BAUMAN, RICHARD. Time Allocation with Concurrent Asymmetrical Responses. (1972) Directed by: Dr. Richard Shull. Pp. 46.

The purpose of the present experiment was to examine the effects of concurrent VI-VT response requirements on time allocation. Using a change-over-key procedure pigeons were trained to peck for food on a VI schedule of grain reinforcement in each component of a concurrent schedule. For two birds main-key responses produced 0.50 of the programmed reinforcers in each concurrent component, either red or amber, while for the remaining two birds 0.70 of the reinforcers were delivered in one component and 0.30 in the other. The schedule corresponding to the equal distribution of reinforcers was conc VI 1.5-min VI 1.5-min while conc VI 1.07-min VI 2.28-min was the schedule in effect when 0.70 of the reinforcers were delivered in the red-key component and conc VI 2.28-min VI 1.07-min was the schedule in effect when 0.30 of the reinforcers were delivered in the red-key component. Following a baseline determination in which both concurrent schedules were VI the schedule in the red-key component was then changed to a VT schedule in which reinforcers were delivered independently of the bird's behavior. Because responding persisted in the VT component the main key was made dark and inoperative and a houselight illuminated the chamber. R-4's continued main-key pecking in the VT component necessitated turning off the houselight. For all birds exposed to the VT component illuminated by the houselight, the proportion of time allocated to the VT component closely approximated the corresponding proportion of VT reinforcers. These subjects included both birds who were exposed to the conc VT 1.5-min VI 1.5-min schedule and one bird who was exposed to the conc VT 1.07-min VI 2.28-min and conc VT 2.28-min VI 1.07-min schedules.

R-4 was also exposed to the conc VT 1.07-min VI 2.28-min and conc VT 2.28-min VI 1.07-min schedules with the red-key inoperative and the houselight off. R-4 spent more time in the VI component during exposure to each of these schedules than would be predicted by the distribution of reinforcers. A probable explanation for this bias involves the condition of reduced illumination during the VT component.

Additional implications of the time distribution data of R-1, B-3, and R-3 were that pigeons do not prefer response independent to response dependent reinforcement and the primary basis for preference in a concurrent schedule is reinforcement frequency. To the extent that concurrent schedules of grain reinforcement are comparable to concurrent chain schedules of grain reinforcement these results provide direct support for the identical findings of Neuringer (1969) and Killeen (1968) who used a concurrent chain schedule.
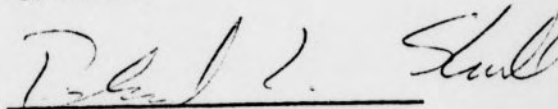
TIME ALLOCATION WITH CONCURRENT
ASYMMETRICAL RESPONSES

by

Richard Bauman

A Thesis 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
Master of Arts

Greensboro
1972

Approved by

_____
Thesis Adviser

APPROVAL PAGE

This thesis has been approved by the following committee
of the Faculty of the Graduate School at The University of North
Carolina at Greensboro.

Thesis
Adviser

Oral Examination
Committee Members

_____
Date of Examination

ii

ACKNOWLEDGEMENTS

The author gratefully acknowledges the guidance of Dr. Richard Shull throughout all stages of this thesis. His criticism and guidance of this research contributed in large part to the final product. Dr. Arron J. Brownstein provided valuable suggestions regarding the analysis, presentation, and discussion of the data while Dr. Scott Lawrence cooperated closely with the author at various stages of this study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

During the past ten years the study of concurrent operants has revealed certain lawful relations whose generality and frequency of replication prompted further investigation. Concurrent operants are defined as "two or more responses of different topography at least with respect to locus, capable of being executed with little mutual interference at the same time or in rapid alternation, under the control of separate programming devices" (Ferster and Skinner, 1957, p. 703); the separate programming devices provide the reinforcement schedules associated with each of the concurrent operants.

Two procedural variations have emerged for programming concurrent schedules, the two-key procedure and the changeover-key procedure.[1] As the name suggests, the two-key procedure uses two separate keys with responses to each key under the control of separate programming devices which are continuously operative except when reinforcement is made available. The organism is free to changeover from one key to the other by simply moving back and forth between the two keys. The changeover-key procedure also uses two keys with one key designated the main key and the remaining key designated the changeover key. Main key responses occur in the presence of two different exteroceptive stimuli, only one of which is present at

---

[1]Both the changeover-key procedure and the two-key procedure evolved from research using pigeons, hence the term key. To better express the generality of these procedures the term key may be read as manipulanda.

2

any point in time. As in the two-key procedure main key responses are re-
inforced according to separate schedules of reinforcement which are con-
tinuously operative except when reinforcement is made available. Responses
on the changeover key simply change the exteroceptive stimulus and the
associated main key schedule.

