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RESPONSES AND TIME IN A TWO-COMPONENT MULTIPLE
SCHEDULE OF REINFORCEMENT.**

**University of North Carolina at Greensboro,
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**BEHAVIORAL CONTRAST: DISTRIBUTION OF RESPONSES
AND TIME IN A TWO-COMPONENT MULTIPLE
SCHEDULE OF REINFORCEMENT**


by

Ronald Granger Hughes

**A Dissertation Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy**

**Greensboro
1974**

Approved by



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APPROVAL PAGE

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HUGHES, RONALD GRANGER. Behavioral Contrast: Distribution of Responses and Time in a Two-Component Multiple Schedule of Reinforcement. (1974) Directed by: Dr. Richard Shull. Pp. 58.

The concurrent properties of component performances on multiple variable-interval schedules of reinforcement were studied in six pigeons under conditions where pecks in each component of a two-component multiple schedule were reinforced according to concurrent schedules. The rationale for studying component performances within the context of a "multiple schedule of concurrent schedules" was based upon the assumption that within each component of a multiple schedule a certain proportion of the animal's time will be governed by the exteroceptive component stimulus of the multiple schedule while the remainder will be distributed among other concurrent response alternatives in direct proportion to their relative reinforcement value. Based upon this assumption, the present study sought to evaluate the hypothesis that behavioral contrast on multiple schedules results, at least in part, from a stimulus-specific shift in the reinforcement value associated with the unchanged component stimulus relative to the reinforcement value associated with stimuli occasioning other concurrent response alternatives.

In the present experiment, the red and green component stimuli of a two-component multiple variable-interval schedule alternated every 5-sec for one group of animals, every 30-sec for a second group, and every 180-sec for a third group. When the key light was red, pecks were reinforced according to a VI 2-min schedule of reinforcement. When the key light was green, pecks were reinforced according to one of the following schedules: EXT, VI 6-min, VI 2-min, or VI 30-sec. During the red and green illuminations, pecks on a second key illuminated with amber light were reinforced according to a VI 2-min schedule of reinforcement. The red and amber component stimuli and their associated schedules formed one

concurrent schedule; the green and amber component stimuli and their associated schedules formed a second concurrent schedule. Taken together, the two concurrent components of the multiple schedule formed a multiple-concurrent schedule designated as, mult (conc VI 2-min VI 2-min) (conc VI 2-min VI x).

Overall response rates in the red VI 2-min stimulus component of the multiple schedule were found to be inversely related to the number of reinforcements per hour in the alternated, green stimulus component. Furthermore, the slopes of power functions relating the ratio of overall response rates in red and green to the ratio of reinforcement rates in red and green were inversely related to the duration of stimulus components.

Changes in the number of reinforcements per hour in the green stimulus component of the multiple schedule produced two distinct effects upon the concurrent performances in the red-amber concurrent portion of the multiple schedule. First, the total number of responses emitted in red and amber was inversely related to the number of reinforcements per hour in green. Changes in the overall number of responses emitted in red and in amber were reflected in corresponding changes in the local response rates in red and in amber. Although changes in local response rates in the unchanged component of the multiple schedule were responsible in part for the corresponding changes in overall response rates, local response rates were unable to account for the effects of reinforcements in green upon the distribution of responses between the red and amber concurrent components, since relative local response rates in red and in amber did not deviate markedly from 0.50 throughout the experiment. Changes in the distribution of responses between red and amber were due to changes in the manner in which subjects allocated time to the red and amber stimuli. When the concurrent schedule associated with the unchanged stimulus component of the multiple schedule was conc VI 2-min VI 2-min, the proportion of

time that subjects allocated to red was inversely related to the number of reinforcements per hour in green. Changes in the proportion of time allocated to the red stimulus component of the multiple schedule occurred in the absence of changes in the obtained rate of reinforcement in red relative to the obtained rate in the amber concurrent component, and in the absence of any marked change in the relative local rates of responding in red and in amber.

While the inverse relationship between overall responses in the unchanged component of the multiple schedule and reinforcement rate in a second component supports the autoshaping account of behavioral contrast, the inverse relationship between reinforcements in one component and the proportion of time that the animal allocates to the unchanged stimulus component supports the hypothesis that behavior contrast is, at least in part, the result of a stimulus-specific shift in the reinforcement value associated with the unchanged component stimulus of the multiple schedule.

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INTRODUCTION

The study of multiple and concurrent schedules of reinforcement has demonstrated that the frequency of reinforcement in the presence of a given stimulus, relative to the frequency of reinforcement during all of the stimuli which simultaneously as well as successively control an organism's behavior, in part determines the rate of responding that the given stimulus controls (Reynolds, 1961; Catania, 1963, 1966; Lander and Irwin, 1968; Herrnstein, 1970; Hughes, 1970).

On concurrent schedules of reinforcement where two or more different reinforcement schedules operate simultaneously and where each is correlated with a different exteroceptive stimulus, the proportion of responses emitted in the presence of each stimulus will "match" the proportion of reinforcements obtained in the presence of each stimulus (Catania, 1966). This proportionality is expressed as

$$\frac{R_1}{R_1 + R_2 + \dots R_n} = \frac{r_1}{r_1 + r_2 + \dots r_n} \quad (1)$$

where R and r stand for responses and reinforcements, respectively, and where the subscripts denote the different components of the concurrent schedule. Response matching as defined in Equation (1) has been shown to be a byproduct of the manner in which the organism distributes its time between the various stimulus conditions of a concurrent schedule (Brownstein and Pliskoff, 1968; Baum and Rachlin, 1969; Brownstein, 1971).

On multiple schedules, however, where component stimuli and their associated schedules operate successively, the approximate proportionality between responses and reinforcements (see Reynolds, 1961; Lander and Irwin, 1968) must necessarily be obtained in a different manner, because the period of time that each stimulus is available on multiple schedules is determined by the experimenter and not by the subject. Consider, for example, a two-component multiple schedule of reinforcement in which the response key is alternately illuminated with red and green light and in which responses in the presence of each illumination produce access to grain on the average of once every three minutes (i.e., 20 reinforcements per hour). If the conditions are then changed so that one of the two schedules continues to provide 20 reinforcements per hour while the other now provides only 5 reinforcements per hour, the proportion of responses emitted in the presence of the stimulus correlated with the schedule providing 20 reinforcements per hour will increase in the absence of any change in the programmed rate of reinforcement.

A change in the rate of responding in an unchanged stimulus component of a multiple schedule when produced by a change in the reinforcement rate associated with a second component is called behavioral contrast (Reynolds, 1961). When response rate increases in the unchanged component following a decrease in the reinforcement rate associated with a second component, the increase in response rate is called positive contrast. When response rate decreases in the unchanged component following an increase in the reinforcement rate associated with a second component, the decrease is called negative contrast.

Behavioral contrast on multiple schedules differs from matching on concurrent schedules in that the proportionality between responses and reinforcements on multiple schedules is obtained in the absence of any direct change in the animal's distribution of time between the two component stimuli. At present, the process by which this proportionality is obtained under multiple schedules remains unclear. The following discussion treats, in turn, two interpretations whereby this proportionality is produced.

Interaction at a Distance

Herrnstein (1970) has attempted to show that the inverse relationship between responses and reinforcements on multiple and concurrent schedules can be derived from a single notion of response strength. For simultaneous choice situations (i.e., concurrent schedules), each source of reinforcement is assumed to exert a full effect on every response alternative. On multiple schedules where the various sources of reinforcement are not simultaneously operative, but rather operate in succession, reinforcement in one component is assumed to affect responding in other components by some fraction of its full effect. Herrnstein has expressed this relationship as

$$R_1 = \frac{kr_1}{r_1 + mr_2 + r_0} \quad (2)$$

where R stands for response rate, r for reinforcement rate, and m for a parameter which is free to vary between 0.0 and 1.0 depending upon the degree of interaction across components. The value of m is assumed to be 1.0 under concurrent schedules and to approach 0.0 under multiple

schedules when components alternate as rapidly as every five seconds (Shimp and Wheatley, 1971; Todorov, 1972; Killein, 1972). The term k is a constant of proportionality, while r_0 is a term denoting the extraneous reinforcement for responses other than those reinforced by the schedules in effect.

The effects of varying component duration upon the value of the right side of Equation (2) have been demonstrated in a number of studies. Shimp and Wheatley (1971) trained pigeons on two-component multiple variable-interval schedules of reinforcement in which the duration of components was either 0.80 or 0.20. As the component duration was shortened, the relative frequency of responding in a component approached a value equal to the relative frequency of reinforcement in that component. In a similar experiment by Todorov (1972), pigeons were trained on a mult VI 30-sec, VI 90-sec schedule of reinforcement where the average duration of exposure to each component stimulus was varied from 5 to 300 seconds. As the component duration was shortened, the relative frequency of responding in a component began to approximate the relative frequency of reinforcement in that component.

Data dealing with the process by which response matching is obtained under multiple schedules with short component durations has been presented by Killein (1972). In Killein's experiments, pigeons were divided into yoked pairs. The master bird in each pair was exposed to a two-component concurrent schedule of reinforcement where responses on a changeover key (see Findley, 1958) produced key color changes on a main key. Each key color on the main key was associated with its own

schedule of reinforcement. Schedules operated simultaneously, although only one stimulus was ever momentarily present on the main key. The yoked bird was located in a second chamber. Each changeover response by the master bird alternated the stimuli presented to the yoked bird. The yoked bird was thus on a multiple schedule in which the duration of each component stimulus was determined by the master bird on the concurrent schedule. When the component schedules were VI 40-sec and VI 120-sec, both birds matched the proportion of responses to the proportion of reinforcements. The basis for matching under these conditions was the distribution of time produced by the master bird on the concurrent schedule. The rate at which the multiple bird responded under these conditions was the same for both components.

In Experiment 2 in the series of experiments, changeovers were produced every 4.5 seconds independently of changeover responses on the part of the master bird. Yoked, multiple birds continued to match under these conditions but did so by either increasing or decreasing the rate at which they responded in the presence of each of the two component stimuli. While confirming the quantitative aspects of Herrnstein's "interaction at a distance" hypothesis (specifically, the role of component duration), Killein's data argue strongly that the process by which matching occurs on concurrent schedules and the process by which matching occurs under multiple schedules with short component durations are in principle different.

Herrnstein's interpretation of behavioral contrast incurs a major conceptual difficulty which follows from a consideration of the concurrent properties of single-key response rates. Herrnstein proposes

that as the overall rate of responding increases, animals do not respond "faster" but rather for a greater proportion of the time (see also Schoenfeld and Farmer, 1970). Conversely, when animals respond at a lower rate, they do not respond "more slowly" but rather spend more time engaged in behaviors other than those explicitly reinforced by the programmed schedule of reinforcement. For the pigeon, responses other than those reinforced by the food schedule might include such activities as grooming, foraging, etc. The reinforcement for such responses is represented collectively in Equation (2) as r_0 .

If positive behavioral contrast in the pigeon involves an increase in the relative reinforcement for pecking and a decrease in the relative reinforcement for behavior other than pecking, then one would expect to observe a change in the animal's distribution of time between pecking and these other activities. Such a shift, however, is not predicted on the basis of Equation (2). According to Equation (2), a decrease in the reinforcement rate in one component of a multiple schedule will produce an increase in the rate of all response alternatives controlled by successively available sources of reinforcement. Of particular interest in the analysis of behavioral contrast are the rates of various responses occurring in the unchanged stimulus component of the multiple schedule. In terms of Equation (2), the rate of occurrence of these responses may be expressed as

$$R_1 = \frac{kr_1}{r_1 + r_{0.1} + m(r_2 + r_{0.2})} \quad \text{and,} \quad R_{0.1} = \frac{kr_{0.1}}{r_1 + r_{0.1} + m(r_2 + r_{0.2})}$$

where R_1 stands for the rate of pecking and $R_{0.1}$ collectively for the rate of all behaviors other than pecking.

Assuming that behavior is continuous, and that a given behavior may be specified in terms of the proportion of time that it occupies as well as by its rate of occurrence, a given behavior can increase or decrease in rate only if it also increases or decreases in terms of the proportion of time that it occupies. The problem faced by Herrnstein's interpretation is therefore one of attempting to explain an increase in the overall number of pecks per unit time in the absence of any change in the overall proportion of time that pecking occupies. Although the value of r_1 increases with respect to the value of r_2 , r_1 does not change its value relative to $r_{0,1}$. Thus in the unchanged component of the multiple schedule if the proportion of time the animal spends pecking matches the relative reinforcement for pecking in that component, no increase in pecking can occur.

The Autoshaping Hypothesis

One way of interpreting an increase in pecking in the unchanged component of a multiple schedule in the absence of any change in the relative reinforcement for pecking in that component is to assume that the additional pecks are different, in kind, from the instrumental pecks maintained by the schedule of response-dependent reinforcement in effect. Several studies have shown that the presentation of food when combined with an appropriate state of food deprivation may directly enhance certain classes of behavior (specifically, pecking in pigeons) independently of, or in the absence of, any specific response-reinforcer dependency.

Brown and Jenkins (1968) showed that key pecking could be developed and maintained in the presence of a pre-food stimulus even though the delivery of food was independent of any response on the part of the organism.

Even when the presentation of food was cancelled by pecks during the stimulus, pecking was maintained by the occasional stimulus-food pairings (Williams and Williams, 1969).

Similar results have been obtained by Staddon and Simmelhag (1970) in a situation where the stimulus correlated with reinforcement was temporal rather than visual. Staddon and Simmelhag argued that when a specific dependency exists between a certain class of responses and the delivery of a reinforcer such as food, the presentation of food in the presence of a particular stimulus may serve not to increase the rate of occurrence of that response, but only to direct it toward the signal. To the extent that stimuli signaling changes in reinforcement conditions for pigeons are most frequently lighted response keys, pecks will be directed at the key.

Although autoshaping has become an area of study all its own, Gamzu and Schwartz (1973) have sought to point out its possible relevance to behavioral contrast. In experiments conducted by Gamzu and Schwartz, pigeons were exposed to multiple schedules of response-independent food presentations. The use of response-independent schedules allowed for the investigation of the effects of the stimulus-reinforcer dependency upon responding, independently of the normal response dependency found under multiple schedules of response-dependent reinforcement. It was observed that when the rates of reinforcement were the same in both components of the multiple schedule, little or no pecking occurred. Under conditions of equal reinforcement, component stimuli did not serve as effective signals. However, when the rates of reinforcement in the two components were different, pecking was maintained at a high

rate. Under the differential reinforcement conditions, each component stimulus was an effective signal by virtue of the fact that each was associated with a different conditional probability of food presentation. These data suggest that response rates on multiple schedules of response-dependent reinforcement might be composites of (1) instrumental pecks maintained by the response-reinforcer contingencies of the programmed schedule and (2) autoshaped responses maintained by the signaling properties of component stimuli when associated with different reinforcement probabilities (see Rachlin, 1973; Keller, 1974).

