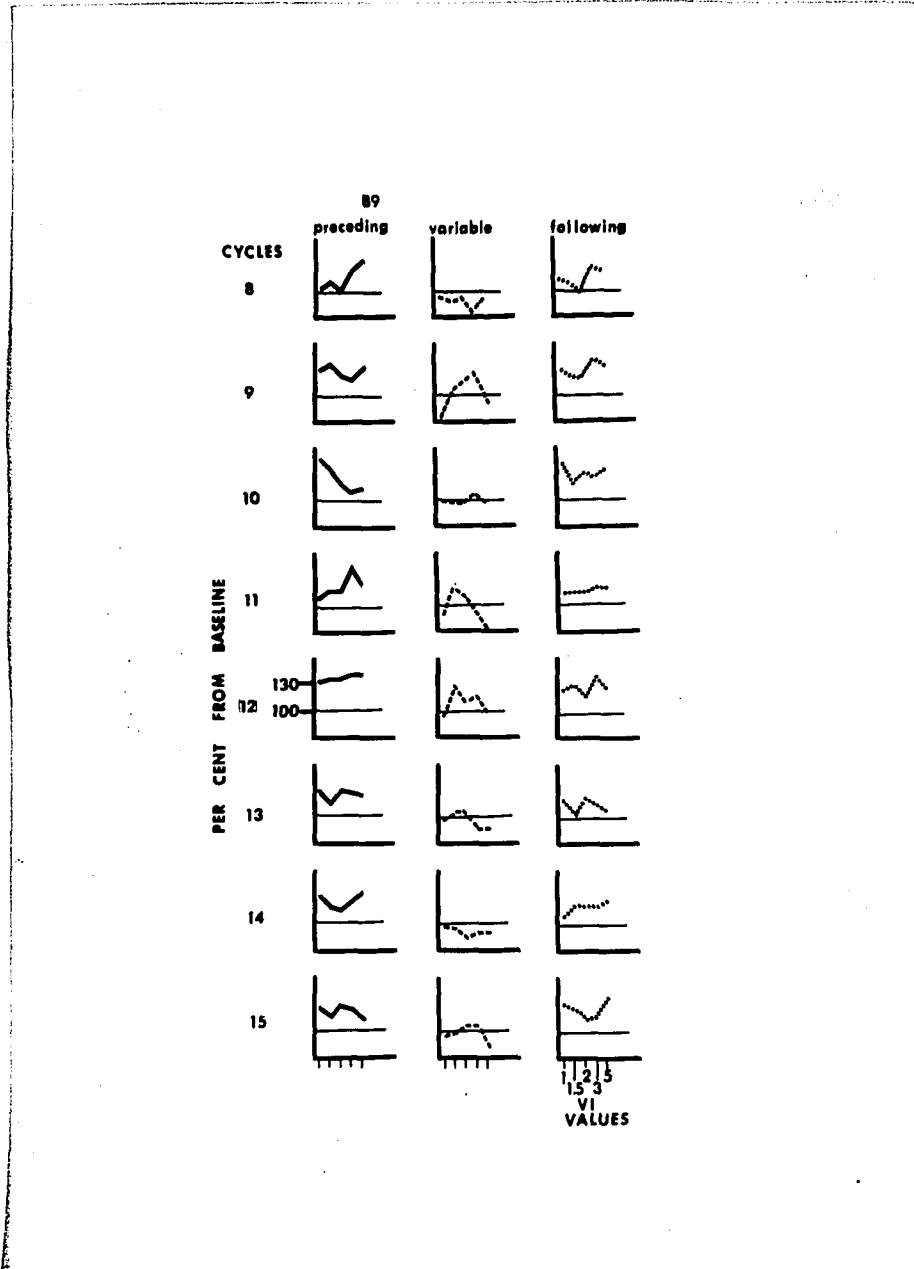


TABLE 5

Within-session and Total Session Response Rates in Variable Component

Subject	Cycle	Number of responses emitted in first presentation of variable component	Mean number of responses emitted for all variable-component presentations in the entire session
B8	8	130	182
	9	157	188
	10	184	210
	11	105	110
	12	156	169
	13	167	225
	14	252	192
B3	8	44	83
	9	57	93
	10	84	83
	11	72	86
	12	57	80
	13	79	95
	14	124	128
B9	8	117	74
	9	80	64
	10	89	88
	11	95	79
	12	70	89
	13	73	92
	14	93	86

the first within-session presentation of the variable component. When the variable component was VI 1-min., the schedule that was in effect was mult VI 1-min. VI 1-min. VI 1-min. As shown in Table 5, for B3 and B8 in six of seven cycles, fewer than the average number of responses in the session were emitted during the first presentation of the component. This was true in only two of seven cycles for B9.

#### Initial Abrupt Manipulation (Procedure 6)

During the Initial Abrupt Manipulation (Procedure 6), the variable component was changed from VI 1-min. to VI 5-min. VI 1-min. was programmed in the preceding and following components. The results produced by the Initial Abrupt Manipulation are shown in Figures 14, 15 and 16. A representation of the mean rate during each component of the last six cycles in the Cyclical Manipulation is included for each subject. This representation was included to facilitate comparisons between the results of the Cyclical Manipulation (Procedure 5) and the Initial Abrupt Manipulation (Procedure 6). As shown in Figure 15 for B8 and Figure 16 for B9, greater increases in relative response rate in the preceding and following components occurred in the Initial Abrupt vs. the Cyclical Manipulations. A similar comparison between response rates in the variable components reveals that for both B8 and B9, response rate was lower in the Initial Abrupt vs. Cyclical Manipulations. In Figure 14 for B3,

Figure 14. Relative response rates for B3 in each component during the Initial Abrupt Manipulation (Procedure 6). Relative response rates were computed as a percent change from the mean rate of the last ten sessions of Baseline in Experiment 3. The abscissa is successive sessions during the procedure. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate. In addition, the mean rate in each component during the last six cycles of the Cyclical Manipulation (Procedure 5) is indicated in each graph by three separate points. In Procedure 5, the mean rate in preceding, variable and following components are represented by an open circle, a filled-in circle, and a filled-in triangle, respectively.