The focus of several early concurrent studies was the generality
and quantitative implications, i.e. response independence and reinforcement
interaction, of Herrnstein's matching law. (Reynolds, 1963 and Catania, 1962,
1963) The matching law predicted that if two response keys are concurrently
available the proportion of responses emitted on a key equals the proportion
of reinforcements assigned to that key. Herrnstein (1961), using a two-
key concurrent procedure, manipulated the proportion of reinforcements
assigned to each key while the combined frequency of reinforcement for
both keys remained constant at 40 reinforcements per hour. The results
showed that the proportion of a pigeon's responses on a key was a linear
function, with a zero intercept and a slope of one, of the proportion of
reinforcements obtained on a given key. In other words the relative fre-
quency of responding for a key approximated the corresponding relative fre-
quency of reinforcement. The following formula describes this relationship:

$$\frac{R_{1\ or\ 2}}{R_1 + R_2} = \frac{r_{1\ or\ 2}}{r_1 + r_2} \qquad \text{(Equation 1)}$$

where R_1 = the number of responses emitted on key 1

R_2 = the number of responses emitted on key 2

r_1 = the number of reinforcements assigned to key 1

---

[2] In the concurrent literature each main key color is usually referred
to as a separate response key. This usage is followed in this paper.

r_2 = the number of reinforcements assigned to key 2

The matching relation shown in Equation 1 is expressed in terms of ratios of numbers of responses and reinforcers rather than ratios of rates of responding and reinforcement. The former expression is a reduced form of the latter because the time base for calculating the relative rates of responding and reinforcement is the total session time. The total session time however cancels out in the calculation of the relative rates of responding and reinforcement. Therefore the corresponding relative response and reinforcement rates reduce to ratios consisting of numbers of responses and reinforcements. In addition the use of numbers of responses or response rate in these ratios follows quite naturally from the discrete nature of the key-peck response. A rate measure was both convenient to record and summarized the continuous emission of pecks in time. The matching relation was therefore, initially a law of response allocation.

Duration as well as number is a dimension of behavioral measurement. Thus in a concurrent changeover procedure the time spent in the presence of a main key color may be considered a suitable measure of behavior to use in expressing the relative amount of behavior occuring in this situation. Catania (1966), using a changeover-key procedure, found that both the relative time spent in a main key component and the relative response rate matched the relative rate of reinforcement. The matching relation was now a law of time allocation as well as response allocation. The following equation describes this relationship:

$$\frac{T_{1 \text{ or } 2}}{T_1 + T_2} = \frac{r_{1 \text{ or } 2}}{r_1 + r_2}$$

where T_1 = the time spent in the presence of key color 1

T_2 = the time spent in the presence of key color 2

The quantities r_1 and r_2 are defined in Equation 1

Catania's study as well as the subsequent studies of time allocation by Brownstein and Pliskoff (1968) and Baum and Rachlin (1969) reveal two prominant issues. The first issue involves the direction of the dependency between time matching and response matching. That is does response matching occur as a consequence of an organisms allocation of time or vice versa. Central to this issue is the independence of time matching from response matching. The second issue concerns the increase in parsimony and generality resulting from a reformulation of the matching law exclusively in terms of time allocation. Catania's discussion of time matching was concerned with the direction of the dependency between response matching and time matching. In this discussion Catania provided the basis for a time allocation account of response matching. Catania contended that if the organism is responding at a constant rate on each key then the relative response and relative time measures for the key are equal. In other words if the local rates, which are the responses emitted on a key divided by the time spent in the presence of the corresponding key color, are equal then the proportion of time and responses for a key are equal. In terms of the local rates if $\frac{R_1}{T_1} = \frac{R_2}{T_2}$ then

$$\frac{R_1}{R_2} = \frac{T_1}{T_2} \text{ , or equivalently } \frac{\dfrac{R_1}{R_1 + R_2}}{\dfrac{R_2}{R_1 + R_2}} = \frac{\dfrac{T_1}{T_1 + T_2}}{\dfrac{T_2}{T_1 + T_2}} \text{ .(Equation 3)}$$

The only way the equality in Equation 3 can hold is for the corresponding relative measures in the numerators and denominators of the left and right side of this equation to be equal. Therefore,

$$\frac{R_1}{R_1 + R_2} = \frac{T_1}{T_1 + T_2} \qquad \text{and} \qquad \frac{R_2}{R_1 + R_2} = \frac{T_2}{T_1 + T_2}$$

Furthermore since the local response rates are equal matching is a consequence solely of an organism's allocation of time. The generality of Catania's time allocation account is suggested by Gilbert's (1958) somewhat parallel analysis of the determinant of total output in a single key situation. Gilbert contended that different behaviors occur at a tempo which is constant for and characteristic of each organism. Consequently tempo varies between organisms. In terms of concurrent measures of behavior, tempo is the single-key analog of a constant local rate. Thus "if an animal spends most of his time at a task and if he works at a tempo unaffected by the experimental conditions the tempo will be the greatest determinant of the total output measure." (Gilbert, 1958, p. 280) Gilbert's concern was thus with variations in total output between organisms and how characteristic tempos of different organisms account for these variations in total output. If however, Gilbert were concerned with variations in a single animals output over time then he would necessarily be required to consider the time spent responding and the time spent not responding, or engaging in unrecorded behavior. Likewise with a constant response rate the time sepnt responding in a concurrent situation determines number of

responses. Thus, if the ratio of time spent responding on a main key to
the total time spent in the presence of a main key color equals the relative
rate of reinforcement for this main key, then response matching is a con-
sequence of this equality.