According to Rachlin's interpretation of the autoshaping hypothesis of behavioral contrast (Rachlin, 1973), the rate of instrumental responding in the unchanged component of a multiple schedule is unaffected by changes in reinforcement for responses in a second component. According to Rachlin, component duration operates not as a factor in determining the value of a parameter (e.g., m in Herrnstein's formulation) common to both multiple and concurrent schedules, but as a factor in determining the period of time over which successive performances will be sampled for recording purposes. According to Rachlin's interpretation of the autoshaping data, the excitatory and inhibitory effects associated with different values of reinforcement are transient. These effects are assumed to be maximal immediately following a transition from a stimulus signaling one reinforcement rate to a second stimulus signaling another rate. Short component durations thereby sample only the maximal excitatory and inhibitory effects.

Common to the interpretations of both Herrnstein and Rachlin is the assumption that the reinforcement for pecking in the unchanged

stimulus component of a multiple schedule relative to the reinforcement for behavior other than pecking is unaffected by changes in the reinforcement rates operating in successive stimulus components. For Herrnstein, this follows directly from Equation (2). For Rachlin, it follows from the partly untested hypothesis that behavioral contrast is to be explained solely as an autoshaping phenomenon, rather than as a shift in the reinforcement value for pecking in the presence of the unchanged stimulus component.

The present experiment sought data bearing upon the issue of a value shift in the unchanged component of a multiple variable-interval schedule. Specifically, the study sought to determine to what extent behavioral contrast in the unchanged stimulus component of a multiple schedule was due to (1) changes in the reinforcement for pecking relative to the reinforcement for a second concurrently available response, and/or to (2) changes in the local characteristics of component response rates.

Inasmuch as the present study investigated the reinforcing properties of component stimuli in terms of the animal's distribution of time between pecking and a second, concurrently available activity, the design allowed for a test of Herrnstein's hypothesis that contrast involves a change in the rate of all behaviors during the unchanged stimulus component in the absence of any change in the proportion of time occupied by each. Inasmuch, too, as the autoshaping hypothesis of contrast and Herrnstein's hypothesis make identical predictions regarding the invariance of the animal's distribution of time, the results bear upon the sufficiency of the autoshaping interpretation in accounting for the local characteristics of component performances on multiple variable-interval schedules.

METHOD

Subjects

Six adult pigeons, all with previous experimental histories, were maintained at approximately 80 percent of their free-feeding body weights throughout the course of the experiment. All animals were housed in individual cages with constant artificial illumination and free access to water.

Apparatus

A three-key experimental chamber similar to that described by Ferster and Skinner (1957) was used. Approximately .15 N (15 grams) of force was required to operate each of the response keys. Effective responses produced an audible click from a feedback relay mounted behind the stimulus panel. Response keys could be transilluminated with either red, green, or amber light. No house light was used. Reinforcement consisted of a 4-sec access to mixed grain for Birds RH-1, RH-2, RH-3, and RH-4, while a 3-sec access period was used for Birds RH-5 and RH-6 in order to keep body weights at approximately 80 percent \pm 15 grams. Daily sessions consisted of 60 reinforcements. Supplemental feeding outside the experimental session was kept to a minimum. Standard electromagnetic relay equipment was used to arrange events. All programming equipment was located in an adjoining room.

General Procedure and Rationale

In order to evaluate the hypothesis that behavioral contrast involves a stimulus-specific shift in the reinforcement value for pecking in the unchanged stimulus component of a multiple schedule, a two-component multiple schedule was arranged as a "multiple schedule of concurrent schedules" (Catania, 1961; Pliskoff, Shull, and Gollub, 1968). Each component stimulus of a two-component multiple schedule constituted one component of a concurrent schedule. The other component of each concurrent schedule was composed of a response-dependent schedule of food presentations and its associated exteroceptive stimulus. This schedule operated continuously and was therefore common to both concurrent schedules. Component schedules of the multiple schedule of reinforcement were correlated with red and green key color lights and ran only during those times when their correlated stimuli were present on the key. An amber key light was correlated with the common schedule. Reinforcements were made available in the presence of all illuminations according to variable-interval schedules of reinforcement. The red and green component stimuli of the multiple schedule alternated regularly every 5 sec for one group of animals, every 30 sec for a second group, or every 180 sec for a third group. No changeover delay was in effect.

The rationale for the multiple-concurrent schedule is as follows. It is assumed that on a simple multiple schedule of reinforcement the animal's behavior is governed not only by the exteroceptive stimulus in whose presence pecking is reinforced but also by stimuli (either interoceptive or exteroceptive) correlated with extraneous sources of reinforcement. Although pecking is the only behavior usually being recorded and

food is the only reinforcer being manipulated, this does not preclude the animal from engaging in behavior other than pecking.

In a simple multiple schedule, the concurrent properties of component performances are hypothetical. The present experiment sought to simulate the concurrent aspects of multiple schedule component performances by arranging a common variable-interval schedule of reinforcement for pecks occurring on a second manipulandum. If responses in one component of the multiple schedule produce reinforcements at the same rate as responses on the common schedule, responses and time will be equally distributed between the two. If changes in the reinforcement for pecking in one component of the multiple schedule produce changes in the relative reinforcement value for pecking in an unchanged component, the proportion of time that the animal spends engaged in pecking in that component will be affected. If the autoshaping interpretation of behavioral contrast is correct, a change in the reinforcement for pecking in one component of the multiple schedule will produce an inverse change in pecking both in the unchanged component stimulus of the multiple schedule and in the presence of the stimulus correlated with the common schedule. The autoshaping interpretation does not, however, predict a change in the animal's distribution of time and responses between the unchanged component stimulus of the multiple schedule and the amber stimulus of the common schedule. On the other hand, changes in the local rates of responding on both the multiple and the common key, as well as a shift in the proportion of time allocated to each, would reflect the operation of both processes (i.e., autoshaping and a value shift) in the generation of behavioral contrast.

In the present study, no attempt is made to argue for the representativeness of pecking as an arbitrary "other" behavior nor for food presentations as an arbitrary reinforcer for these behaviors. Food reinforced pecking was chosen as a behavior common to both components of the multiple schedule primarily on the basis of programming considerations and in order to overcome difficulties involved in dealing with responses of different topographies or qualitatively different reinforcers.

Specific Procedure

Preliminary Training: Initially the center key was transilluminated with white light and the two side keys were dark and inoperative. For one session, pecks produced food reinforcement according to a continuous reinforcement schedule (i.e., CRF). Following CRF training on the center key, the center key was darkened and covered for the remainder of the experiment. Ten sessions followed in which the subjects responded alternately to the left and right side keys. On even numbered sessions the right and left response keys were transilluminated with red light; on even numbered sessions, with green light. On a given day, either red or green appeared equally often in both left and right positions, alternating every 180 seconds. During this phase of preliminary training, responses in red and responses in green were reinforced according to variable-interval 2-min schedules of reinforcement. When a point was reached at which responding occurred readily to the illuminated key regardless of color or position, the previously dark key was transilluminated with amber light. The amber key now appeared concurrently with the red or green key. Responses in the presence of each illumination were reinforced according to variable-interval 2-min schedules of reinforcement. Separate

VI tapes were associated with red, green, and amber schedule components. Red and green stimulus conditions alternated every 180 seconds. The red/green key and the amber key alternated position (i.e., either left or right in the chamber) following reinforcements on the amber key. The multiple key (i.e., the red/green key) and the concurrent key (i.e., the amber key) thus alternated on the average of once every two minutes and over the course of a session appeared equally often in both left and right positions. The schedule in effect during this phase of training was designated as mult (conc VI 2-min, VI 2-min) (conc VI 2-min, VI 2-min). When responding was stable under the multiple-concurrent schedule, animals were placed into one of the following groups. For Birds RH-1 and RH-3, the red and green component stimuli of the multiple schedule alternated every 5 seconds, for Birds RH-2 and RH-4, the red and green component stimuli alternated every 30 seconds; and for Birds RH-5 and RH-6, component stimuli alternated every 180 seconds.

Baseline training: An extended period of baseline training was conducted for all animals prior to the first introduction of a change in the reinforcement rate associated with the green component stimulus of the multiple schedule. Stability of baseline performance was judged according to the following criteria: (1) relative response rates in the red-amber and the green-amber concurrent schedules approximated 0.50, (2) relative local response rates in each concurrent schedule approximated 0.50, and (3) relative time in each concurrent schedule approximated 0.50. In addition to initial baseline training a minimum of 10 daily sessions preceded each condition in which reinforcement rate was altered in the green stimulus component (S-2) of the multiple schedule.

Manipulation of Reinforcement Rates in the Green Stimulus Component:

The mean value of the VI schedule associated with the green stimulus component (S-2) of the multiple schedule was varied according to the sequence shown in Table 1. Throughout the sequence of manipulations shown in Table 1, the schedule of reinforcement associated with the common amber component was always VI 2-min. Neither was any change made in the schedule associated with the red, VI component of the multiple schedule. Thus the relative reinforcement rate for red during the red-amber concurrent portion of the multiple-concurrent schedule was always 0.50. Each condition was studied for a minimum of 10 consecutive sessions except where procedural errors caused this period to be shortened (see Table 1).

Omission of the Common Operant: Prior to the termination of the experiment proper, the amber concurrent key was darkened for Birds RH-1, RH-2, RH-3, and RH-4 so that the red and green component stimuli of the multiple schedule appeared in isolation on the left and right side keys. On alternate days, red appeared on the left key and green on the right. Approximately 10 sessions were conducted for each bird where the schedules associated with red and green were both variable-interval schedules with a mean of 2 minutes. For the 10 sessions that followed, reinforcement was discontinued in the green stimulus component. Responses in the red stimulus component continued to produce reinforcement according to a variable-interval 2-min schedule of reinforcement.

TABLE 1
ORDER OF SCHEDULE CONDITIONS IN THE GREEN
STIMULUS COMPONENT OF THE MULTIPLE
SCHEDULE

5-sec Component Duration		30-sec Component Duration		180-sec Component Duration	
RH-1	RH-3	RH-2	RH-4	RH-5	RH-6
VI 2-min (26)	VI 2-min (38)	VI 2-min (24)	VI 2-min (15)	VI 2-min (40)	VI 2-min (30)
VI 6-min (12)	VI 30-sec(15)	VI 30-sec(10)	VI 6-min (9)	VI 6-min (19)	VI 6-min (31)
VI 2-min (10)	VI 2-min (24)	VI 2-min (14)	VI 2-min (13)	VI 2-min (34)	VI 2-min (47)
VI 30-sec(16)	VI 6-min (11)	VI 6-min (18)	VI 30-sec(12)	VI 30-sec(10)	EXT (8)
VI 2-min (26)	VI 2-min (13)	VI 2-min (16)	VI 2-min (14)	VI 2-min (16)	VI 2-min (16)
EXT (12)	EXT (13)	EXT (10)	EXT (18)	EXT (10)	VI 30-sec(10)
VI 2-min (16)	VI 2-min (4)	VI 2-min (3)	VI 2-min (40)		
VI 2-min*(10)	VI 2-min*(10)	VI 2-min*(11)	VI 2-min*(10)		
EXT* (10)	EXT* (10)	EXT* (10)	EXT* (10)		

*Multiple schedule with common operant omitted.

RESULTS

In the present study, changes in the reinforcement rate associated with one component of a multiple schedule produced changes in the animal's performance in an unchanged component which can be characterized along three dimensions: (1) the concurrent properties of performances in the component of the multiple schedule in which reinforcement rate was directly manipulated, (2) response rates in the two stimulus components of the multiple schedule, and (3) the distribution of pecks and time between the common schedule stimulus and the stimulus correlated with the unchanged component of the multiple schedule. The first two aspects of the present performances deal with the functional equivalence of the multiple-concurrent schedule and simple multiple schedules; the last aspect deals with the question of a stimulus-specific shift in the reinforcement value associated with the unchanged component stimulus of the multiple schedule.

Concurrent Properties of Performances in the Component of the Multiple Schedule in Which Reinforcement Rate Was Directly Manipulated:

On a concurrent schedule of reinforcement, the relative number of responses that an organism emits in the presence of a given stimulus, and the relative time that the organism spends in the presence of that stimulus, closely approximate the relative number of reinforcements obtained in its presence. In the present study, each component stimulus of a multiple variable-interval schedule operated concurrently with a common, variable-interval schedule which provided reinforcements on the average of once

every two minutes. Figures 1.1 through 1.3 show the number of pecks emitted in the green stimulus component of the multiple schedule relative to the total number of pecks emitted in both the multiple and common schedule components during green as a function of the relative reinforcement rate during green. Data points represent the mean performance over the sixth through the tenth sessions of each condition. The diagonal line in each figure represents the hypothetical matching line. Points falling on this line indicate a direct proportionality between relative responses and relative reinforcements. When the relative number of reinforcements in the presence of the green stimulus component of the multiple schedule was equal to the relative number of reinforcements for the common operant, responses were evenly distributed between the two conditions. As the relative reinforcement for green decreased, the relative number of pecks emitted in green also decreased. The same relationship was observed between relative time in green and the relative reinforcement associated with green. The data clearly demonstrated that when reinforcement rate was changed in one component of a multiple schedule changes in response rate in that component were due to changes in the animals' distribution of time between pecking governed by the component stimulus of the multiple schedule and pecking governed by the common schedule stimulus. To the extent that the common schedule simulates extraneous sources of reinforcement operating within multiple schedules, directly produced changes in the reinforcement in one component of a multiple schedule alter responding in that component by altering the reinforcement for pecking relative to the reinforcement for behaviors other than pecking.

Figure 1.1 Relative Response Rate and Relative Time in the Green Stimulus Component of the Green-Amber Concurrent Schedule as a Function of the Relative Reinforcement Rate in Green. Duration of Multiple Schedule Components Equals 5-sec.