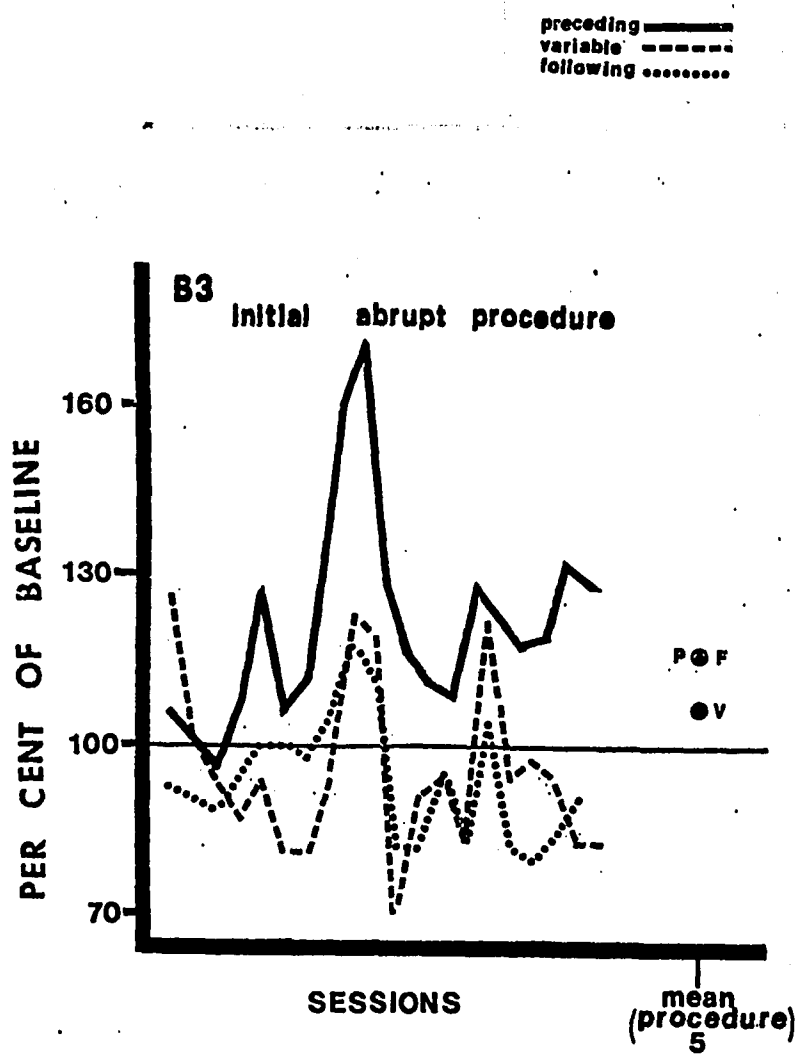


Figure 15. Relative response rates for B8 in each component during the Initial Abrupt Manipulation (Procedure 6). Relative response rates were computed as a percent change from the mean rate of the last ten sessions of Baseline in Experiment 3. The abscissa is successive sessions during the procedure. The ordinate scale is the percent of baseline response rate. Relative rates of responding in the preceding, variable and following components are represented by solid lines, broken lines, and dotted lines, respectively. In addition, the mean rate in each component during the last six cycles of the Cyclical Manipulation (Procedure 5) is indicated in each graph by three separate points. In Procedure 5, the mean rate in the preceding, variable, and following components are represented by an open circle, a filled-in circle, and a filled-in triangle, respectively.