Catania's account of response matching in terms of time allocation
fit the data well. However the question of whether time matching was in-
dependent of response matching remained unanswered. Brownstein and Pliskoff
(1968) were concerned with the independence of time matching from response
matching and therefore studied time allocation without a specified response
requirement. In this study three pigeons were trained to change the
illumination of a standard pigeon chamber by pecking a (changeover) key.
The changeover key was the only key present. Thus no discrete response
was specified once the illumination had changed. Independent variable-
interval tape programmers operated concurrently and administered reinforce-
ments independently of responses in the presence of each color. The
results showed that for all subjects relative time approximated the rela-
tive rate of reinforcement. These results support the notion that a re-
sponse requirement is not necessary for organisms to allocate time and
the formulation of the matching law as a law of time allocation.

Baum and Rachlin (1969) using two continuous responses and the
response measure time spent responding further strengthened the reinter-
pretation of the matching law as a law of time allocation. The continuous
response used by Baum and Rachlin necessitated the use of a continuous re-
sponse measure, time spent responding, as opposed to the discrete-rate
measure. The converse of this however is not true. That is the use of
a discrete response does not require a discrete response measure. The

continuous measure time spent responding is an alternative descriptive
measure of the discrete occurences of a response. In the Baum and Rachlin
study the time spent responding was the time spent standing in each of two
locations. A shuttle box with two movable floor sections was used. A
green light was positioned over the right floor section, a white light
over the middle of the box, and a red light was mounted above the left
floor section. When a pigeon stood on a particular floor section the
corresponding overhead light was illuminated. The results showed that
the proportion of the session spent on either side was approximately
proportional to the relative number of reinforcements delivered on that
side. For Baum and Rachlin the matching law was of necessity a law of
time allocation, however taken together Catania's formulation of time
allocation based on discrete responses, Brownstein and Pliskoff's (1968)
results which show time matching without response matching, and these
results suggest that time is a more general measure of behavior than
number. That is, time is a measure of all responses. In addition to
the increase in generality from treating the matching law as a law of
time allocation is an increase in parsimony resulting from the use of
one dependent measure for discrete and continuous responses. Baum and
Rachlin's use of continuous responses, and therefore a temporal response
measure, emphasized the generality of duration as a dimension of behavioral
measurement and provided an explicit formulation of the matching law in
terms of time allocation.

The previous studies which were concerned with the notion of time
allocation were characterized by a common procedural element, namely the
use of symmetrical response requirements. Catania (1966) used the key

peck while Baum and Rachlin (1969) used standing in one of two locations.
In the case of Brownstein and Pliskoff (1968) the response of spending
time was common to both illuminations. This symmetry might also be viewed
as an equivalent class of not key pecking responses common to both illumi-
nations. The proposed study was designed to extend the generality of time
allocation by the use of concurrent asymmetrical response requirements.
The asymmetry of the response requirements was accomplished by delivering
reinforcement contingent on responses while the main key was amber and
independently of responses while the main key was red. Using a changeover-
key procedure, reinforcements for amber key responses were delivered con-
tingent on responses, at variable intervals since the preceding reinforce-
ment, i.e. on a VI schedule, and reinforcements assigned to the red key
were delivered independently of responses, at variable times since the
preceding reinforcement, i.e. on a VT schedule. Without becoming involved
in what is reinforced on the VT schedule it should be noted that both
contingencies, the VI and the VT, result in the reinforcement of two
different response classes. If time matching is obtained using concurrent
asymmetrical response requirements the implications for time allocation
appear twofold. First, the demonstration of time matching with this
paradigm extends the generality of time matching to a different combination
of response requirements. Second, time matching with asymmetrical responses
strengthens the inference that pigeons match time independently of responses
with symmetrical-discrete responses.

The time allocation issue is central to the proposed study however
the use of a concurrent changeover-key procedure with asymmetrical responses
is closely related to the concurrent-chains research of Neuringer (1969)

and Kileen (1968) who were concerned with whether birds prefer not to work for food. The conventional concurrent chains paradigm consists of two keys, associated with each are two schedules of reinforcement and two different key colors. Both first link schedules of each chain are concurrent variable interval schedules with equal mean values; the key colors associated with both initial inks are identical. If either first link VI schedule sets up the next response on this key changes the key color and simultaneously the opposite key becomes dark and inoperative. Further responses on the lighted key result in reinforcement. In conceptualizing the changeover-key procedure as a concurrent-chains procedure the changeover response of the changeover-key procedure is analogous to the first link schedule of a concurrent chain with each main key schedule corresponding to the terminal link schedules of the concurrent chain. In the case of the changeover-key procedure the first link schedule is an FR 1, i.e. only one response is necessary to gain entry to the terminal link schedule, or in this case, main key schedule.