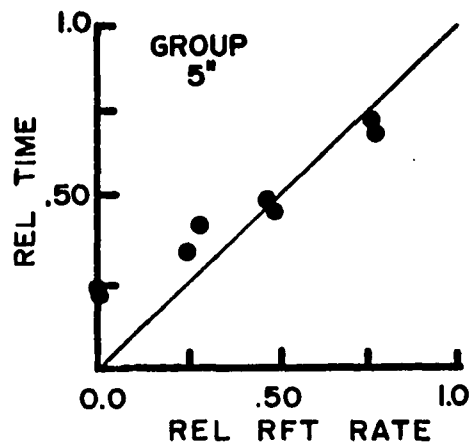
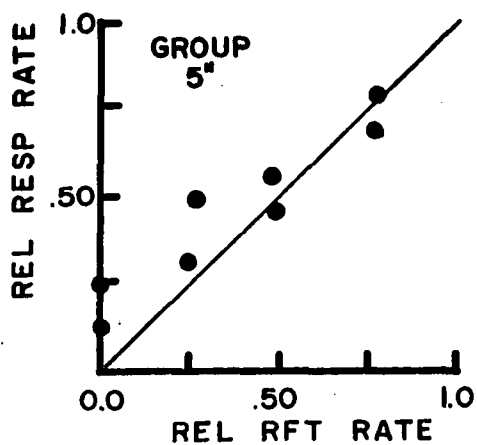
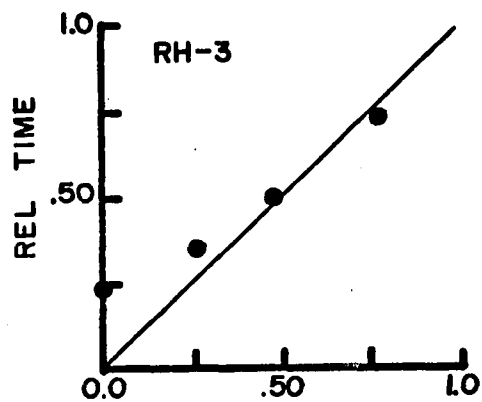
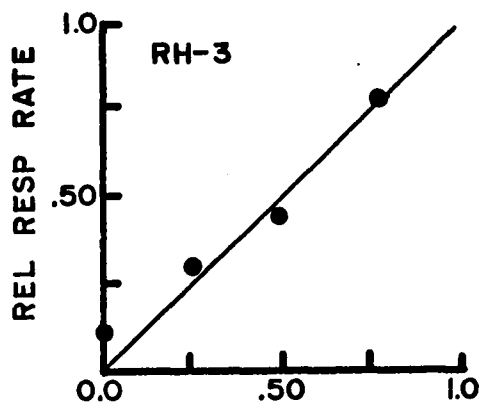
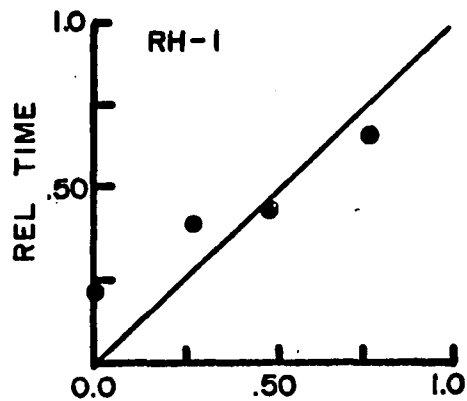
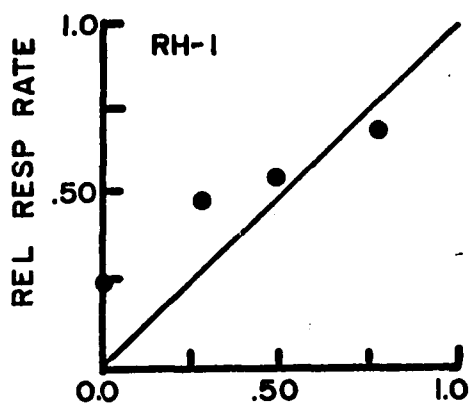


Figure 1.2 Relative Response Rate and Relative Time in the Green Stimulus Component of the Green-Amber Concurrent Schedule as a Function of the Relative Reinforcement Rate in Green. Duration of Multiple Schedule Components Equals 30-sec.

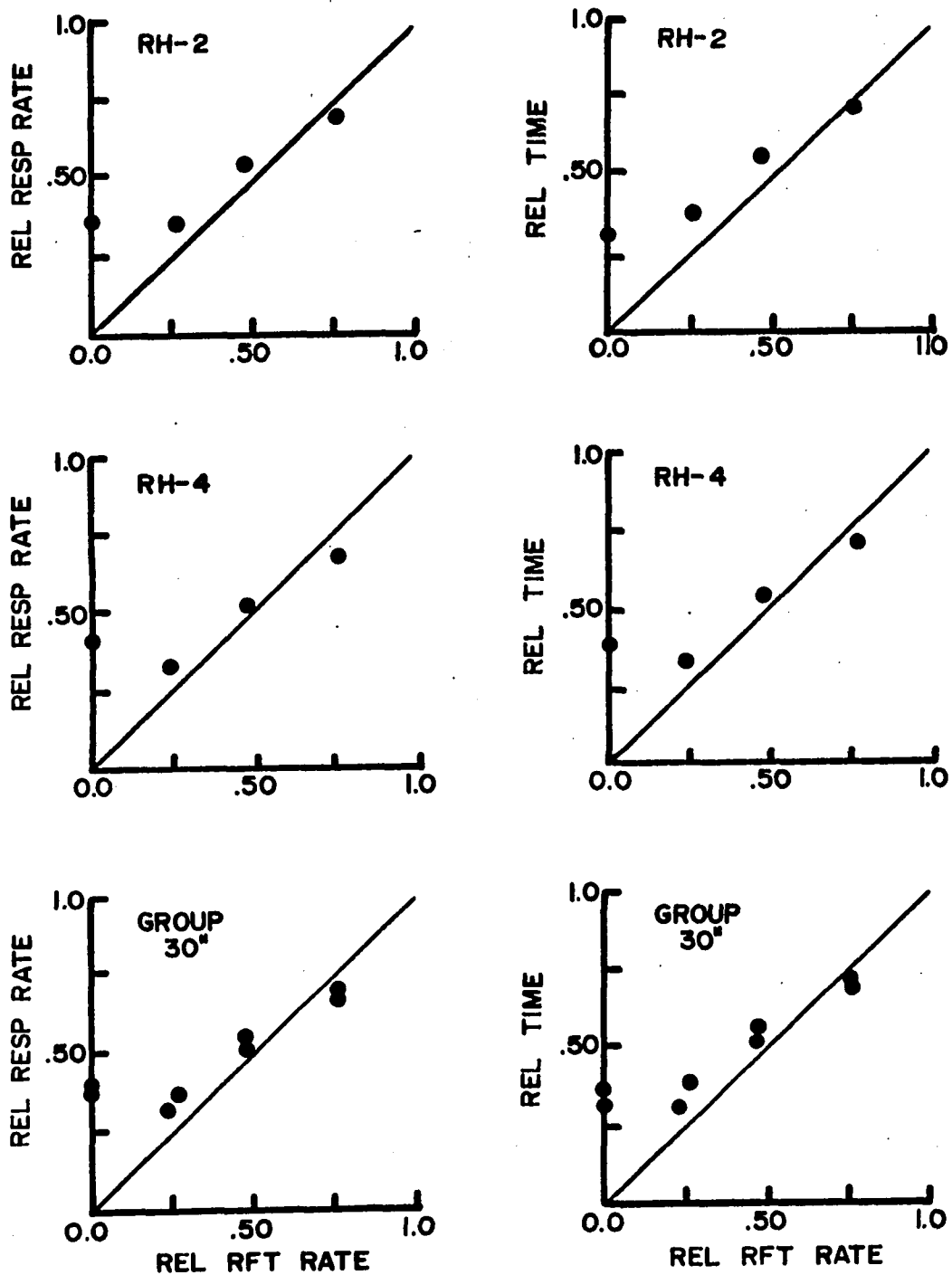
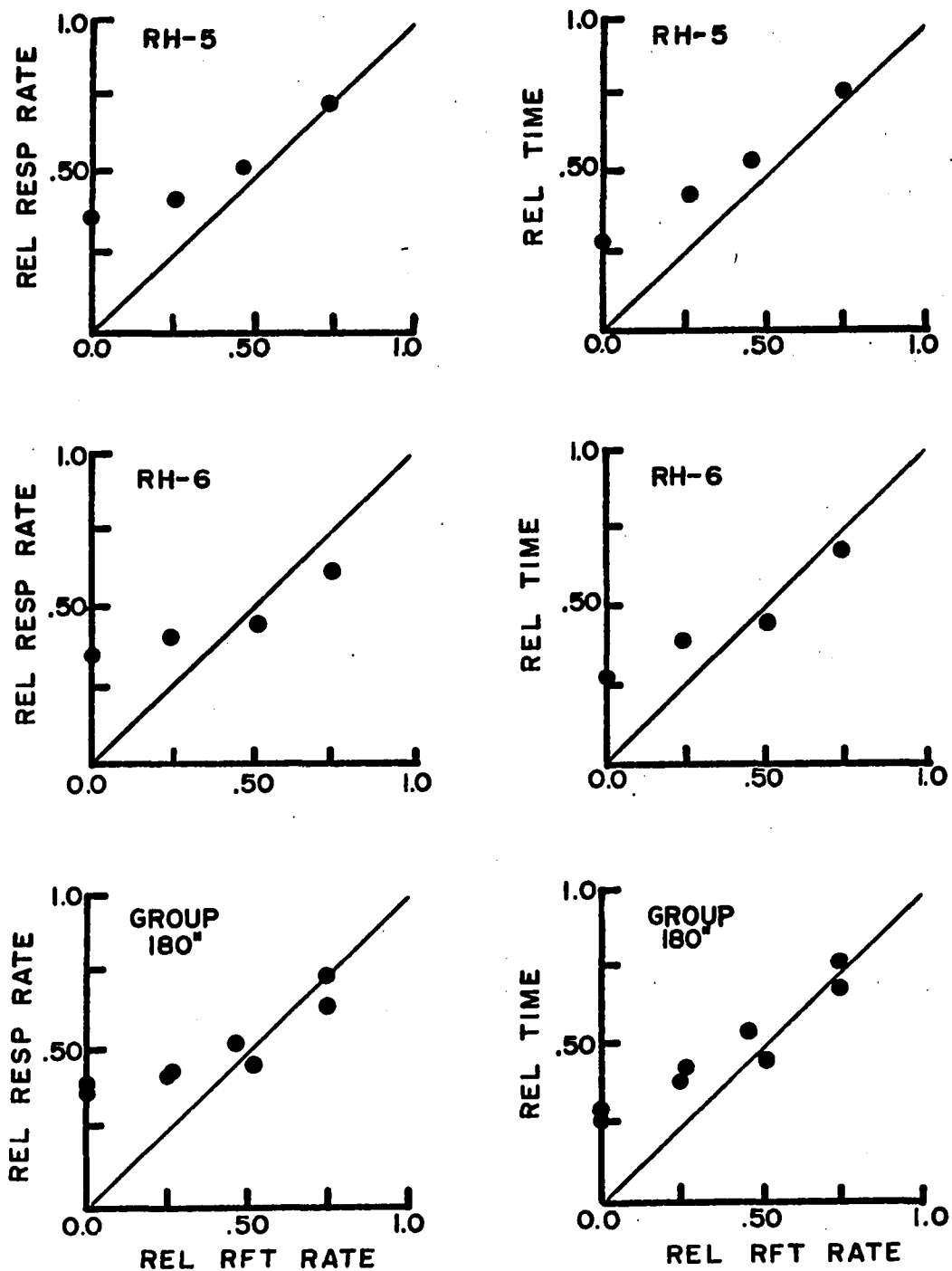


Figure 1.3 Relative Response Rate and Relative Time in the Green Stimulus Component of the Green-Amber Concurrent Schedule as a Function of the Relative Reinforcement Rate in Green. Duration of Multiple Schedule Components Equals 180-sec.



The orderliness of the concurrent performances in the stimulus component of the multiple schedule in which reinforcement rate was manipulated not only supports the assumptions of the multiple-concurrent model of simple multiple schedule performances, but shows that the concurrent properties of these performances are maintained under conditions in which the component stimuli of the multiple schedule alternate as frequently as every 5 seconds.

Response Rates in the Two Stimulus Components of the Multiple Schedule

Figures 2.1 through 2.6 show the individual daily performances of all subjects for the first 10 sessions under each of the three different schedule conditions. For each subject, overall response rate, local response rate, and time in the multiple schedule have been normalized with respect to the mean performance for that animal obtained under the last five days of the preceding baseline period. Normalization was accomplished by dividing each successive day's performance by the mean performance index obtained during the last five days of the preceding baseline period. Thus, a normalized performance value of 1.0 indicates that no change occurred in S-1 (the unchanged stimulus component) following a change in the reinforcement rate in S-2 of the multiple schedule. Normalized values less than 1.0 indicate a decrease relative to the preceding baseline period, and a value greater than 1.0 indicates an increase relative to the preceding baseline period. Examination of Figures 2.1 through 2.6 reveals the following with respect to overall response rate, local response rate, and proportion of time spent in components S-1 and S-2 of the multiple schedule.

Overall Response Rates: Overall response rate is defined in terms of the number of responses emitted in the presence of a given

Figure 2.1 Normalized Daily Performances for Bird RH-1 in the Red and Green Components of the Multiple Schedule When Component Duration is 5-sec.