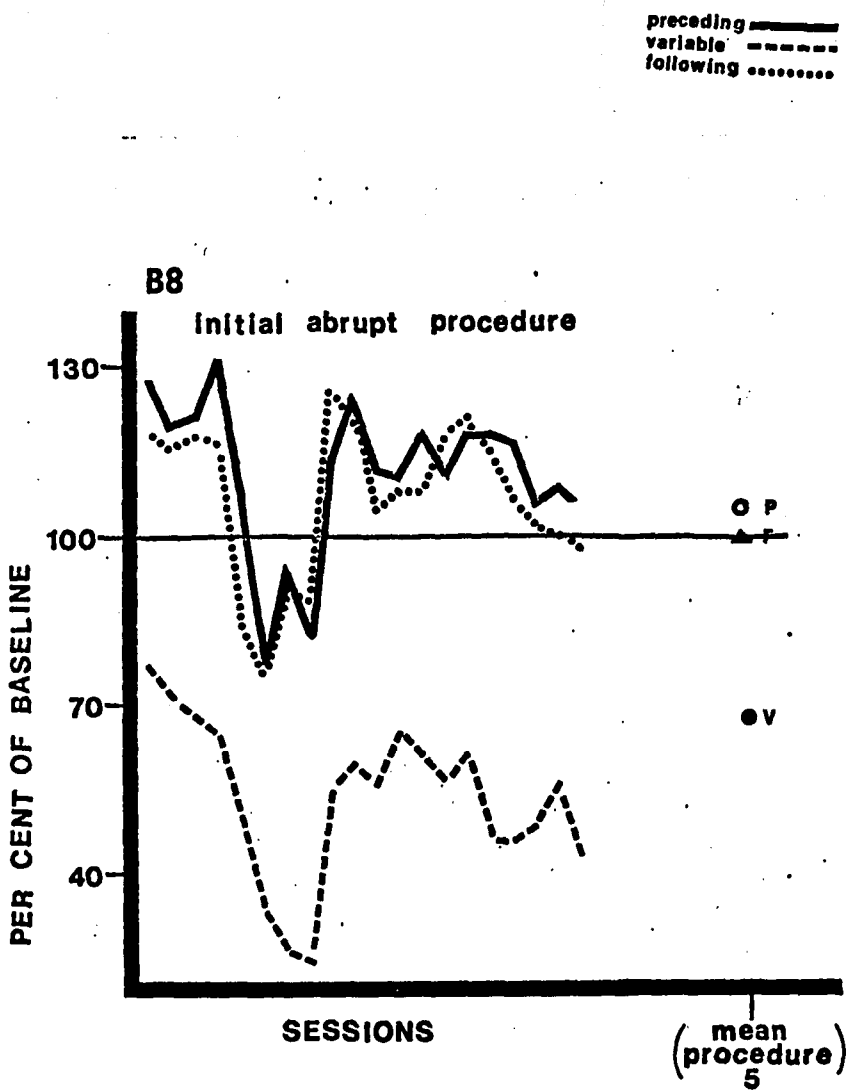
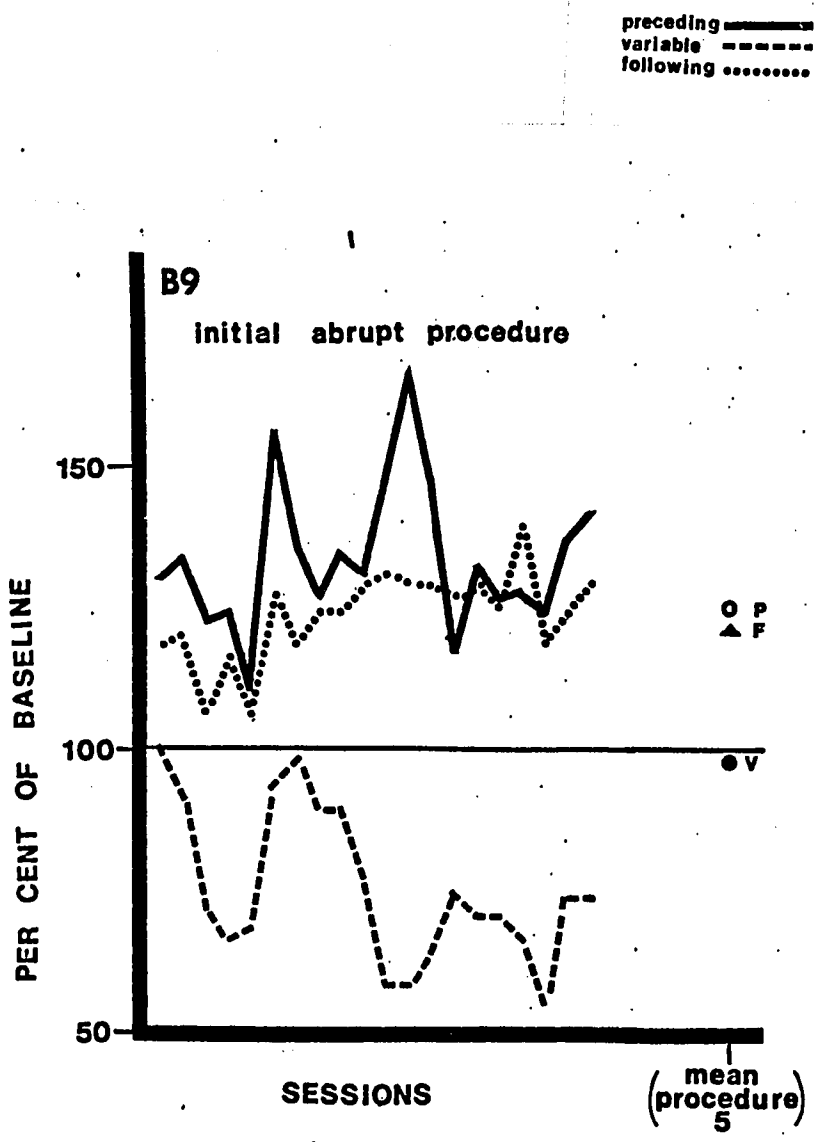


Figure 16. Relative response rates for B9 in each component during the Initial Abrupt Manipulation (Procedure 6). Relative response rates were computed as a percent change from the mean rate of the last ten sessions recorded during Baseline of Experiment 3. The abscissa is successive sessions during the procedure. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate. In addition, the mean rate in each component during the last six cycles of the Cyclical Manipulation is indicated in each graph by three separate points. In Procedure 5, the mean rate in the preceding, variable, and following components are represented by an open circle, a filled-in circle, and a filled-in triangle respectively.



response rate in the preceding component was greater in the Initial Abrupt vs. Cyclical Manipulations. In both the variable and following components, for B3, the response rates were lower in the Initial Abrupt vs. the Cyclical Manipulations.