Neuringer (1969) and Kileen (1968) used concurrent chains to study the preference of pigeons for different terminal link contingencies. The preference of an organism for the contingencies which operate during the terminal links is shown by the response rates during each of the corresponding initial links. Neuringer studied the preference of pigeons for a terminal-link-fixed-interval (FI) schedule and a terminal-link-fixed-time (FT) schedule. The reinforcement in an FT schedule is delivered at fixed times since the preceding reinforcement, independently of responses. The FT schedule and an accompanying blackout were programmed as a terminal link of one chain while the FI schedule was the terminal link of the

opposite chain.   The results showed only a small preference for the FI

schedule which, in a later manipulation, was found to be caused by the

blackout occuring during the FT link. Kileen (1968) found when comparing

equal reinforcement frequencies in both terminal links, disparate reinforce-

ment frequencies in the terminal links, and equal terminal link reinforce-

ment frequencies but different contingencies, i.e. VI 30-sec in one terminal

link and Tandem VT 30-sec DRO 1.5-sec in the other terminal link, reinforce-

ment frequency was the only basis for preference. The Tandem VTDRO con-

tingency specifies that on the average a 30 sec interval must elapse which

is immediately followed, independently of responses by a 1.5 sec interval

during which time all responses reset a timer. After the timer times out

reinforcement is delivered. Thus reinforcement follows a response by at

least 1.5 secs. This 1.5 sec delay caused a suppression in responding.

The results showed that the left-key-initial-link rates were similar except

for the chain schedule which offered the higher frequency of terminal-link

reinforcement, in which case the initial link rate was greater than the

others.   In both Neuringer and Kileen's study response independent and

response dependent schedules of reinforcement were used. Kileen used

equal value VI and VT terminal link schedules while Neuringer used equal

value FI and FT schedules. The proposed study used concurrent VI-VT

schedules which correspond to the terminal link schedules in a concurrent

chain. The measure of preference in the proposed paradigm however is the

distribution of time allocated to each of the main key (terminal link)

schedules. To the extent that the measure of preference in a concurrent

chain, i.e. the initial link response rates, is comparable to the measure

of preference in the concurrent VI-VT paradigm, i.e. the distribution of

time allocated to each main key schedule, the results of Neuringer suggest that no preference for response independent (VT) over response dependent (VI) reinforcement should occur and Kileen's results suggest that reinforcement frequency should be the only basis for preference in the proposed study.

METHOD

Subjects

Three male Carnauex pigeons and one male Silver King pigeon were maintained at 80% of their free feeding weight. All subjects had previous key pecking experience on a variety of reinforcement schedules.

Apparatus

A Lehigh Valley Model 1519 two-key pigeon chamber was used. Two translucent response keys 25mm in diameter were situated 254mm from the floor and 64mm from the center of the intelligence panel. During the interreinforcement intervals the key lights provided the only illumination in the chamber. The minimum key peck force necessary for reinforcement was 0.196N. A feedback relay provided an audible click following each key peck equal to or greater than 0.196N. One of two Lehigh Valley Model 1346 multi-stimulus projectors was used to illuminate the left (main) key with either red or amber light while the remaining projector illuminated the right (changeover) key with either a verticle or horizontal bar 19mm long and 3mm wide. Standard relay equipment controlled the contingencies. The relay equipment included a single VI tape programmer which controlled the inter-reinforcement intervals while a stepping switch randomly assigned reinforcements to the red or amber key. The use of a single VI tape programmer deviated from the conventional concurrent procedure which uses two independent VI tape programmers which are continuously operative except when reinforcement is made available, i.e. sets up. Stubbs and Pliskoff (1969)

first reported using the single VI tape procedure to keep the programmed relative rate of reinforcement equal to the obtained relative rate. The holes in the VI tape, which mark the opportunities for reinforcement, were geometrically distributed to keep the probability of reinforcement constant at any point in time since the last reinforcement. In addition a stepping switch was programmed to randomly assign reinforcements to one main key color or the other. One consequence of this procedure is, if the VI tape has set up and the bird is not responding on the key to which re-inforcement is assigned a changeover response followed by a main-key response is necessary to collect the available reinforcement. Only if this reinforcement is collected can further reinforcements be obtained on the prechangeover key, i.e. the main key on which the bird was responding before the changeover. The single VI-tape procedure however is functionally equivalent to the conventional two-tape procedure. That is the approximation of relative time and number of responses to the relative rate of reinforce-ment obtains using both procedures.

Procedure

Preliminary Training: During preliminary training R-1, R-3, R-4, and B-3 were trained to respond on the left (main) key. The color of the left key was either red or amber and alternated on the average every eight reinforce-ments. A reinforcement consisted of four secs access to mixed grain. The schedule of reinforcement in the presence of both key colors was gradually increased from continuous reinforcement (CRF) to a VI 1.5-min schedule. The tape which previously covered the right (changeover) key was removed and every main key peck following a changeover response was reinforced.