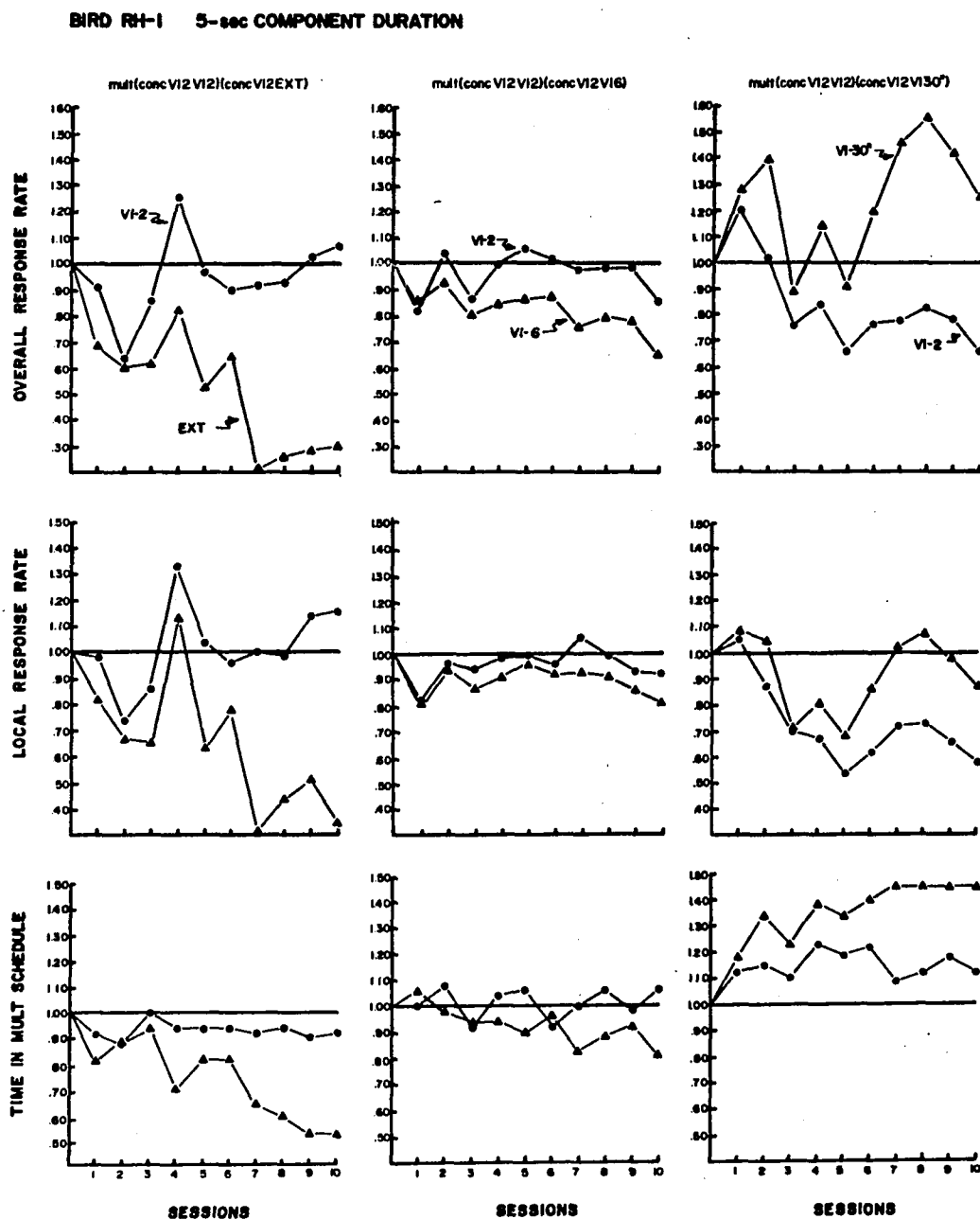


Figure 2.2 Normalized Daily Performances for Bird RH-3 in the Red and Green Components of the Multiple Schedule When Component Duration is 5-sec.

BIRD RH-3 5-sec COMPONENT DURATION

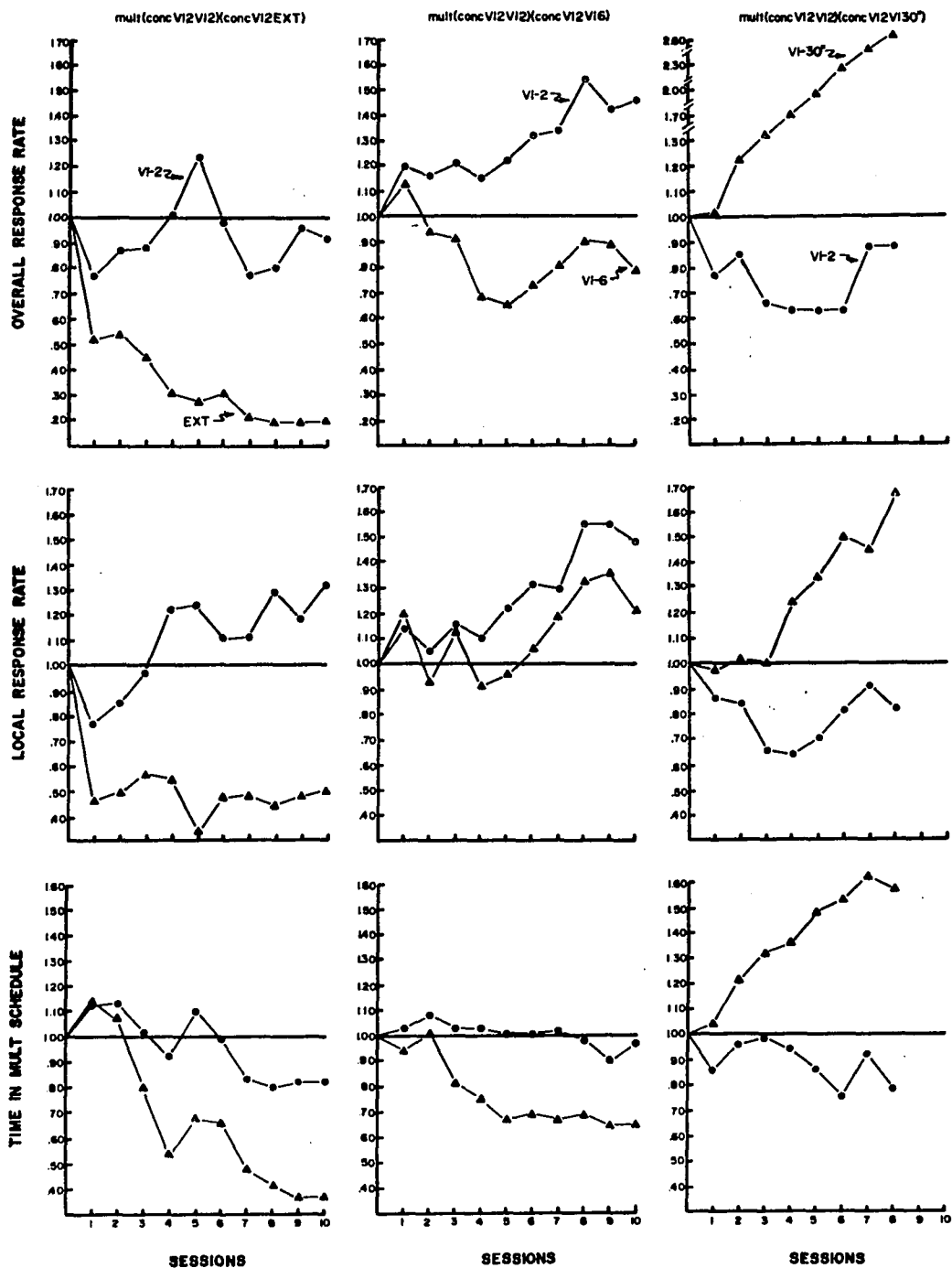


Figure 2.3 Normalized Daily Performances for Bird RH-2 in the Red and Green Components of the Multiple Schedule When Component Duration is 30-sec.

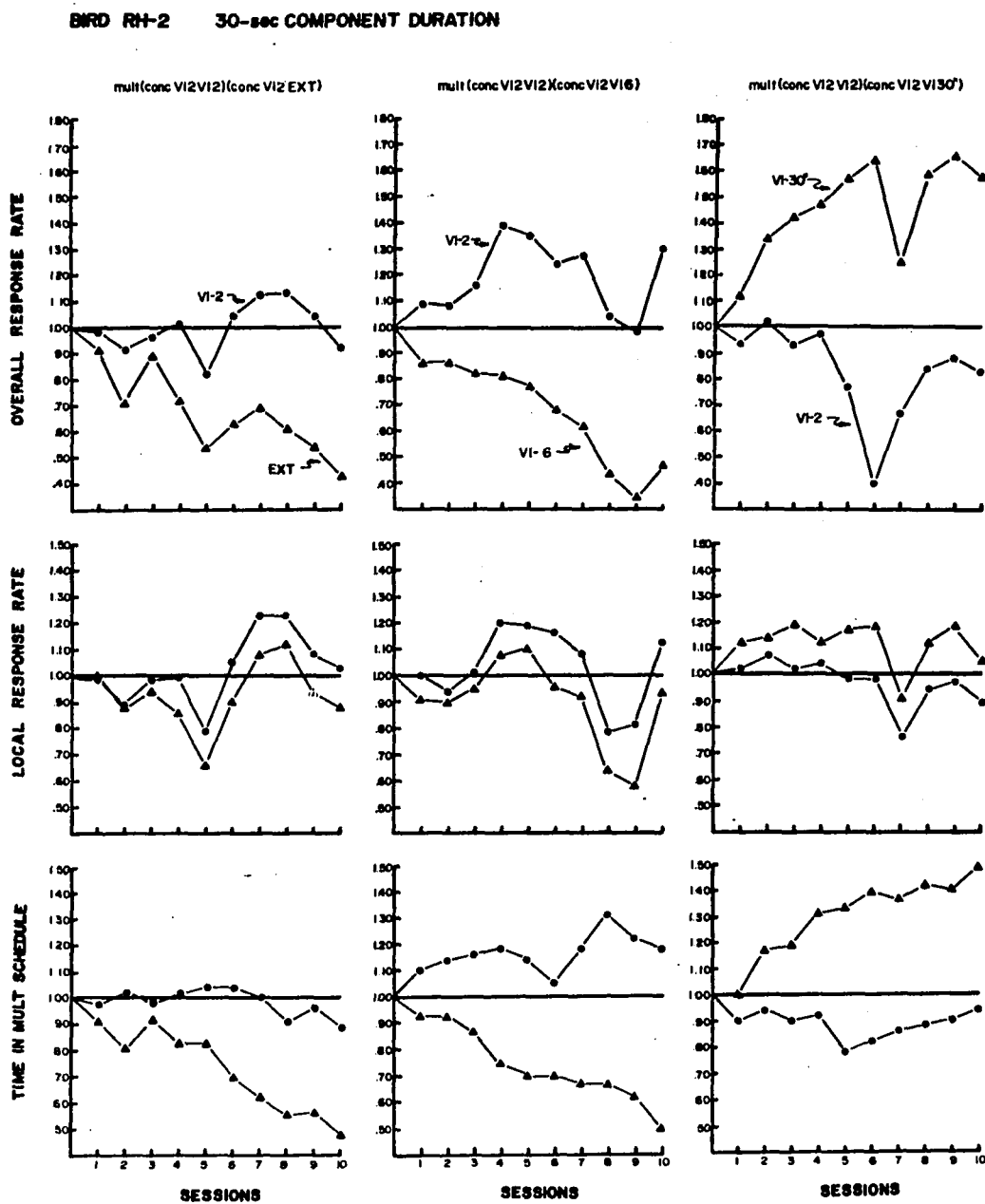


Figure 2.4 Normalized Daily Performances for Bird RH-4 in the Red and Green Components of the Multiple Schedule When Component Duration is 30-sec.

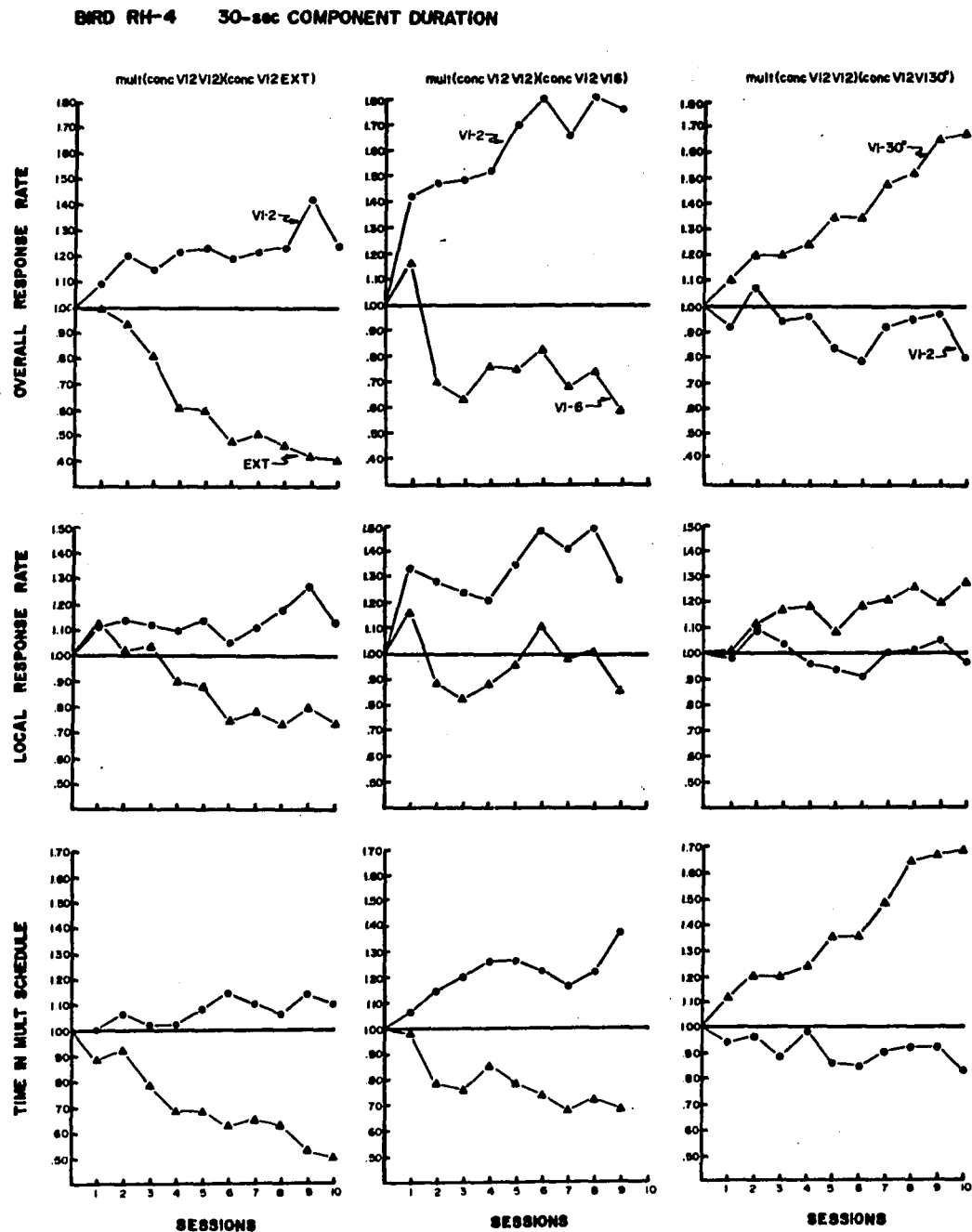


Figure 2.5 Normalized Daily Performances for Bird RH-5 in the Red and Green Components of the Multiple Schedule When Component Duration is 180-sec.