To summarize the trends observed in the data, for all subjects relative response rates in the variable component were lower during the Initial Abrupt vs. the Cyclical Manipulations. In at least one of the two constant components, greater increases in relative response rate occurred in the Initial Abrupt Manipulation (Procedure 6) than the highest mean rate recorded in the Cyclical Manipulation (Procedure 5). Further analysis indicates that for two of three subjects, the greatest increases occurred in the preceding vs. following components.

#### Baseline Recovery (Procedure 7)

Figures 17, 18 and 19 show the relative response rates in each component during Baseline Recovery (Procedure 7) and Final Abrupt Manipulations (Procedure 8). During Baseline Recovery, the programmed contingency was VI 1-min. VI 1-min. VI 1-min. As shown in Figure 17, for B3, when the reinforcement frequency in the variable component was increased by reinstating VI 1-min., relative response rate in this component also increased. Concurrently, response rate in the preceding and following components initially increased and subsequently de-

Figure 17. Relative response rate for B3 in each component during Baseline Recovery (Procedure 7) and Final Abrupt Manipulation (Procedure 8). Relative response rates were computed as a percent change from the mean rate of the last ten sessions of Baseline recorded in Experiment 3. The abscissa shows the number of sessions in each procedure. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

preceding ———  
variable - - - - -  
following .....  
.....

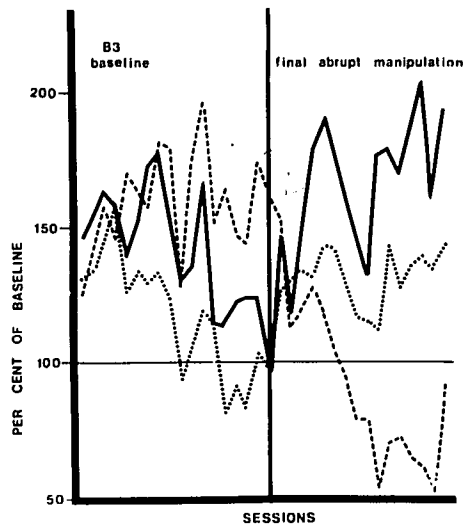


Figure 18. Relative response rate for B8 in each component during the Baseline Recovery (Procedure 7) and Final Abrupt Manipulation (Procedure 8). Relative response rates were computed as a percent change from the mean rate of the last ten sessions of Baseline recorded in Experiment 3. The abscissa shows the successive sessions in each procedure. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

preceding —————  
variable - - - - -  
following .....

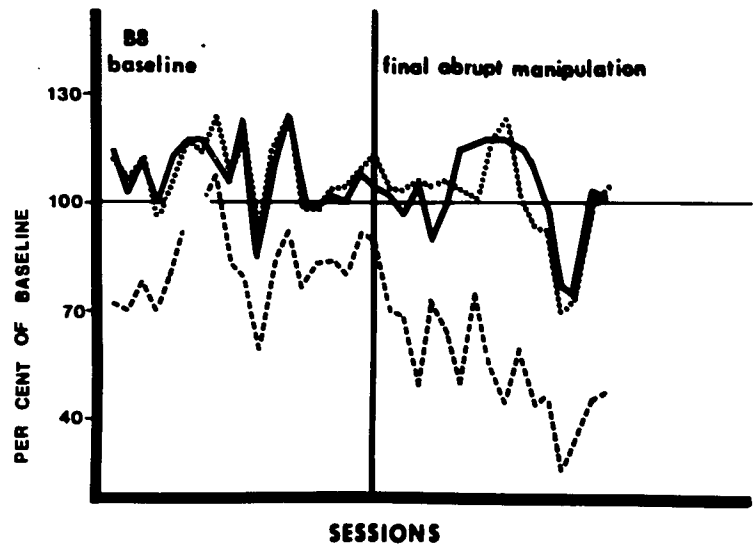
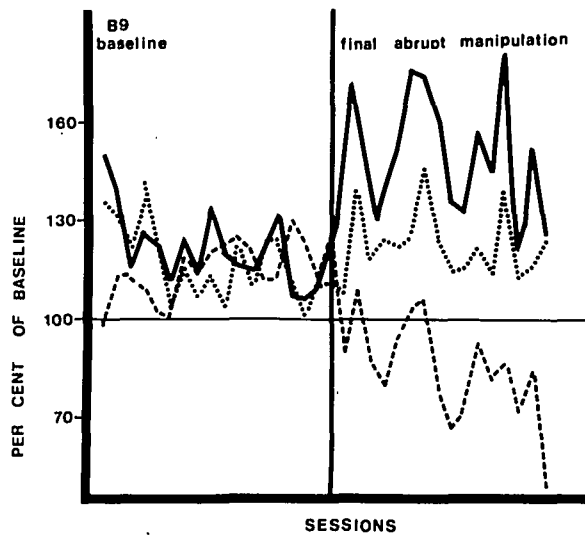


Figure 19. Relative response rate for B9 in each component during Baseline Recovery (Procedure 7) and Final Abrupt Manipulation (Procedure 8). Relative response rates were computed as a percent change from the mean rate of the last ten sessions of Baseline recorded in Experiment 3. The abscissa shows the successive sessions in each procedure. The ordinate scale is the percent of baseline response rate. The horizontal line represents 100% of baseline response rate.

preceding ———  
variable - - - - -  
following .....  
.....



creased as a function of training. This decrease in response rate in the constant components as the response rate in the variable component increased is known as negative contrast (Reynolds, 1961a).

In Figure 19, for B9, a small magnitude of change in response rate occurred in each component during Baseline Recovery. Moreover, during terminal sessions of this procedure, similar values of response rates that were greater than baseline values occurred in each component.