The reinforcement schedule associated with the red and amber keys was then increased to VI 1.5-min. Stated otherwise 0.50 of the reinforcements were obtained in the presence of each main key color. During this condition, concurrent (conc) VI 1.5-min VI 1.5-min No COD (changeover delay), and in all subsequent conditions each subject was run daily with a session lasting for 60 reinforcements.

conc VI 1.07-min VI 2.28-min No COD Condition: When visual inspection of the cumulative records from the previous condition, conc VI 1.5-min VI 1.5-min No COD, indicated that stable responding had developed the percentage of reinforcements to each key was changed so that 0.70 of the reinforcements were delivered for responses made on one key and 0.30 of the reinforcements were delivered for responses made on the other main key. All subjects were exposed to the 0.70 condition to determine a COD value which produced matching. Briefly stated pigeons may allocate 0.50 of their responses and time to a key regardless of the distribution of reinforcements, thus the initial exposure to the 0.50 condition does not allow the separation of matching from insensitivity.

conc VI 1.07-min VI 2.28-min COD Condition: Following the conc VI 1.07-min VI 2.28-min No COD condition a two sec COD was introduced which was timed from the first response on the changeover key. The COD specified a minimum time interval which separated responses on the changeover key from the reinforced response on the main key, and thus reduced the possibility that responses on one key would accidentally come under the control of reinforcements programmed for responses on the other key. Without a COD responding on one key would not be independent of responding on the other key, one

consequence of which is an insensitivity of the subject to shifts in the reinforcement distribution. The COD was present throughout all subsequent manipulations. These relative rates of reinforcement were maintained until the relative response and time measures for each key approximated the relative number of reinforcements obtained on a key.

Variable Time Condition: During the previous conditions reinforcements were contingent on responses. In this condition reinforcements assigned to the red key were delivered at variable times since the last reinforcement, independently of responses, i.e. on the VT schedule. The reinforcements assigned to the amber key were delivered at variable intervals since the last reinforcement, contingent on the occurence of a response. Before the VT contingency was introduced R-1 and B-3 were reexposed to the conc VI 1.5-min VI 1.5-min schedule with a COD. When relative time and response rate approximated the relative rate of reinforcement the VT contingency was introduced for R-1 and B-3. R-3 and R-4 were exposed to the VT contingency immediately following the conc VI 1.07-min VI 2.28-min COD schedule: The effect of the VT contingency corresponded to the effects of Neuringer's (1969) FT contingency and Kileen's (1968) Tandem VTDRO contingency, i.e. a decline in response rate. Thus the concurrent VI-VT contingency provided a test of the time allocation account of response matching with asymmetrical response requirements and the subject's preference for response contingent versus noncontingent reinforcement. All subjects were maintained on this schedule for at least 30 days.

RESULTS

Measures and Calculations

The following measures were computed for each bird:

1. a. The relative time, $\dfrac{T_R}{T_R + T_A}$, spent in the red

    key component was calculated for each of the terminal
    5 sessions of a given condition.

    b. In addition the ratio, $\left[\dfrac{T_R}{T_A}\right]$, of the time spent
    in the red key component, $\left[T_R\right]$, over the time spent in
    the amber key component, $\left[T_A\right]$, was calculated from the
    median red and median amber time. The median red and
    median amber time were selected from the last 5 sessions
    of a given condition.

2. The relative number of red key responses, $\dfrac{R_R}{R_R + R_A}$,
    was calculated for each of the terminal 5 sessions of
    a given condition.

3. a. The relative number of reinforcements, $\dfrac{r_R}{r_R + r_A}$,
    obtained in the red key component was calculated for each
    of the experimental conditions.

    b. The ratio, $\left[\dfrac{r_R}{r_A}\right]$, of the number of reinforcements
    obtained during the red key component, $\left[r_R\right]$, over

the number of reinforcements obtained during the amber

key component, $\left[r_A\right]$, was also calculated. For the

conditions in which the relative number of red component

reinforcers was 0.50 the predicted ratio was 1 while for

those conditions in which the relative number of red key

reinforcers was 0.70 and 0.30 the ratios were 2.33 and

0.43 respectively. Matching implies that $\left[\dfrac{T_R}{T_A}\right] = \left[\dfrac{r_R}{r_A}\right]$.

4. The local response rates, $\dfrac{R_R}{T_R}$ and $\dfrac{R_A}{T_A}$, were

computed for the last 5 sessions of each condition

from the number of responses emitted on the red key.

R_R, or amber key, R_A, divided by the corresponding

time spent in each component, T_R or T_A.

5. The number of changeovers per 100 sec was computed

for each bird. The median number of changeovers was

divided by the median total session time, with each

median selected from the terminal 5 sessions of a

given condition. This quotient was then multiplied

by 100.

6. For R-3 and R-4 the red-key absolute response rate,

$\dfrac{R_R}{T_t}$, and the amber-key absolute response rate, $\dfrac{R_A}{T_t}$,

was computed from the number of responses emitted on

the red or amber key divided by the total session time,

T_t. These measures were computed for each of the ter-

minal 5 sessions of a given condition.

In all cases data for the schedule in effect prior to the introduction of the VT contingency, data from exposure to the VT contingency, and data from manipulations made while the VT contingency was in effect are shown. Only one redetermination point was obtained (R-1). B-3 sustained a serious beak injury following exposure to the terminal VT contingency. This injury precluded further use in the experiment. The VT contingency is still in effect for R-3 and R-4 with a distribution of reinforcements other than 0.70-0.30 or 0.30-0.70. Table 1 shows the schedule conditions each bird was exposed to, the relative rate of reinforcement in the red-key component, and the number of sessions exposure to each concurrent schedule.[1]

Local Response Rate Data

To provide a description of the effect of the VT contingency on response rate during the VT component, local rates of responding were computed. The use of local response rates permit an independent assessment of response rate in both VI and VT components because variations in the time spent responding in one component does not mathematically affect the rate measure for the other component.