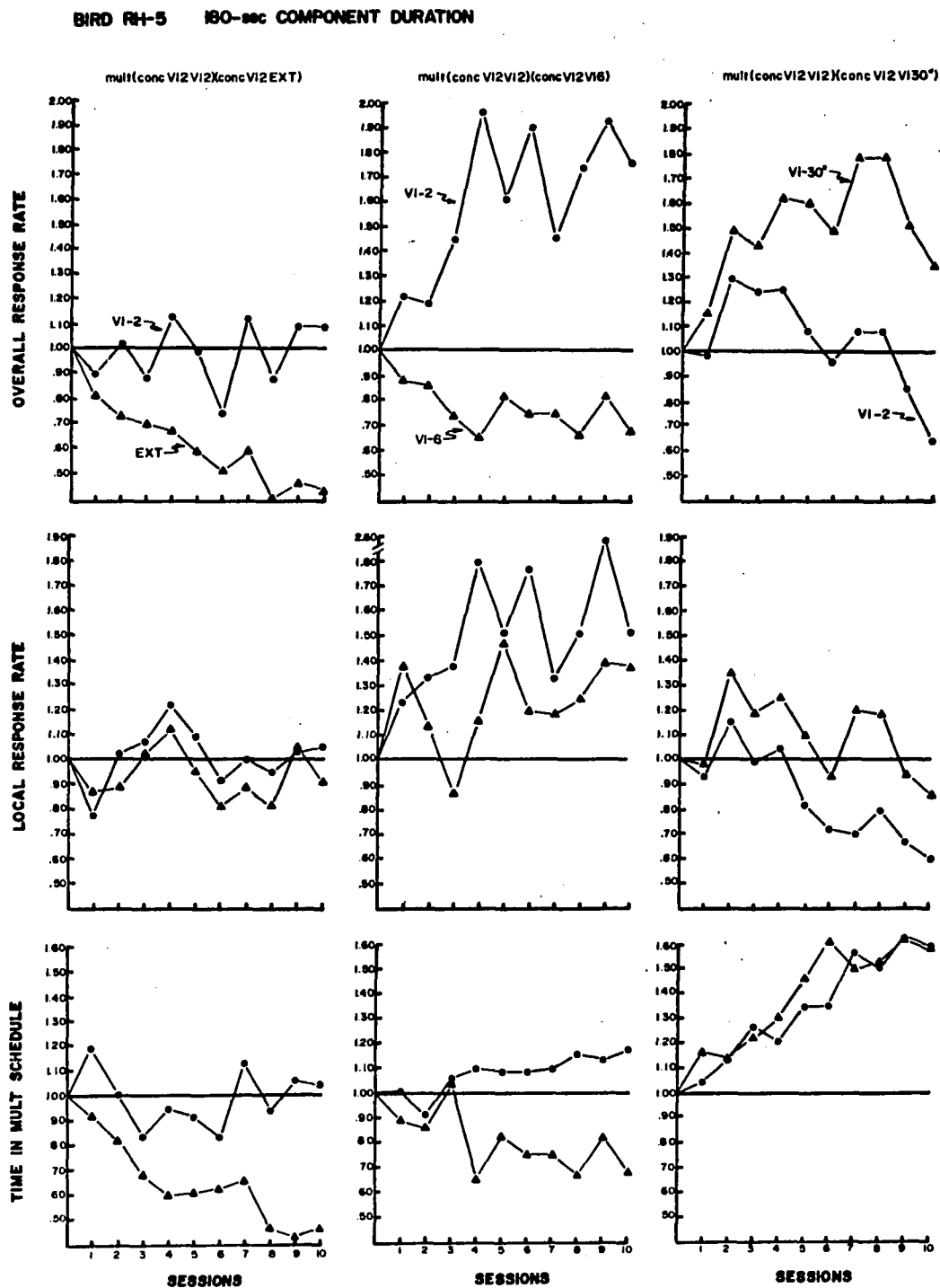
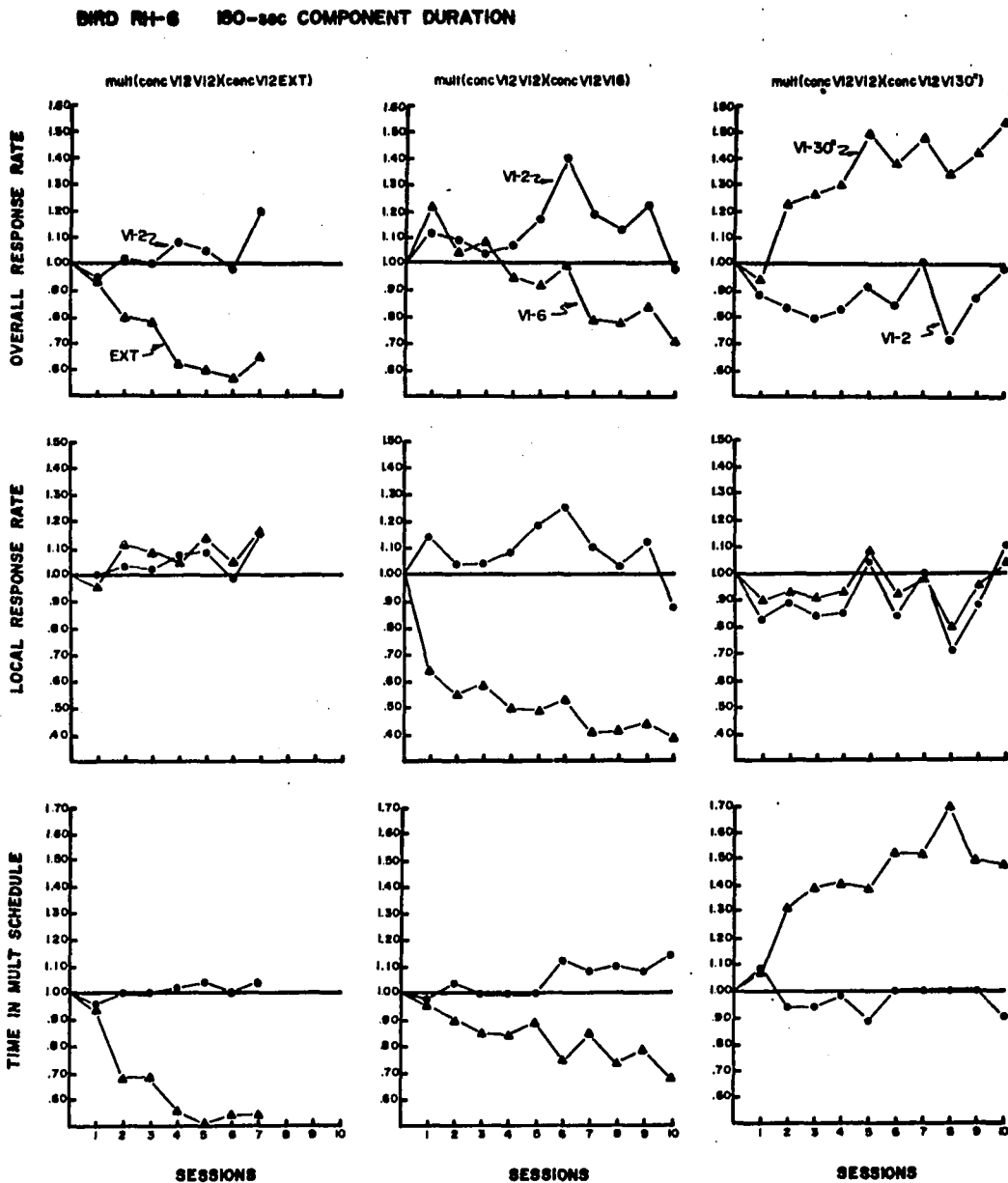


Figure 2.6 Normalized Daily Performance for Bird RH-6 in the Red and Green Components of the Multiple Schedule When Component Duration is 180-sec.



stimulus divided by the time during which that stimulus is available. For example, the overall response rate in the red stimulus component (S-1) of the multiple schedule is defined in the terminology of the present procedure as, $R_1/(T_1 + T_{0.1})$. Overall response rate in the green stimulus component is defined as, $R_2/(T_2 + T_{0.2})$. Under multiple variable-interval schedules of reinforcement, direct changes in the reinforcement rate associated with one component produce opposite changes in the overall rate of responding in an unchanged component (Reynolds, 1961; Lander and Irwin, 1968; Hughes, 1970).

The top row of panels in each figure show the daily overall response rates (normalized) in S-1 and S-2 of the multiple schedule for the first 10 sessions following a change in the reinforcement rate in S-2. Overall response rates in S-2 are shown by triangles. Overall response rates in the unchanged stimulus component (S-1) are shown by circles.

Changes in the reinforcement rate associated with S-2 produced systematic changes in overall response rates in S-2 (see also Figures 1.1 through 1.3), while changes in S-1 were less clear in some instances. When reinforcements in S-2 were delivered on the average of once every 30 seconds (i.e., according to a VI 30-sec schedule of reinforcement), negative contrast was produced for five of six subjects in the unchanged VI 2-min component. When reinforcements in S-2 were delivered according to a VI 6-min schedule of reinforcement, clear positive contrast effects were obtained for five of six subjects. However, when reinforcement was discontinued in S-2, only RH-4 showed contrast. Aside from a slight increase in overall response rate for Bird RH-2 for sessions 6-9, all other

animals either showed no change (e.g., RH-5 and RH-6) or induction (e.g., RH-1 and RH-3). It cannot be determined whether the slight upward trend on session 7 for RH-6 is an indication of contrast since the Extinction phase for RH-6 had to be discontinued following seven sessions due to a procedural error. The failure of the Extinction condition to produce positive contrast in more of the subjects appears not to have been due to the failure to achieve a reduction in responding in S-2, since lesser reductions in responding under the VI 6-min condition produced marked positive contrast for five of the six subjects. Neither does the absence of positive contrast in Birds RH-1 and RH-3 appear to have been attributable to the absence of control by the exteroceptive stimuli of the multiple schedule, since for both animals the Extinction condition was the last in the sequence of experimental conditions (see Table 1) and since examination of performances under the VI 6-min schedule condition showed that positive contrast was obtained for both animals.

To further investigate the failure to achieve positive contrast under conditions where reinforcement was discontinued in one component of the multiple schedule, the common schedule and its associated exteroceptive stimulus were removed. Components of the multiple schedule continued to alternate every 5 seconds for RH-1 and RH-3 and every 30 seconds for RH-2 and RH-4. Birds RH-5 and RH-6 were not studied in this phase of the experiment. To maintain the same overall number of reinforcements in S-1 and S-2 during the course of a session, sessions now terminated after 30 reinforcements. Following 10 sessions of training on mult VI 2-min, VI 2-min, reinforcement was discontinued in the green stimulus

component (S-2) of the multiple schedule. Overall response rates (normalized) for each bird are shown in Figure 3 for the first 10 sessions following the introduction of Extinction in S-2. Although Bird RH-3 still failed to show positive contrast, Birds RH-1, RH-2, and RH-4 showed large contrast effects under the VI-Extinction condition. In addition to the omission of the common operant, the key on which the multiple schedule appeared now alternated every other session rather than following reinforcements on the amber key. There appears no obvious reason, though, why such a procedural difference should occasion differences in performance under the two conditions.

Aside from the absence of positive behavioral contrast under the VI-Extinction condition of the multiple-concurrent schedule, a clear inverse relationship was observed between the overall rate of responding in the unchanged component of a multiple variable-interval schedule and the number of reinforcements per hour in a second component. This relationship is expressed in Figure 4 which shows the overall response rate in the red stimulus component of the multiple schedule as a function of the number of reinforcements per hour in the green stimulus component. The value of each point in Figure 4 was calculated by first multiplying the response rate of each baseline condition by whatever value was found necessary to either raise or lower the baseline rate to 25 responses per minute (approximate mean response rate for all birds over all baseline determinations) and then multiplying the mean value for sessions 6-10 of each immediately following experimental condition by this numerical factor. The transformation makes possible comparison of the normalized data contained in Figures 2.1 through 2.6

Figure 3 Overall Response Rate in the Unchanged VI Component of the Multiple Schedule, mult VI 2-min EXT, With the Common Operant Removed.