As shown in Figure 18, for B8, during Baseline Recovery the response rate in each component alternately increased and decreased as a function of experimental sessions. Generally, the response rates in the variable component were below baseline and the response rates in the two constant components were above baseline values.

Final Abrupt Manipulation (Procedure 8)

During the Abrupt Manipulation (Procedure 8), the schedule of reinforcement in the variable component was changed from VI 1-min. to VI 5-min. Reinforcement frequency was fixed at VI 1-min. for the two constant components. In Figure 17 and 19, for B3 and B9 respectively, as the response rate in the variable component decreased, the response rates in the alternated constant components increased. This phenomenon has been labeled behavioral contrast (Reynolds, 1961a). The magnitude of the change in response rate over baseline values appears

greater in the Final Abrupt vs. Cyclical Manipulations for both subjects. Further analysis of changes in response rate in the two constant components indicates that for both B3 and B9, as shown in Figures 17 and 19 respectively, greater increases occurred in the preceding vs. following components.

Data generated by B8, as shown in Figure 18, are more difficult to interpret. Response rates in the constant components during the Final Abrupt Manipulation (Procedure 8) are lower than the values recorded during Baseline Recovery (Procedure 7). Thus, this cannot be considered a true case of behavioral contrast.

To facilitate a comparison between the effects of the procedures, the mean rate of responding for the Cyclical, Initial Abrupt, Baseline Recovery and Final Abrupt procedures are presented in Table 6. The value reported in the Cyclical Manipulation represents the mean rate of responding during the last six cycles of this procedure. The values reported in Initial Abrupt, Baseline Recovery, and Final Abrupt Manipulations represent the mean rate of responding recorded during all sessions of the procedures. In summary, greater increases in both constant components in the Initial Abrupt vs. Cyclical Manipulations were demonstrated by B8 and B9. This trend is consistent in only the following components for B3. Behavioral contrast was demonstrated by two of three subjects during the Final Abrupt

TABLE 6

Response Rates in each Component in Experiment 3

Subject	Mean percent of baseline response rate			Procedure
	Preceding	Variable	Following	
B3	115	105	115	Cyclical shift
	121	96	94	Initial abrupt shift
	143	158	111	Baseline recovery
	166	91	131	Final abrupt shift
B8	105	68	100	Cyclical shift
	111	54	107	Initial abrupt shift
	107	83	109	Baseline recovery
	102	54	100	Final abrupt shift
B9	125	97	121	Cyclical shift
	133	75	123	Initial abrupt shift
	122	115	117	Baseline recovery
	150	84	123	Final abrupt shift

Manipulation, and these increases in response rate were greater when the reinforcement density was changed in one abrupt shift in schedule, as opposed to a progressive series of changes in the variable component (Cyclical Manipulation).

Each experimental manipulation produced differences in rates of responding between the preceding and following components. In general, greater increases in rates of responding occurred in the preceding component rather than the following component. During the Cyclical Manipulation (Procedure 5) for B8 and B9, the greatest mean percent increase in response rate occurred in the preceding component. The percent change in rate of responding in the preceding and following components were the same for B3. During the Initial Abrupt Manipulation (Procedure 6) for all subjects, greater increases in rates of responding occurred in the preceding component. During the Final Abrupt Manipulation for B3 and B9, greater increases in rates of responding occurred in the preceding components. For B8, during the Final Abrupt Manipulation, the response rates in both constant components were less than or equal to those rates produced by the Cyclical (Procedure 5) and Baseline Recovery (Procedure 7) Manipulations.

## Discussion

These three experiments provide evidence that the rate of change of reinforcement frequency is a fundamental parameter of behavioral contrast. The following discussion concerns four major findings of the experiments and the implications of these results.

### Gradual vs. Abrupt Changes in Reinforcement Density

Results obtained from two methods of gradually changing the reinforcement frequency from VI 1-min. to VI 5-min. in the variable component of a three-ply-mult schedule were compared with the effects of an abrupt shift from VI 1-min. to VI 5-min. in the same schedule. In general, a majority of Ss demonstrated greater increases in relative response rate in the fixed components with abrupt vs. gradual decrease in reinforcement frequency in the variable component. In Experiment 1, B2 and B7 demonstrated a greater increase in response rate during the Abrupt Manipulation (Procedure 2) rather than the Gradual Manipulation (Procedure 1). In Experiment 2, substantially greater increases in rates of responding occurred for each S in the Second Abrupt Manipulation (Procedure 4) than in any previous experimental conditions. This comparison is true for B2 for the mean of the second ten sessions during the Second Abrupt Manipulation (Procedure 4). During the first ten sessions of this procedure for B2, construction in the lab generated unusually high noise levels which may

have disturbed the bird. An inspection of Figure 4 shows that mean of the second ten sessions and not the first ten sessions was a more accurate representation of the subject's performance. The trend observed in the second ten sessions was consistent with the remaining sessions. In the third experiment, during the Initial Abrupt Manipulation (Procedure 6), greater increases in response rate occurred for each S than the mean rate of responding recorded during the Cyclical Manipulation (Procedure 5). The Final Abrupt Manipulation (Procedure 8) produced greater increases in response rate than in both Cyclical and Baseline Recovery (Procedure 7) procedures for two of three Ss. It appears, therefore, that rate of change of reinforcement frequency is an important parameter of interactive behavioral phenomena.