Fig. 1 shows the local response rate data for R-1 and B-3, both of whom were exposed to the conc VT 1.5-min VI 1.5-min schedule while Fig. 2 shows these data for R-3 and R-4, both of whom were exposed to the conc VT 1.07-min VI 2.28-min schedule.[2]

---

[1] See Appendix, Table I, p. 38.

[2] See Appendix, Figures 1 and 2, pp. 39 and 40.

Fig. 1 and 2 show that for all 4 birds the local response rate for the VT key (open points) decreased with exposure to the VT contingency. The reduction in the VT-key local response rate was accompanied by a reduction in the VI-key local response rate (closed points) for R-3 and R-4. The VI-key local rate increased for R-1 and B-3. However computing the difference between the median VI-key local rate for R-1 and B-3 during exposure to the conc VI 1.5-min VI 1.5-min and conc VT 1.5-min VI 1.5-min schedules revealed that the increase for B-3 was small and insignificant (0.02 responses/sec) while the increase for R-1 was somewhat larger (0.26 responses/sec).

Because main-key responding persisted in both VI and VT components the main key was darkened during the VT component, the feedback relay disconnected, and a red houselight illuminated the chamber. This schedule is labeled conc VT 1.5-min VI 1.5-min RKI (Red Key Inoperative) for R-1 and B-3 and conc VT 1.07-min VI 2.28-min RKI for R-3 and R-4. Although the VT-key local rate decreased to zero for R-1, B-3, and R-3 the difference between the median VT-local rate for R-4 during exposure to this schedule and to the conc VT 1.07-min VI 2.28-min schedule slightly increased (0.10 responses/sec). To facilitate a decrease in the VT-key local rate for R-4 the houselight (H.L.) was turned off, thus the only illumination in the chamber during the VT component was the white horizontal bar on the changeover key. This schedule is labeled conc VT 1.07-min VI 2.28-min RKI H.L. off. The VT-key local rate fell abruptly to zero with an accompanying decrease in the VI-key local rate. The VI-key local rate for B-3 during exposure to the conc VT 1.5-min VI 1.5-min RKI schedule decreased, closely approximating the VI-key local rate during exposure to the initial conc VI 1.5-min VI 1.5-min schedule.

During the previous conditions R-3 and R-4 obtained 0.70 of the programmed reinforcers in the VT component. In the final condition 0.30 of the reinforcers were delivered during the VT component. This schedule is labeled conc VT 2.28-min VI 1.07-min RKI (H.L. off for R-4). With the exception of the large increase in the VI-key local rate on the first of 5 terminal sessions for R-4 the VI-key local rate for R-4 and R-3 was similar during this condition and during exposure to the conc VT 1.07-min VI 2.28-min RKI (H.L. off for R-4) schedule.

Time and Response Distribution Data

The plots in Fig. 3 and 4 of the relative response, time and reinforcement measures for the red component as a function of the different experimental conditions permit an assessment of the effect of the VT contingency on time and response allocation.[3]

Fig. 3 shows the time and response distribution data for R-1 and B-3 during the terminal 5 sessions of each condition. Both R-1 and B-3 obtained 0.50 of the programmed reinforcers during the VT component. During exposure to the conc VI 1.5-min VI 1.5-min schedule both birds allocated an approximately equal proportion of time and responses to each concurrent component. Thus with concurrent key pecking requirements and an equal distribution of reinforcers the proportion of time and responses allocated to each component approximately equaled the obtained relative rate of reinforcement (heavy horizontal line).

---

[3]See Appendix, Figures 3 and 4, pp. 41 and 42.

During exposure to the <u>conc</u> VT 1.5-min VI 1.5-min RKI schedule the relative response rate for the VT-key fell to zero. However the proportion of time allocated to the VT component continued to closely approximate the obtained relative rate of reinforcement. Thus with concurrent VI-VT response requirements, unequal local response rates, and an equal distribution of reinforcers the relative time spent in the VT component approximately equaled the obtained relative rate of reinforcement.

Fig. 4 shows the relative time, response, and reinforcement measures for R-3 and R-4 during the terminal five sessions of a given experimental condition. Both R-3 and R-4 were exposed to unequal, 0.70-0.30 and 0.30-0.70, reinforcement distributions. During exposure to the <u>conc</u> VI 1.07 min VI 2.28-min schedule the relative amount of time and the relative number of responses were approximately equal to the obtained relative rate of reinforcement. Thus with concurrent key pecking requirements and an unequal distribution of reinforcers the proportion of time and responses allocated to each component approximated the corresponding relative rate of reinforcement.