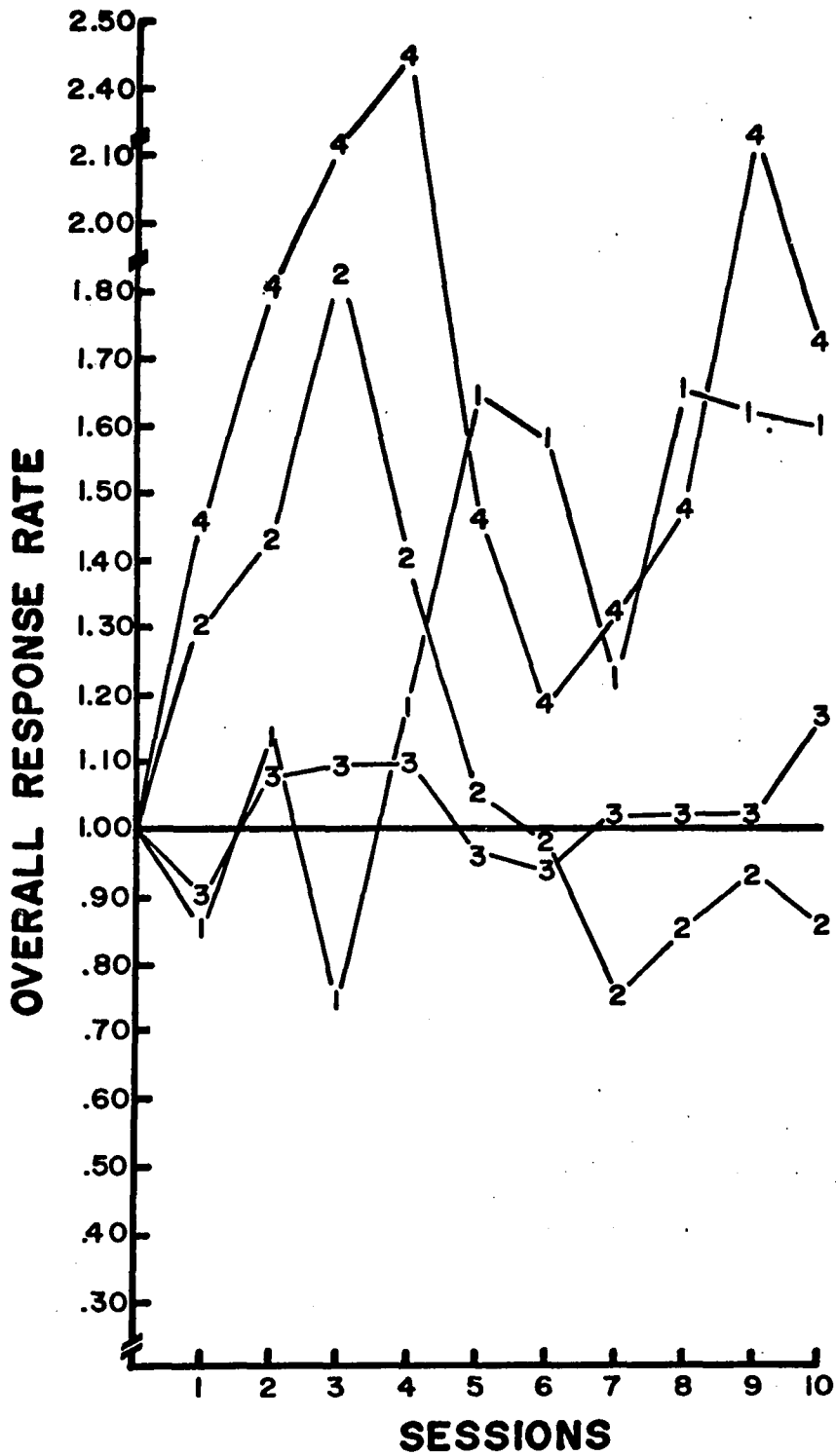
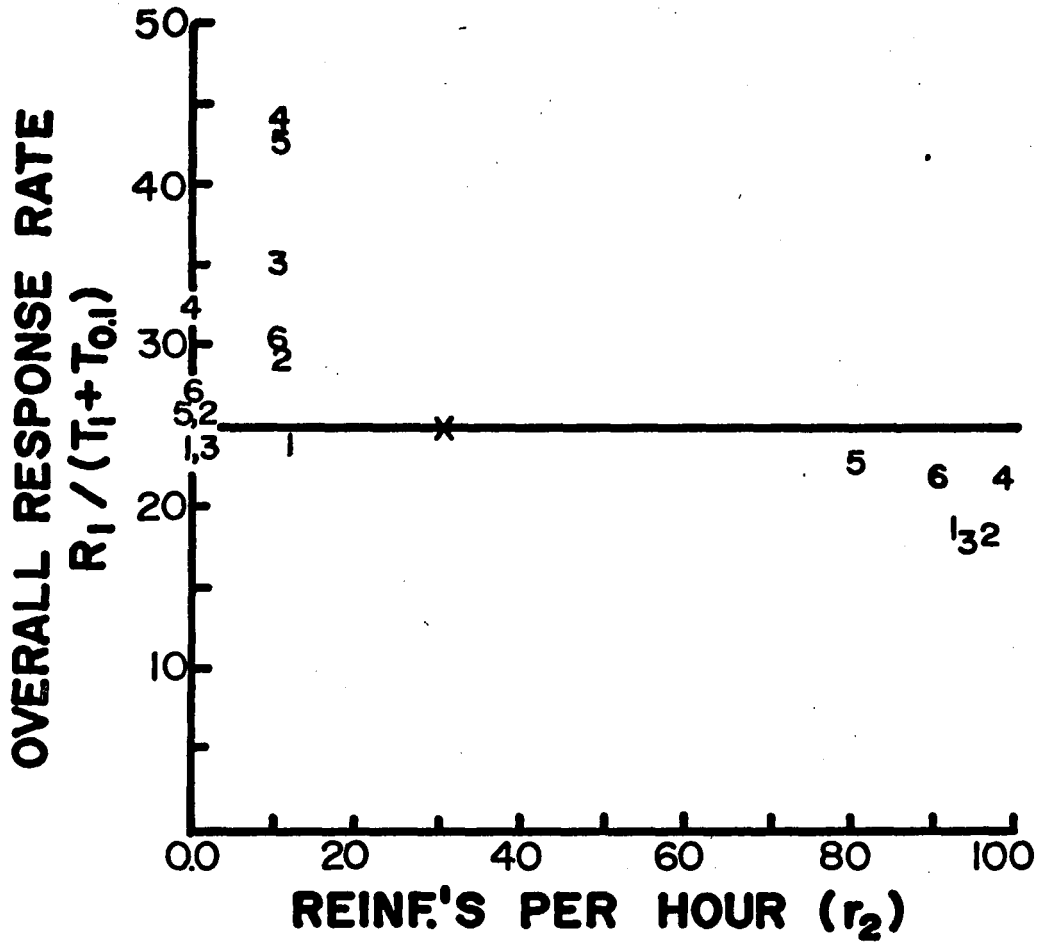


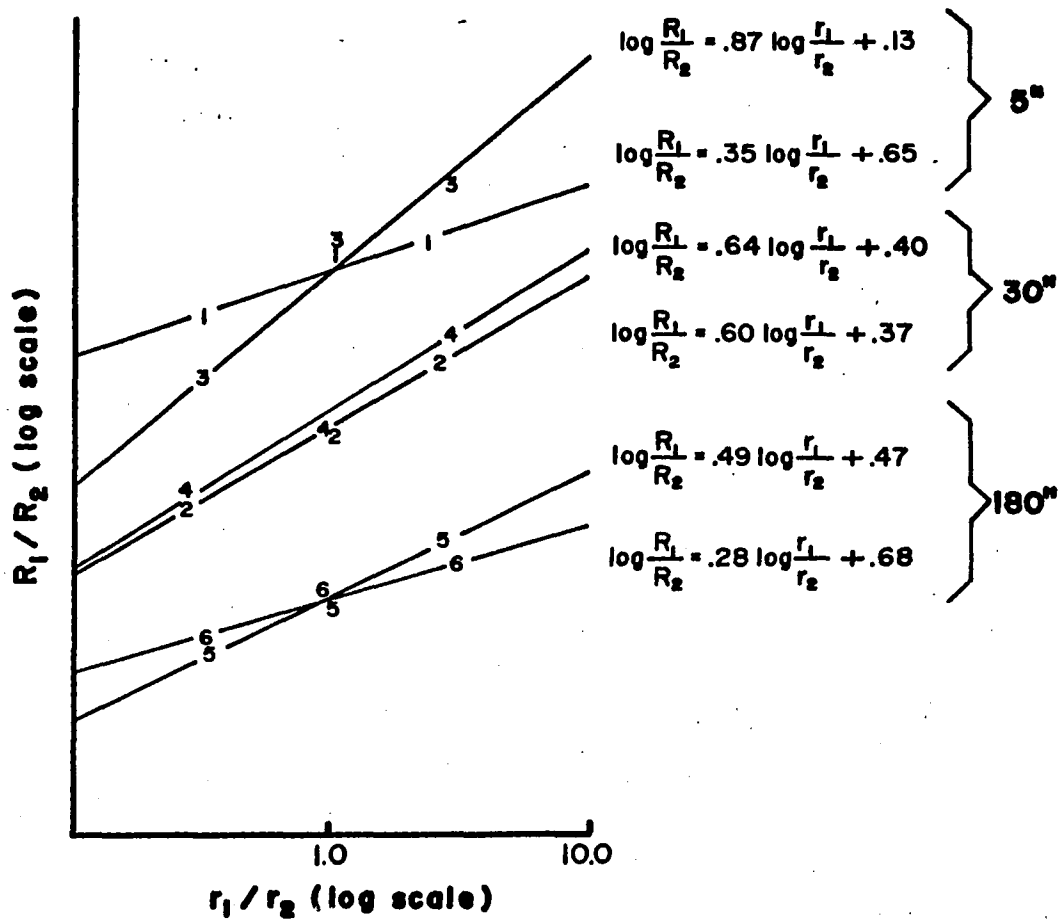
Figure 4 Overall Response Rate in the Red, Unchanged Component of the Multiple Schedule as a Function of Reinforcements Per Hour in the Green Stimulus Component



on a scale for which the ordinate is expressed in terms of responses per minute rather than a normalized value.

Although Figure 4 shows no evidence of an effect due to component duration, a plot of the ratio of overall response rates in the two components as a function of the ratio of their associated reinforcement rates reveals a clear effect. Figure 5 presents a log-log plot of R_1/R_2 as a function of r_1/r_2 . The individual functions for each animal are reasonably well described by a power function of the general form, $\log Y = m \log X + b$. Functions have been empirically determined according to a least squares procedure described by Lewis (1960). The pair of functions for each component duration group have been displaced vertically for a comparison of their respective slopes. The points for the Extinction phase in S-2 have not been included in the determination of the functions since the value of $r_1/r_2 = 0.0$ is not defined by the power function. The differences between the slopes of the power functions for the 180-sec condition and the pooled slopes of the power functions for the 5-sec and 30-sec conditions were statistically significant ($X^2 = 3.40$, $df = 1$, $p \leq 0.10$). With the exception of the data for Bird RH-1 who failed to show positive contrast under both the Extinction and VI 6-min conditions, there exists a distinct effect due to component duration. These data further support the functional similarity of behavior maintained by the multiple-concurrent schedule and behavior maintained by simple multiple schedules of reinforcement. The slopes of the power functions in the present experiment closely approximate the values found under simple multiple schedules of reinforcement (Killein, 1972; Shimp and Wheatley, 1971; Todorov, 1972). Lander and Irwin (1968) found

Figure 5 Log-Log Plot of the Ratio of Response Rates as a Function of the Ratio of Reinforcement Rates in the Multiple Schedule.



that with component durations set at three minutes, a slope of approximately 0.30 came close to describing the relationship between relative responses and relative reinforcements in a multiple variable-interval schedule. The data are in agreement with Herrnstein's formulation of the quantitative properties of multiple schedule performances in that as component duration is shortened, relative responses begin to approximate relative reinforcements across components.

Local Response Rates: Whereas the time base for determining overall response rate customarily corresponds to the time during which a stimulus may occasion responses, the time base for determining the animal's local rate of responding is limited to that time during which responses are actually emitted in the presence of a given stimulus. On a concurrent schedule, for example, since both stimuli are simultaneously available for the entire session, the time base for overall response rates is the total session time, usually excluding reinforcement time. Local response rate on a concurrent schedule takes into account the fact that the animal distributes its time between the available response alternatives so that only some proportion of the total session time is spent in the presence of either stimulus condition. Thus, on concurrent schedules relative local response rates may remain invariant as changes in reinforcement conditions produce changes in relative overall response rates.

To the extent that local response rates and overall rates in multiple schedules are thought of as being synonymous one assumes that the time which the animal allocates to each component stimulus of a multiple schedule is identical to the total time which each stimulus

is available. The multiple-concurrent procedure of the present study allowed a separation of component time into that proportion of time allocated to the component stimulus of the multiple schedule and that proportion of time allocated to the common operant.

The analysis of local response rates is of importance in the present study for the following reasons. If, following a change in reinforcement rate in the green component of the multiple schedule, the animal continues to distribute its time equally between the common operant and the red stimulus component of the multiple schedule, but increases its local rate of responding on the red key, this would argue that contrast was a stimulus-specific autoshaping phenomenon. If an increase in local response rate occurs on both the red and the common, amber key in the absence of a change in the proportion of time allocated to each, contrast could still be attributed to autoshaping, where because pecking was also chosen as the common operant, elicited pecks are directed onto both response keys. The distribution of auto-pecks across both keys might be expected inasmuch as the amber-red stimulus combination and the amber-green stimulus combination constitute reliable signals for two different rates of reinforcement. Even though no stimulus change occurs on the amber key, amber is always reliably correlated with differential rates of reinforcement signaled by red and green on the multiple schedule.

Local response rates in S-1 and S-2 for the first 10 sessions following a change in the reinforcement rate in S-2 are shown in the second row of Figures 2.1 through 2.6. Local response rates have been normalized with respect to the preceding baseline, using the same

procedure as that described earlier for normalizing overall response rates. Closed circles show local response rates in the unchanged VI 2-min component of the multiple schedule; triangles show local response rates in the green stimulus component of the multiple schedule. For each occasion when positive contrast occurred in S-1 of the multiple schedule, there also occurred an increase in the local response rate in S-1. On only one occasion did an increase in local response rate occur in the absence of an accompanying increase in overall response rate. Under conditions where an increase in responding was produced in S-2, local rates decreased in the unchanged VI component of the multiple schedule for all birds, except RH-4 and to some extent also RH-2. Decreases in local response rates were correlated with decreases in overall response rates (negative contrast). Figure 6 shows a clear inverse relationship between local response rates in S-1 and reinforcements per hour in S-2. The value of each point was determined by multiplying the mean local rate for session 6-10 of each experimental condition by whatever factor was necessary to either raise or lower the value of the preceding baseline to 45 responses per minute (approximate mean local response rate for all subjects over all baseline determinations).

An important aspect of the data concerning local response rate is indicated in Table 2, which shows the relative local response rates in the red stimulus component of the multiple schedule. Relative local response rate in red was determined by dividing the local response rate in red by the sum of the local response rates in red and in amber (the common operant present during red). Table 2 shows that aside from a

Figure 6 Local Response Rate in the Red, Unchanged Stimulus Component of the Multiple Schedule as a Function of Reinforcements Per Hour in the Green Stimulus Component.