The differences between the Gradual or Cyclical Manipulations as compared to the Abrupt Manipulations are not in the final value of reinforcement frequency to which the organism was exposed, but rather the rate of change of the schedule of reinforcement. The Gradual or Cyclical Manipulations may be considered analogous to Terrace's "errorless" discrimination procedure (1963a). In "errorless" discrimination, the Ss are presented with a graded series of exposures to a stimulus correlated with S-. The errorless discrimination procedure produced a smaller contrast effect than discrimination with errors. Similarly, the Gradual

and Cyclical Manipulations in this series of experiments produced smaller increases in response rate than in the Abrupt Manipulations.

In a recent replication of Terrace's "errorless" discrimination experiment (1963a), Koderá and Rilling (1974)<sup>1</sup> reported findings similar to those in the present study. Contrary to Terrace's observations, Koderá and Rilling (1974) found that behavioral contrast reliably occurred in pigeons following "errorless" discrimination. Independent of the number of "errors" made by a pigeon in discrimination training, differential reinforcement procedures influenced the amount of behavioral contrast produced. Specifically, abrupt vs. gradual changes in the manner of introduction of the stimulus associated with S- produced a greater magnitude of behavioral contrast. This substantiates, in part, some of the findings in the present study in that the rate of change of stimulus conditions is a determinant of the magnitude of contrast effects.

Previous research in behavioral contrast has examined relative reinforcement frequency in the constant component (Reynolds, 1961a) and the reduction in rate

\* Koderá, T. L., & Rilling, M. Procedural antecedents of behavioral contrast: A reexamination of errorless learning. Journal of the Experimental Analysis of Behavior, submitted May 1974.

of responding in the variable component (Terrace, 1963a) as determinants of contrast. Gamzu and Schwartz (1973) suggest that positive contrast occurs because the multiple schedule interactions sets up conditions which produce "autoshaped" responses. Rachlin (1973) further suggests that these "autoshaped" responses occur as a function of component alternation. The present study neither refutes or supports any single explanation of contrast. Rather, the findings extend the analysis of multiple schedule interaction by demonstrating that the rate of change of reinforcement density is a fundamental parameter of contrast.

One interesting extension of the present study would be to examine the relative aversiveness of gradual and abrupt changes in reinforcement schedules. For example, using the concurrent chain procedure (Fantino, 1967), VI 1-min. would be programmed for both keys during the first component of the chain. Variable-interval 5-min. would be programmed in one of the second components of the chained schedule. The other second component would consist of the progressive sequence of VI values (VI 1, VI 2, VI 3, VI 4, VI 5-min.) programmed as in the Cyclical Manipulation of the present study. The findings reported here suggest that greater increases in response rate would occur in the first component of the chain in which the second component is programmed with the gradual manipulation in reinforce-

ment schedule.

The importance of the change in stimulus conditions has rarely been investigated, although it is a component of many experimental procedures. Two procedures under which abrupt vs. gradual changes in stimulus conditions have been examined are pseudoconditioning and punishment. Pseudoconditioning is the strengthening of a response to a previously neutral stimulus through the repeated elicitation of the response by another stimulus without the paired presentation of the two stimuli (Kimble, 1961). In their study of pseudoconditioning, Wickens and Wickens (1942) trained two different groups of rats to escape from shock which came on gradually for one group and abruptly for another. Each group was then subdivided and tested with a light that came on either gradually or abruptly. The majority of animals in the two groups where the test stimuli were similar in onset characteristics (sudden or gradual) demonstrated pseudoconditioning by performing the original response learned to escape shock. Wickens and Wickens (1942) suggested that pseudoconditioning may be a form of true conditioning where the response to shock is transferred to a light stimulus because of the similarity in the presentation of the stimulus conditions.

The importance of the manner of introduction of stimuli has been demonstrated using a punishment pro-

cedure. In this procedure, a specified response is followed by the presentation of a noxious stimulus (Kimble, 1961). The sudden introduction of punishment appears to have different effects than if punishment is increased gradually. For example, Masserman (1946) found that cats would continue to respond under severe punishment if the punishing stimulus had been introduced at a low intensity and increased over a period of time. Miller (1960) noted that less response reduction resulted from punishment if the intensity of the punishing stimulus was increased gradually over successive days than if it was introduced suddenly. In their study of multiple schedule interaction, Brethower and Reynolds (1962) reported that the initial introduction of high intensity punishment resulted in a decrease in relative response rate to minus 80% of baseline in one animal. An extension of the Brethower and Reynolds (1962) study in which shock intensity was increased gradually or abruptly might also provide evidence for this issue.

The findings of the present study and the pseudo-conditioning and punishment studies cited above suggest a widespread application of the rate of change of stimulus conditions to the analysis of many variables that are used in the prediction and control of behavior.

#### Baseline Recovery

During Baseline Recovery (Procedure 7 in Experiment 3), VI 5-min. VI 1-min. VI 1-min. schedule was

changed to mult VI 1-min. VI 1-min. VI 1-min. For B3, as the rate of responding in the variable component increased, the rate of responding in the alternated component decreased. This effect has been characterized as negative contrast (Reynolds, 1961a). Terrace (1968) reported a failure to find evidence of negative contrast when a mult VI 5-min. VI 5-min. schedule was changed to mult VI 5-min. VI 1-min. Similar to the findings of the present study, Terrace found that only one of three Ss demonstrated negative contrast. Reynolds (1961a) also reported that the magnitude of change in response rate in negative contrast was not as pronounced as the changes which characterized positive contrast.

According to Rachlin (1973), both positive and negative contrast can be explained by the same principles. Positive contrast is due to excited responses that are added to instrumental responses. Negative contrast is due to inhibited responses that are subtracted from the instrumental areas. Further research is needed to determine if positive and negative contrast can be considered to be a function of similar variables (e.g., relative reinforcement frequency) or a function of different variables (Dunham, 1968).