During the terminal five sessions exposure to the <u>conc</u> VT 1.07-min VT 2.28-min RKI schedule the VT-relative-response rate for R-3 fell to zero however the relative amount of time spent in the VT component remained at the previous baseline (<u>conc</u> VI 1.07-min VI 2.28-min) level. Thus these data show that with concurrent VI-VT response requirements, unequal local rates of responding, and an unequal distribution of reinforcers the proportion of time spent in the VT component closely approximated the obtained relative number of VT reinforcers. For R-4 the proportion of time spent in the VT component approximated the obtained relative rate of VT reinforcement. However the maximum relative amount of time allocated to the VT

component during the terminal 5 days of this condition was 0.60. Although

four of five relative time points for R-4 are below 0.60 during the terminal

5 sessions exposure to the conc VT 1.07-min VI 2.28-min RKI H.L. off sched-

ule, the proportion of time allocated to the VT component during exposure

to this schedule (conc VT 1.07-min VI 2.28-min) with and without the red

key operative and the houselight on is approximately the same. That is,

during exposure to the conc VT 1.07-min VI 2.28-min RKI schedule approxi-

mately 0.65 of the total responses were made in the VT component while

during exposure to the same schedule with the houselight off, no main-key

responses were made in the VT component. Thus a substantial amount of

behavior was eliminated from the red-key component without noticeably

affecting the amount of time allocated to this component.

The relative amount of time spent in the VT component for R-4 during

exposure to the conc VT 2.28-min VI 1.07-min RKI H.L. off schedule was

also less than the obtained relative number of VT reinforcements; all

points for the terminal 5 days of this condition are displaced below the

obtained relative-reinforcement-rate function. For R-3 the relative time

allocated to the VT component during exposure to this schedule was approxi-

mately equal to the obtained relative number of VT reinforcers. The data

for R-3 provide additional support for the contention that with concurrent

VI-VT response requirements, unequal local rates of responding, and an un-

equal reinforcement distribution the relative time spent in the VT component

closely approximated the relative number of VT reinforcers.

The previous linear plots of relative time as a function of the

experimental conditions provided an adequate measure for showing the

effect of the VT contingency on the allocation of time. However logarithmic

plots of time ratios for the various experimental conditions as a function

of the corresponding reinforcement ratios provide a different and possibly

clearer framework from which to examine and discuss the bias of R-4 for

the VI component during exposure to the conc VT 1.07-min VI 2.28-min and

conc VT 2.28-min VI 1.07-min schedules with the red key inoperative and

the houselight off. In addition logarithmic plots of the time and reinforce-

ment ratios preserve the information shown in the linear-relative time

plots. Fig. 5 shows the data for R-1 and B-3, both of whom obtained 0.50

of the programmed reinforcements during the VT component while Fig. 6 con-

tains the time ratio data for R-3 and R-4 who both obtained an unequal,

either 0.70 or 0.30, relative number of reinforcers in the VT component.[4]

The closed points in Fig. 5 and 6 are the baseline (conc VI x-min VI y-min)

time ratios while the open points are the data for the conc VT x-min VI

y-min RKI (H.L. off for R-4) schedule, where x is equal to either 1.5,

1.07, or 2.28 min and y is equal to either 1.5, 1.07, or 2.28 min. Only

these points are presented for each bird. Thus for R-1 and B-3 the closed

point with abscissa value 1 in Fig. 5 is the time ratio for the conc VI

1.5-min VI 1.5-min schedule. Both of these points, for R-1 and B-3, fall

close to the matching line (heavy black diagonal). Thus with concurrent key

pecking requirements and an equal distribution of reinforcers the ratio of

time spent in the red-key component to the time spent in the amber-key

component was approximately equal to the corresponding reinforcement ratio.

_____

[4]
See Appendix, Figures 5 and 6, pp. 43 and 44.

The open points for R-1 and B-3 with abscissa value 1 in Fig. 5 are the time ratios for the conc VT 1.5-min VI 1.5-min RKI schedule. Both of these points also fall close to the matching line. Thus with concurrent VI-VT response requirements, unequal local rates of responding, and an equal distribution of reinforcers the ratio of VT time to VI time is approximately equal to the corresponding reinforcement ratio.

In Fig. 6 the closed (conc VI 1.07-min VI 2.28-min) points for R-3 and R-4 fall above and between x-values 2 and 3. Both baseline points fall close to the matching line. Thus with concurrent key peck-ing requirements and an unequal distribution of reinforcers the ratio of red to amber time closely approximated the corresponding reinforcement ratio.

The open (conc VT 1.07-min VI 2.28-min RKI H.L. off for R-4) points for R-3 and R-4 fall above and between x-values 2 and 3. For R-3 this point is approximately identical to the closed (conc VI 1.07-min VI 2.28-min) point. Thus with concurrent VI-VT response requirements, unequal local rates of responding, and an unequal distribution of rein-forcers the ratio of VT time to VI time is approximately equal to the corresponding ratio of reinforcers. This point for R-4 however is dis-placed below the matching line towards an ordinate value of 1 which im-plies a more equal distribution of time between components.