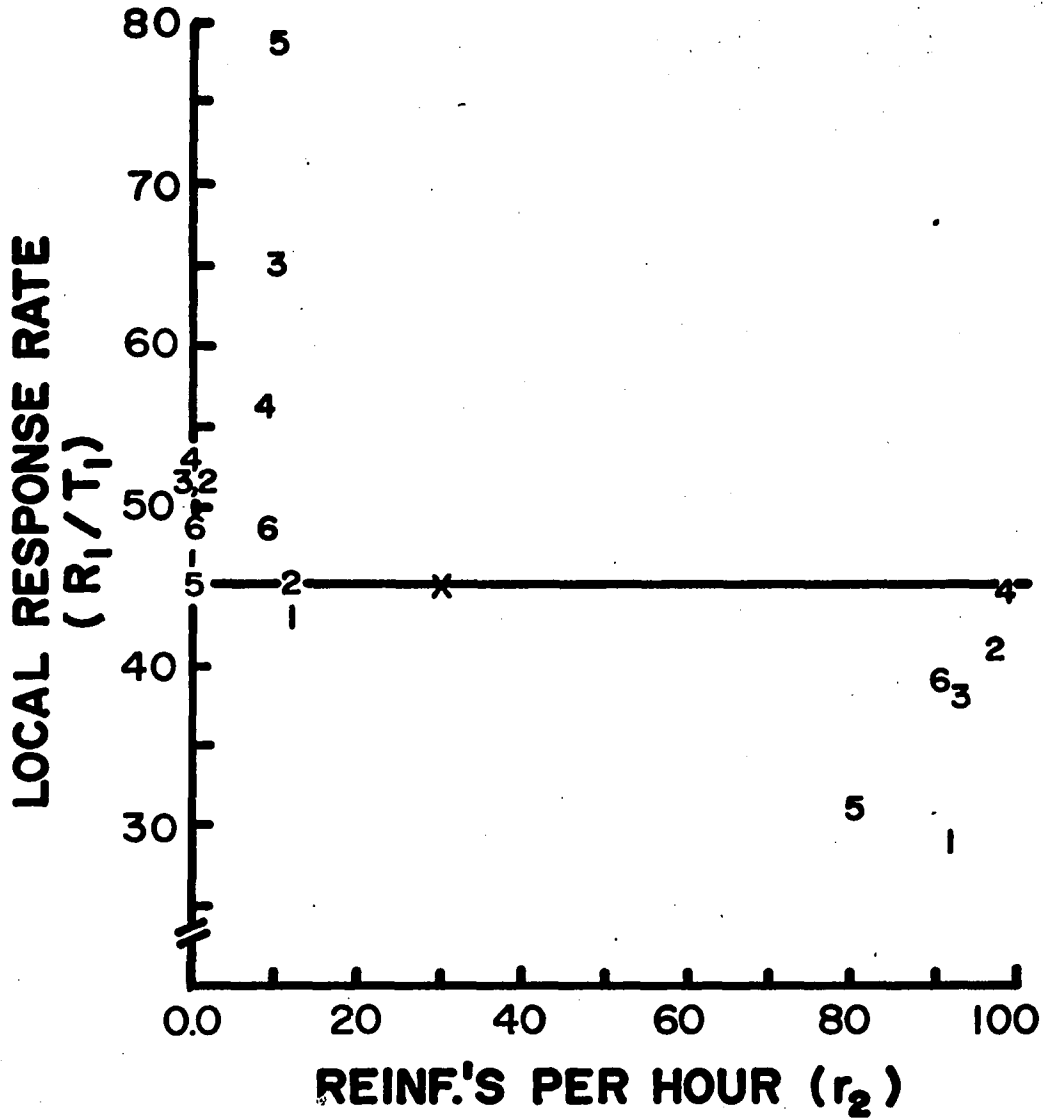


TABLE 2
 RELATIVE LOCAL RESPONSE RATE IN THE RED
 STIMULUS COMPONENT OF THE RED-
 AMBER CONCURRENT SCHEDULE

5-sec Component Duration		30-sec Component Duration		180-sec Component Duration	
RH-1	RH-3	RH-2	RH-4	RH-5	RH-6
VI 2-min (.61)	VI 2-min (.48)	VI 2-min (.49)	VI 2-min (.47)	VI 2-min (.47)	VI 2-min (.47)
VI 6-min (.56)	VI 30-min(.41)	VI 30-min(.49)	VI 6-min (.47)	VI 6-min (.48)	VI 6-min (.45)
VI 2-min (.52)	VI 2-min (.46)	VI 2-min (.48)	VI 2-min (.49)	VI 2-min (.46)	VI 2-min (.48)
VI 30-sec(.46)	VI 6-min (.50)	VI 6-min (.46)	VI 30-sec(.47)	VI 30-sec(.41)	EXT (.47)
VI 2-min (.55)	VI 2-min (.48)	VI 2-min (.46)	VI 2-min (.46)	VI 2-min (.45)	VI 2-min (.46)
EXT (.60)	EXT (.48)	EXT (.50)	EXT (.50)	EXT (.45)	VI 30-sec(.45)

slight bias in favor of the concurrent amber key for all birds except RH-1, changes in the reinforcement rate associated with S-2 of the multiple schedule produced little change in the relative local response rate in S-1. Behavioral contrast in the present study does not appear to have been confined solely to the multiple key. Changes in reinforcement rate in S-2 produced opposite changes in the local rate of responding both in the red stimulus component and in the common amber component during red.

The Distribution of Responses and Time Between the Common Operant and the Unchanged Component Stimulus of the Multiple Schedule

In the unchanged component of the multiple schedule, the red component stimulus of the multiple schedule and the amber stimulus associated with the schedule for the common operant formed a concurrent schedule of reinforcement. In terms of the programmed schedules of food reinforcement associated with each, the concurrent schedule can be defined as conc VI 2-min, VI 2-min. The value of the schedules associated with red and with amber remained unchanged throughout the entire experiment. Within the red-amber concurrent schedule, two measures of the concurrent performance were of primary interest in assessing the effect of reinforcement rate in the green component upon the reinforcement value of the unchanged, red component. The first was the animal's distribution of time between the red and the amber stimulus conditions. The second was the proportion of responses emitted in the presence of each stimulus. Since the relative reinforcement for each component was 0.50 throughout the experiment, the expectation in regard to an animal's performance would be that it would spend half of its time and emit half of its responses

in each of the two stimulus conditions. While a stimulus-specific autoshaping effect on the red key could alter the distribution of responses, only a shift in the reinforcement value of the two stimuli involved could alter the distribution of time between the two. A change in the reinforcement value of the red component stimulus was thus defined for the purpose of the present experiment in terms of a change in the relative time allocated to the red component stimulus of the concurrent schedule.

Proportion of Time in the Unchanged Component of the Multiple

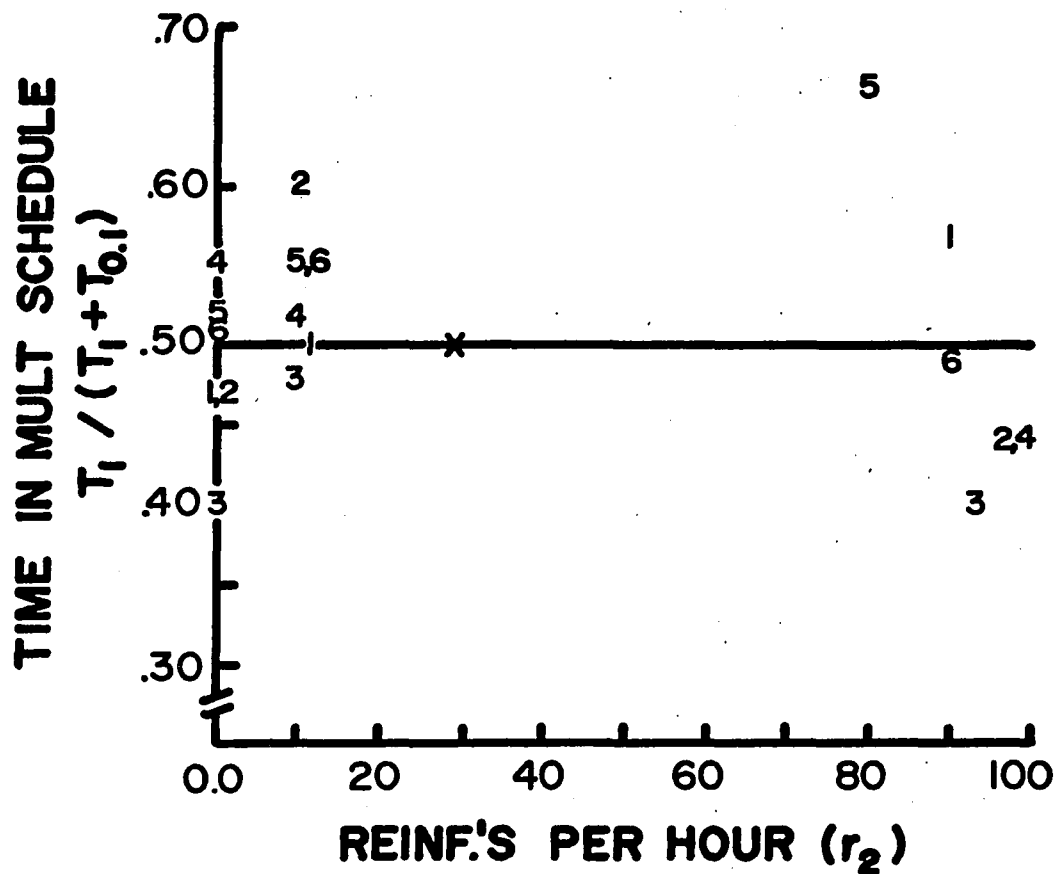
Schedule: The proportion of time allocated to each component stimulus of the multiple schedule for each of the first ten sessions of each condition is shown in the bottom row of panels in Figures 2.1 through 2.6. The time allocated to each component stimulus of the multiple schedule was defined as the relative time spent in the presence of the red and green component stimuli in their respective concurrent schedules. Within each concurrent schedule the time in the presence of each stimulus was defined as the period of time bounded at one end by the first peck following a changeover and at the other end by the first response following a changeover back to the other stimulus. In Figures 2.1 through 2.6, the proportion of time in each component of the multiple schedule has been normalized with respect to the mean proportion of time spent in that condition during the preceding baseline period. Thus values greater than 1.0 indicate that the animal is spending a greater proportion of its time in the presence of that stimulus than during the preceding baseline condition. Values less than 1.0 indicate that the animal is now spending less of its time in the presence of the stimulus.

The main concern in the present study was with the proportion of time spent in the unchanged VI 2-min stimulus component of the multiple schedule following a change in the reinforcement rate in the green, VI component. In Figures 2.1 through 2.6 circles indicate the proportion of time spent in the presence of the unchanged VI component of the multiple schedule.

The only subject showing positive behavioral contrast in the unchanged component when reinforcement was discontinued in the other component was Bird RH-4. Bird RH-4 also showed an increase in the proportion of time spent in the unchanged component. While this increase was on the order of only 10 percent, all daily values clearly exceeded the range of values obtained under the last five days of the preceding baseline period. When VI 6-min was programmed in the green stimulus component of the multiple schedule all subjects with the exception of RH-1 showed marked increases in overall response rates in the unchanged VI 2-min component, and with the exception of RH-3, these increases were all accompanied by increases in the proportion of time that the animal spent in the unchanged VI 2-min component of the multiple schedule. When reinforcement rate was increased in the green stimulus component of the multiple schedule, four of six animals showed a decrease in the proportion of time allocated to the unchanged VI 2-min component of the multiple schedule. Discontinuing reinforcement in the green component had little effect upon the animal's distribution of time between S-1 and the common operant.

Overall, Figure 7 shows a clear inverse relationship between the proportion of time allocated to the unchanged VI component of the multiple

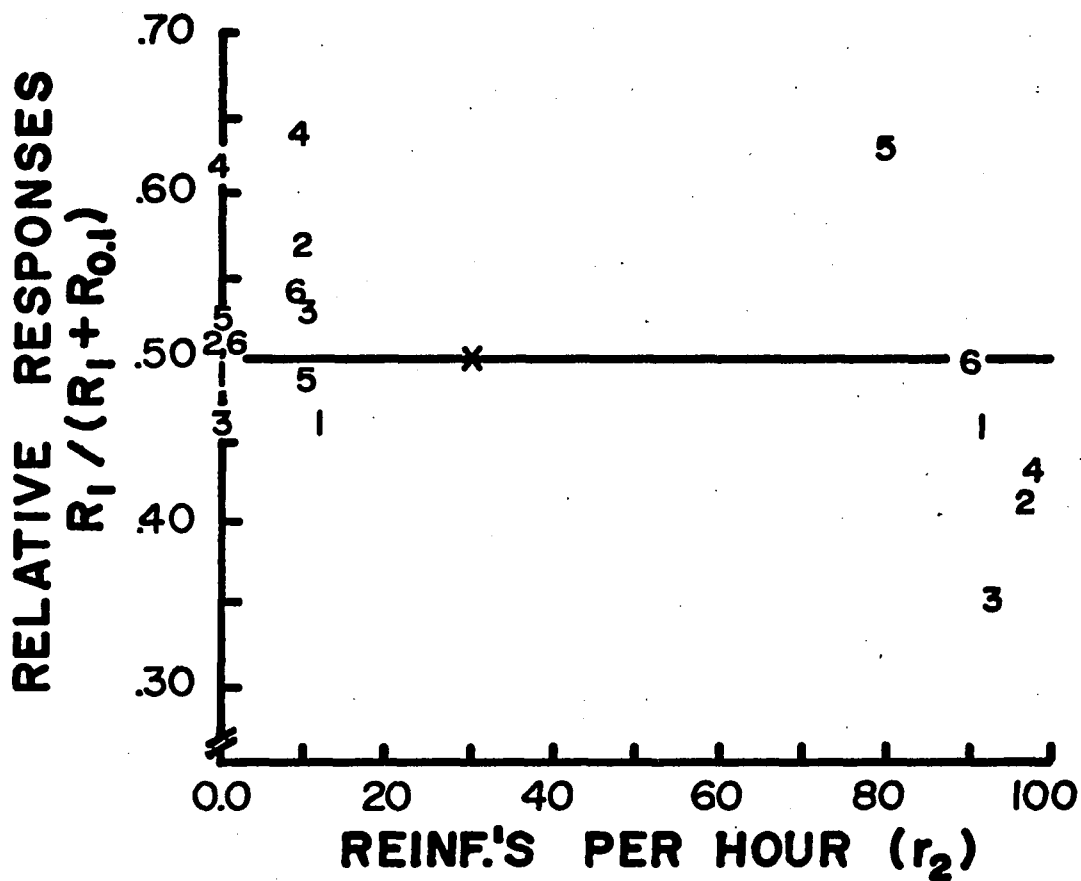
Figure 7 Proportion of Time in the Red, Unchanged Stimulus Component of the Multiple Schedule as a Function of Reinforcements Per Hour in the Green Stimulus Component.



schedule and reinforcement rate in a second VI component. A Friedman Two-Way Analysis of Variance by Ranks showed the differences to be statistically significant ($X^2_T = 84.05$, $N = 6$, $k = 4$) beyond the $p \leq .001$ level. The data, however, for Birds RH-1 and RH-5 caution against drawing any general conclusions with respect to the necessity of a value shift in producing behavioral contrast. For both RH-1 and RH-5, an increase in the reinforcement rate in the green stimulus component produced opposite changes in the overall and local rates of responding in the unchanged VI component. Although negative contrast was observed in the unchanged component, the animals in both cases allocated more time to the unchanged VI component than to the common operant. At present, the reason why these effects were obtained in two of six animals is unclear.

Proportion of Responses Emitted in the Unchanged Component of the Multiple Schedule: Figure 8 shows the number of responses emitted in the unchanged VI component of the multiple schedule relative to the total number of responses emitted in that component plus the common operant component as a function of the number of reinforcements per hour in the other VI component of the multiple schedule. The data points have been determined in a manner identical to those in previous figures where performances have been adjusted to a common baseline for purposes of comparison. According to Figure 8, a clear inverse relationship existed in the present study between the reinforcement for pecks in one component of a two-component multiple variable-interval schedule and the overall number of pecks emitted in a second, unchanged VI component.