In both Experiment 2 and Experiment 3, baseline rates of responding were not recovered during the respective Baseline Recovery procedures (Procedure 3 and Procedure 7). Generally, the rates of responding were

higher in most components during Baseline Recovery than during previous baseline conditions. Two hypotheses can be advanced to account for the irreversibility of the effects of the changes in schedules of reinforcement. The first is that Baseline Recovery may not have been sufficiently extended. Thus, a transitional stage rather than a steady state of performance might have been reflected in the data. A second hypothesis is that irreversibility of effects may appear when there are concomitant changes in other dimensions of the behavior in addition to its rate of occurrence. For example, changes in intensive and topographical properties of responding due to adventitious reinforcement contingencies might account for a failure to recover baseline rates of responding. Adventitious reinforcement is the chance occurrence of a behavior immediately prior to the delivery of food. This chance correlation increases the subsequent rate of the adventitious reinforced behavior (Sidman, 1960). It is possible that high rates of responding under one procedure may be maintained under a different procedure due to adventitious reinforcement of the behavior.

Terrace's (1968) replication of Bloomfield's (1967) contrast study gives supporting evidence for the first hypothesis. Permanent contrast effects described by Bloomfield (1967) were found to disappear with the addition of the T0 procedure and extended training (60

sessions). This seems to suggest that the full effects of the change in reinforcement schedules be demonstrated with extended training. In Experiment 2 and 3 of the present study, the Baseline Recovery procedure remained in effect for 35 and 18 days, respectively. While it is possible that these data represent a transition between conditions, the variability of rate of responding in each consecutive session was not greater than 10% of the mean of the last five sessions. No consistent increasing or decreasing trend was observed in the data. The low percentage of variability implies that a steady state of performance was achieved during the terminal sessions of Baseline Recovery.

The second hypothesis suggests that the high relative rates of responding may have occurred during the Baseline Recovery procedures because of adventitious reinforcement of topographical variations of the response. Comparable findings reported by Boren (1953) suggest that variations in response topography persist throughout a baseline recovery procedure. Specifically, Boren examined fixed-ratio schedules of reinforcement, schedules under which reinforcement becomes eligible after the occurrence of a specified number of responses. The results indicate that as the response requirement was increased, in an ascending series, the response rate reached an asymptotic value. After maximal rate had been reached, Boren then reduced the size of the

fixed-ratio schedule. He found that some rats did not reproduce the quantitative performance shown in the original series. Further analysis of the organisms' behavior indicated that with the high ratio requirements, changes occurred in the topography of the animals' responses that maximized the rate of responding. Typically, at high ratio values the animals leaned against the chamber wall with their paws at the height of the lever, thus eliminating the necessity of rising up to the lever before making a response. In addition, some animals grasped the lever with their teeth and vibrated it at near the maximal rate possible. The failure to recover baseline rates of responding in the present experiment may represent a phenomenon similar to that reported by Boren (1953).

#### Cyclical Manipulation

During the Cyclical Manipulation (Procedure 5), the inverted "U-shaped" function in the variable component is at variance with the function predicted by data generated under VI schedules by Ferster and Skinner (1957). These investigators have shown that the rate of responding under a VI schedule is directly proportional to the rate of reinforcement. Based on these findings, response rates generated by the Cyclical Manipulation should be a negatively decelerated function of the programmed VI values (VI 1, VI 1.5, VI 2, VI 3, VI 5-min.), rather than the obtained inverted

"U-shaped function. For all Ss, the response rates under the last three VI values (VI 2, VI 3, VI 5-min.) progressively decreased. This substantiates the finding of Ferster and Skinner (1957) that rate of responding is proportional to the density of reinforcement. However, the present finding that response rates under the first VI values (VI 1, VI 1.5-min.) progressively increased is contrary to the function generated by the above authors. A closer examination of the cyclical procedure suggests a possible explanation of this result. Although the experimental procedure consisted of daily changes in the reinforcement schedule, the birds did not appear to immediately discriminate these variations. Rather, a "delay" seemed to occur such that the rates of responding in one session seemed to be influenced by the contingency programmed during the preceding session. Data recorded during the Cyclical Manipulation give support to a "delay" explanation of the "U-shaped" functions. In this procedure, VI 1-min. sessions were always preceded by a VI 5-min. session. Generally, low rates of responding occurred under VI 5-min., and this low rate seemed to persist through the early portions of exposure to VI 1-min. As shown in Table 5, two of three Ss emitted fewer responses during the first within-session presentation of this component compared with the mean number of responses for the entire session. Thus, the "U-shaped" function might have been generated

by the "delay" in the effects of the schedule change. It is also possible, however, that the "delay" effect is contaminated by a "warm-up" effect. Ferster and Skinner (1957) have shown that rate of responding during the first few minutes of exposure to a VI schedule is lower than the terminal response rate. To evaluate how much of the "delay" was influenced by the contingency programmed in the preceding session vs. a "warm-up" effect necessitates the examination of response rates under the first presentation of the other VI values (VI 1.5, VI 2, VI 3, VI 5-min.). Since the data in their present form do not lend themselves to this type of analysis, the "delay" explanation is included as a speculation.

The trends observed during the Cyclical Manipulation in the constant components are less conclusive. For two of three Ss, the systematic reduction of reinforcement frequency in the variable component produced greater rate increases in the constant components than in the variable component. This is consistent with the results reported by Reynolds (1961a) who found that reduction in the frequency of reinforcement in the variable component produced increases in rates of responding in the constant components.

#### Preceding vs. Following Components

Both the gradual and abrupt reductions of reinforcement frequency in the variable component produced

changes in rates of responding in the two constant components. In the Gradual and Abrupt Manipulations, greater increases in rates of responding occurred in the preceding component than in the following component.

The locus of contrast effects has been previously examined in multiple schedule interations. A related study of behavioral contrast (Nevin and Shettleworth, 1966) suggested that the rate of responding in a constant VI component of a multiple schedule depended upon the reinforcement frequency in the preceding component. Nevin and Shettleworth (1966) found that if the reinforcement frequency in the preceding component was higher than the constant component, the initial rate in the constant component was low and increased with time within sessions. Conversely, if the reinforcement frequency in the preceding component was lower than the constant component, the initial rate in the constant component was high and decreased with time within sessions. Terrace (1966) suggested that rate increases due to emotional effects depended on prior stimulation. In addition, Rachlin (1973) reported that the greatest rate increase occurred at the point of transition between a low density and high density component of a multiple schedule. The results of these studies suggest that greater increases in response rate should occur in the constant component that follows the variable component.

Although the results of the present study appear to contradict the findings reported by Nevin and Shettleworth (1966), several procedural differences existed between the two studies. In their study, an extinction component, a VI 1-min. component, and a VI 5-min. component were presented to the organism in a random alternation. In the present study, two VI 1-min. components and one VI 5-min. component were presented to the organism in a fixed alternation. The fact that greater increases occurred in the preceding vs. following component may be due to the regular order of presentation used in the present study. For example, it is possible that the preceding stimulus cued the lower density variable component. Facilitation in rate due to a "warning stimulus" has been previously demonstrated by Pliskoff (1966). In his study, two pre-schedule-change stimuli were superimposed on the same baseline. One warning stimulus preceded a transition into higher reinforcement frequency. It was found that response rate during the warning stimulus was greater preceding the transition to the lower reinforcement frequency than it was preceding the higher reinforcement frequency. Thus, rather than refuting Nevin and Shettleworth's (1966) research, the present study extends the experimental analysis of multiple schedule interaction.

#### Summary

Data generated under two methods of gradually re-

ducing the reinforcement frequency in the variable component of a three-ply-mult schedule were compared with the effects of an abrupt reduction in reinforcement frequency. In general, greater rate increases occurred in the two constant components under the procedures that abruptly reduced the reinforcement frequency in the variable component. Systematic analysis of the rate changes in the two constant components revealed that greater increases occurred in the preceding rather than following components.

These and other findings were discussed in view of data and experimental procedures in the current operant conditioning literature. Rather than supporting or refuting any single explanation of behavioral contrast, the present study extends the experimental analysis of this phenomenon by demonstrating that the rate of change in reinforcement density is a fundamental parameter of behavioral contrast.

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APPENDIX A

Absolute Response Rate Recorded during Baseline in Experiment 1  
(Number of Responses per Second)

	Bird B2			Bird B5			Bird B7		
	Pre.	Foll.	Var.	Pre.	Foll.	Var.	Pre.	Foll.	Var.
1	1.07	0.93	0.69	0.66	0.75	0.77	1.00	0.83	0.44
2	1.07	1.12	0.84	0.70	0.70	0.75	0.78	0.90	0.71
3	1.21	1.35	1.21	0.74	0.67	0.71	0.79	1.11	0.73
4	0.89	1.04	0.83	0.80	0.77	0.72	0.82	1.24	0.86
5	1.10	1.06	0.93	0.77	0.77	0.77	0.71	1.30	0.81
6	1.08	0.97	0.82	0.82	0.79	0.79	1.01	1.26	0.96
7	1.00	0.91	0.88	0.86	0.76	0.80	1.00	1.15	0.76
8	1.15	0.87	0.81	0.83	0.84	0.60	0.87	0.94	0.85
9	1.06	0.92	0.84	1.02	0.91	0.92	0.98	1.03	0.96
10	1.16	0.90	0.85	0.94	0.88	0.85	0.99	1.10	0.95
11	1.16	1.16	1.09	0.97	0.88	0.84	1.06	1.19	0.88
$\bar{X}$	1.09	1.02	0.86	0.83	0.79	0.78	0.91	1.10	0.81

APPENDIX B

Absolute Response Rate Recorded during Baseline in Experiment 3  
(Number of Responses per Second)

	Bird B3			Bird B8			Bird B9		
	Pre.	Foll.	Var.	Pre.	Foll.	Var.	Pre.	Foll.	Var.
1	0.57	0.74	0.60	1.14	1.25	1.38	0.53	0.66	0.67
2	0.57	0.57	0.53	1.67	1m69	1.78	0.64	0.61	0.60
3	0.58	0.53	0.48	1.58	1.53	1.67	0.60	0.59	0.57
4	0.79	0.69	0.52	1.87	1.65	1.88	0.50	0.48	0.44
5	0.68	0.60	0.45	1.64	1.62	1.64	0.47	0.43	0.47
6.	0.73	0.82	0.47	1.63	1.62	1.45	0.47	0.48	0.50
7	0.93	0.83	0.43	1.67	1.75	1.62	0.38	0.44	0.43
8	0.74	0.68	0.45	1.74	1.44	1.76	0.46	0.49	0.62
9	0.78	0.65	0.45	1.79	1.83	2.05	0.44	0.55	0.54
10	0.43	0.43	0.35	1.42	1.38	1.65	0.47	0.41	0.45
$\bar{X}$	0.68	0.65	0.47	1.62	1.58	1.69	0.50	0.51	0.60