Figure 8 Relative Responses in the Red Stimulus Component of the Red-Amber Concurrent Schedule as a Function of the Reinforcements Per Hour in the Green Stimulus Component of the Multiple Schedule.



DISCUSSION

The primary importance of the present data lies in their relevance to the theoretical issue of whether or not behavioral contrast involves a shift in the reinforcement value for responding in the unchanged stimulus component of a multiple schedule. Several investigators (see Terrace, 1972; Rilling, et al., 1969) have suggested that during the formation of a successive discrimination the stimulus correlated with a reduction in reinforcement rate may become aversive and that the animal may actually terminate this stimulus or escape from its presence if given the opportunity to do so (Rand, personal communication). A reduction in reinforcement frequency as well as the addition of response-contingent electric shocks (Brethower and Reynolds, 1963) both constitute what Bloomfield (1969) has referred to as a "change for the worse" in one stimulus component of a multiple schedule. By creating an aversive state of affairs, or a change for the worse in one component of a multiple schedule, it is argued that these operations alter the reinforcement value of the unchanged stimulus component as well. Operations such as punishment or blackout which produce contrast in the absence of changes in relative programmed rates of reinforcement may do so because they somehow alter the reinforcement value of the unchanged component stimulus.

Reinforcement value has thus far been studied chiefly within the context of preference (Autor, 1969; Herrnstein, 1961; Killein, 1968; 1970). The study of preference most often makes use of concurrent chain schedules

(see Autor, 1969). On a typical concurrent chain schedule, reinforcement is programmed on each of two response keys. The initial links of the chain are concurrently available while the terminal links of the chain are mutually exclusive. When responding during one of the initial links produces the terminal links of its associated chain, the other key becomes dark, and responding continues in the chosen terminal link until a predetermined number of reinforcers have been obtained. Preference for the conditions of one terminal link stimulus relative to the other is indicated by a greater relative number of responses on one of the keys in the initial links or by a greater proportion of time in the presence of one of the initial link stimuli.

In an experiment by Newsom (1970), pigeons were exposed to multiple fixed-interval schedules of reinforcement with equal reinforcement rates in the two components, and on alternate days, to a concurrent chain schedule having terminal links identical to the components of the multiple schedule. When responding was suppressed in one multiple schedule component by use of a blackout procedure, three of six subjects showed positive behavioral contrast in the unchanged multiple schedule component and indicated decreased preference for the terminal link in which responding was suppressed. Expressed another way, there occurred an increase in the relative reinforcement value associated with the terminal link stimulus in which contrast was observed.

In the present study, the reinforcement value associated with the unchanged stimulus component of a multiple variable-interval schedule was defined in terms of the time that the animal allocated to the unchanged component stimulus relative to the time allocated to a stimulus

correlated with a concurrently available VI schedule. The present data clearly showed that the proportion of time that an animal allocated to the unchanged stimulus component of a multiple variable-interval schedule was inversely related to the rate of reinforcement operating in a second VI component. The generality of these findings is increased by the apparent high degree of functional similarity between performances maintained under simple multiple schedules of reinforcement and those maintained under the complex multiple-concurrent schedule of the present study. The effects of component duration upon the interaction of component reinforcement rates observed under simple multiple schedules (Killein, 1972; Shimp and Wheatley, 1971; Todorov, 1972) was replicated in the present study where a multiple schedule was treated as a multiple schedule of concurrent schedules.

The effects of reinforcement rate in one component upon the animal's distribution of time among concurrent response alternatives in a successive component is significant, for these effects occurred in the absence of any direct change in the reinforcement for pecking relative to the reinforcement for alternative responses as well as in the absence of any change in the relative local rates of responding on the multiple and common VI schedules.

A rather straightforward conceptualization of behavioral contrast is suggested by these data. Essentially the suggestion is that the overall rate at which an animal responds in the unchanged stimulus component of a multiple schedule will be jointly determined by factors affecting two separately controlled aspects of its performance: (1) its local rate of responding, and (2) the manner in which it distributes its

time between responding and other concurrently available response alternatives. Expression of this relationship in the terminology of the multiple-concurrent schedule is given by

$$\frac{R_1}{T_1 + T_{0.1}} = \frac{R_1}{T_1} \times \frac{T_1}{T_1 + T_{0.1}}$$

where R and T stand for responses and time, respectively, and where the subscripts define schedule events and extraneous events.

The local response rate term on the right side of the equation is assumed to vary with those factors governing the occurrence of certain classes of behavior which may vary independently of the response-reinforcer contingencies of the programmed schedule. The operation of these factors constitutes Rachlin's "biological principle" of behavior contrast (see Rachlin, 1973). The animal's distribution of time, on the other hand, will be governed by the extent to which simultaneous as well as successive reinforcements alter the reinforcement value of the stimulus in whose presence responding is occurring. The animal's distribution of time, according to Rachlin, is governed by the "economic" principle.

The present data provide a clearer understanding of the operation of the biological and economic principles in multiple schedules. By extending the operation of the economic principle to both components of the multiple schedule, contrast can be viewed as the joint effect of a value shift and the elicitation of noninstrumental pecks by the stimulus-reinforcer properties of the component schedules. Although the present experiment did not attempt to manipulate local response rate and reinforcement value independently in order to determine the relative importance

of each in producing behavioral contrast, the data of Birds RH-1 and RH-5 suggest that while contrast may be correlated with a stimulus-specific value shift, such a shift may not constitute a necessary condition for the occurrence of behavioral contrast.

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APPENDIX

SUMMARY DATA

BIRD RH-1

Schedule In S-2	Overall Resp Rates (Resp Per Min)			Overall Rft Rates (Rfts Per Hour)			Local Resp Rates (Resp Per Min)				Time In Mult		Rel Conc Rates In Green		
	R_1	$R_{0.1}$	R_2	r_1	r_2	r_c	R_1	$R_{0.1}$	R_2	$R_{0.2}$	T_1	T_2	R	T	r
VI 2-min	29.36	18.45	28.23	30	29	30	59.03	37.90	58.95	38.08	0.50	0.48	0.59	0.48	0.49
VI 6-min	28.17	21.40	24.47	32	10	30	55.39	43.65	52.99	43.11	0.51	0.46	0.51	0.46	0.25
	28.68	22.94	21.98	29	12	29	57.42	46.01	52.09	40.66	0.50	0.42	0.49	0.42	0.28
VI 2-min	27.05	18.36	23.04	31	30	30	52.79	48.70	38.16	34.65	0.52	0.47	0.56	0.47	0.50
VI 30-sec	24.25	14.54	25.74	29	90	28	40.42	36.94	36.95	36.77	0.60	0.61	0.64	0.61	0.76
	20.73	16.93	31.71	29	92	29	34.95	41.84	25.63	43.45	0.59	0.68	0.69	0.68	0.76
VI 2-min	21.78	17.52	18.28	31	29	31	44.23	35.73	40.85	34.19	0.49	0.45	0.49	0.45	0.49
EXT	20.19	15.97	11.96	29	0	29	30.46	30.46	32.19	28.96	0.46	0.38	0.40	0.38	0.00
	21.14	17.26	6.21	32	0	29	46.47	31.54	27.89	27.77	0.45	0.28	0.24	0.21	0.00
BIRD RH-3															
VI 2-min	29.05	29.64	24.55	31	30	31	58.39	61.93	62.84	54.41	0.52	0.47	0.46	0.47	0.49
VI 30-sec	20.56	29.59	35.62	29	93	29	43.14	56.96	56.94	45.61	0.48	0.60	0.65	0.60	0.76
	21.32	40.77	59.58	30	93	28	49.50	71.56	80.58	59.09	0.42	0.74	0.80	0.74	0.77
VI 2-min	28.21	23.80	22.06	31	26	31	48.15	57.59	53.00	52.79	0.59	0.52	0.47	0.52	0.46
VI 6-min	33.59	24.15	18.98	28	10	30	54.72	62.61	43.12	55.37	0.61	0.43	0.38	0.43	0.25
	39.99	29.87	18.14	30	10	29	69.58	68.86	51.72	61.51	0.57	0.35	0.31	0.35	0.25
VI 2-min	33.96	26.28	22.65	31	28	31	54.14	59.81	46.13	53.06	0.56	0.48	0.45	0.48	0.49
EXT	32.34	23.65	9.40	32	0	30	54.68	60.21	22.71	32.77	0.60	0.41	0.28	0.41	0.00
	32.65	30.47	5.86	34	0	31	61.22	57.37	26.03	52.39	0.46	0.23	0.11	0.23	0.00

APPENDIX (CONTINUED)

SUMMARY DATA

BIRD RH-2

Schedule In S-2	Overall Resp Rates (Resp Per Min)			Overall Rft Rates (Rfts Per Hour)			Local Resp Rates (Resp Per Min)				Time In Mult		Rel Conc Rates In Green		
	R	R _{0.1}	R ₂	r ₁	r ₂	r _c	R ₁	R _{0.1}	R ₂	R _{0.2}	T ₁	T ₂	R	T	r
VI 2-min	25.70	27.03	27.20	30	29	31	51.68	53.85	53.84	53.31	0.50	0.52	0.52	0.52	0.48
VI 30-min	23.74	30.57	37.67	29	95	30	52.98	55.35	55.34	63.66	0.44	0.62	0.61	0.62	0.76
	18.61	27.65	41.97	27	97	30	47.07	49.36	57.09	63.49	0.44	0.73	0.71	0.73	0.76
VI 2-min	24.07	24.88	32.00	30	31	30	47.12	50.95	50.95	53.35	0.51	0.61	0.61	0.61	0.50
VI 6-min	29.23	25.36	26.38	28	11	29	50.36	60.51	60.51	53.47	0.58	0.51	0.51	0.51	0.27
	28.02	21.66	16.31	29	11	28	46.72	54.93	42.18	47.59	0.61	0.39	0.36	0.39	0.26
VI 2-min	26.85	23.75	27.42	29	28	31	47.22	55.34	50.72	54.25	0.57	0.54	0.54	0.57	0.47
EXT	25.18	22.50	20.73	27	0	29	43.96	51.71	44.18	45.25	0.57	0.47	0.46	0.47	0.00
	28.27	24.71	15.92	29	0	30	53.09	52.91	49.89	39.06	0.53	0.32	0.37	0.32	0.00
BIRD RH-4															
VI 2-min	17.97	21.24	18.43	29	28	30	36.66	41.73	39.52	38.52	0.49	0.47	0.47	0.46	0.48
VI 6-min	27.31	19.06	14.80	28	11	29	47.01	52.00	37.49	35.80	0.58	0.39	0.39	0.39	0.23
	31.58	19.58	13.04	29	10	30	45.47	51.22	39.25	34.28	0.61	0.33	0.32	0.33	0.24
VI 2-min	20.83	20.71	18.47	27	29	31	40.47	42.77	42.77	40.32	0.52	0.46	0.46	0.46	0.49
VI 30-sec	19.72	22.92	25.07	32	95	30	40.80	44.70	44.86	47.91	0.48	0.56	0.52	0.52	0.76
	18.47	24.64	34.71	28	98	30	40.03	45.77	49.40	54.52	0.46	0.71	0.68	0.71	0.77
VI 2-min	19.89	22.52	27.96	29	31	31	38.92	46.24	46.67	49.56	0.51	0.60	0.58	0.60	0.50
EXT	23.49	22.23	22.25	31	0	30	43.62	48.13	46.26	46.43	0.53	0.47	0.47	0.47	0.00
	25.13	18.57	12.64	29	0	29	44.67	44.67	35.62	33.99	0.56	0.36	0.37	0.36	0.00

APPENDIX (CONTINUED)

SUMMARY DATA

BIRD RH-5

Schedule In S-2	Overall Resp Rates (Resp Per Min)			Overall Rft Rates (Rfts Per Hour)			Local Resp Rates (Resp Per Min)				Time In Mult		Rel Conc Rates In Green		
	R ₁	R _{0.1}	R ₂	r ₁	r ₂	r _c	R ₁	R _{0.1}	R ₂	R _{0.2}	T ₁	T ₂	R	t	r
VI 2-min	12.52	10.34	15.56	28	28	29	23.58	26.27	26.27	33.07	0.53	0.57	0.52	0.57	0.48
VI 6-min	16.69	13.85	13.01	28	8	27	30.51	33.65	33.64	31.83	0.55	0.48	0.43	0.48	0.23
	21.65	18.51	13.69	28	10	29	41.14	44.64	35.74	33.04	0.59	0.44	0.43	0.44	0.26
VI 2-min	12.11	14.05	12.56	28	24	29	24.09	28.27	24.93	29.10	0.50	0.50	0.46	0.50	0.45
VI 30-sec	14.14	11.89	18.31	30	94	29	23.66	30.03	29.25	33.04	0.60	0.63	0.60	0.63	0.73
	11.17	7.76	19.94	28	80	27	16.73	24.14	25.61	30.36	0.66	0.78	0.75	0.78	0.75
VI 2-min	15.10	20.10	18.87	29	28	30	31.87	38.68	36.08	30.61	0.47	0.53	0.56	0.53	0.49
EXT	14.88	19.49	13.26	29	0	30	33.04	35.76	34.95	23.91	0.46	0.38	0.47	0.38	0.00
	15.86	19.47	8.80	27	0	30	32.09	39.69	33.02	22.78	0.49	0.27	0.36	0.28	0.00
BIRD RH-6															
VI 2-min	27.01	30.96	32.07	29	29	30	54.87	61.16	60.93	65.18	0.49	0.53	0.51	0.53	0.49
VI 6-min	29.68	34.28	33.60	31	10	29	60.19	69.38	70.99	68.51	0.49	0.47	0.48	0.47	0.26
	32.05	32.39	26.51	30	10	30	58.99	70.01	65.55	62.51	0.54	0.40	0.42	0.40	0.25
VI 2-min	30.49	30.04	31.21	28	29	31	58.02	63.44	62.13	63.31	0.52	0.52	0.51	0.50	0.48
EXT	31.12	31.58	23.30	31	0	31	60.41	63.08	66.30	54.82	0.52	0.36	0.40	0.38	0.00
	33.26	32.31	19.06	30	0	30	62.08	69.81	68.33	45.62	0.53	0.28	0.36	0.28	0.00
VI 2-min	28.99	29.77	28.09	29	31	29	54.78	63.37	62.59	58.96	0.53	0.45	0.46	0.45	0.50
VI 30-sec	24.80	26.22	35.08	29	85	29	49.32	54.08	59.82	69.66	0.51	0.59	0.54	0.59	0.73
	25.81	26.38	40.40	29	90	30	47.11	57.48	54.42	76.28	0.52	0.69	0.63	0.69	0.75