The open (conc VT 2.28-min VI 1.07-min RKI H.L. off for R-4) point for R-3 and R-4 in Fig. 6 falls above and between x-values 0.4 and 0.5. For R-3 this point falls on the matching line. Thus, these data show that the ratio of VT time to VI time equaled the corresponding reinforce-ment ratio when the response requirements were concurrent VI-VT, the local

rates of responding were unequal, and 0.30 of the reinforcers were obtained

during the VT component. The relationship suggested by both VT points for

R-3, conc VT 1.07 or 2.28-min VI 2.28 or 1.07-min RKI, require some qualifi-

cation because only two data points were collected. That is additional ex-

posure to intermediate and extreme reinforcement ratios might reveal a

curvilinear rather than the proposed linear relationship between time and

reinforcement ratios. The fact that the conc VT 2.28-min VI 1.07-min RKI

point fell on the matching line and the conc VT 1.07-min VI 2.28-min RKI

point slightly below it might suggest either type of relation. In the case

of R-4 both of these points are displaced below the matching line, with the

latter point displaced more than the former. Again the exact relationship

which these points suggest is indeterminable.

Changeover Rate Data

Fig. 7 shows the changeover rate/100 sec for all birds as a function[5]

of each experimental condition. The changeover rate for R-4 during exposure

to the conc VT 1.07-min VI 2.28-min RKI schedule are not reported. The change-

over rate for R-4 during exposure to this schedule with the houselight off

is reported with the changeover rates of R-3 who was exposed to this sched-

ule with the houselight on and R-1 and B-3 who were exposed to the conc VT

1.5-min VI 1.5-min RKI schedule. For R-1, B-3, and R-3 this rate remained ·

approximately constant across experimental conditions. However for R-4 the

changeover rate during exposure to the conc VT 1.07-min VI 2.28-min RKI H.L.

off schedule was approximately two times the rate which prevailed during

---

[5]See Appendix, Figure 7, p. 45.

the terminal schedule, conc VT 2.28-min VI 1.07-min RKI H.L. off. The changeover rate during this terminal condition more closely approximated the changeover rate which occured during exposure to the initial conc VI 1.07-min VI 2.28-min schedule.

Absolute Response Rate Data

The red-key absolute rate for R-3 and R-4 are shown in Fig. 8.[6] For R-3 and R-4 the red-key absolute response rate remained approximately constant across all conditions in which 0.70 of the programmed reinforcers were delivered in the red-key component.

Observational Data

R-3 and R-4 were observed for 5 sessions. Three high frequency behaviors were observed for R-4 during the VT component. One was pecking around the changeover key. This appeared to be the most frequent behavior. The second behavior included walking diagonally to the far back side of the chamber and either remaining there for a period of from 3 to 7 sec or returning to the changeover key immediately. Several hopper presentations occured while R-4 was in or returning from the corner. This behavior emerged during the observation period. The third behavior consisted of turning his head to the right and slightly down when he was situated in front of the changeover key. The behavior of R-3 during the VT component consisted of remaining stationary but crouched down in front of the food hopper opening at which he would make pecking motions. Several coincidences

---

[6]

See Appendix, Figure 8, p. 46.

of this hopper pecking and hopper presentations were observed.   R-3 also

turned counterclockwise after a reinforcement.   This behavior was almost

entirely confined to the time immediately after reinforcement and terminated.

Furthermore it was noted that the duration of a turn approximated the

shorter reinforcement intervals on the VI tape.   Thus the presentation of

the hopper a short time after a preceding hopper presentation occured upon

the completion of a turn.   If the hopper was not presented after the com-

pletion of a turn the bird invariably changed over to the VI component.

DISCUSSION

The purpose of the present experiment was to assess the effects of concurrent VI-VT response requirements on time allocation. Main-key pecking was maintained on a VI schedule of food reinforcement in one component of a concurrent schedule while main key responding was eliminated during the other concurrent component, in which reinforcers were delivered on a VT schedule. The time distribution data for R-1 and B-3 support the contention that with an equal distribution of reinforcers and concurrent VI-VT response requirements pigeons allocate an approximately equal amount of time to each component of the concurrent schedule. The data for R-3 extends these findings to unequal reinforcement distributions. That is the relative VT-time for R-3 was approximately equal to the obtained relative rate of reinforcement in both conditions during which the red key was inoperative. Wilkie (1971) using conc VI 1-min VI 1-min schedules and a changeover-key procedure, found that one rat allocated an approximately equal proportion of time to both concurrent components while the second rat spent about 0.60 of his time in the VT component. While the distributions of time and reinforcers did approximate one another the VT relative response rate for both rats in Wilkie's study was not zero. Thus the present data confirm Wilkie's finding of an approximate correlation between the time and reinforcement distributions and extend his findings to a different species, response, distribution of reinforcers, and procedure in which main-key responding was eliminated during the VT component.

The data shown in Fig. 6 for R-4 however, show a displacement of both RKI H.L. off points below the matching line. This implies that R-4 was spending less time in the VT component during both of these conditions than would be predicted from the reinforcement ratios. The delivery of more response-independent reinforcers during exposure to the conc VT 1.07-min VI 2.28-min RKI H.L. off schedule than during exposure to the conc VT 2.28-min VI 1.07-min RKI H.L. off schedule might offer a possible explanation for this bias. During exposure to the former schedule 0.70 of the reinforcers were delivered in the VT component while in the latter schedule 0.30 of the reinforcers were delivered in the VT component. Steiner (1969) demonstrated that intracranial stimulation, delivered independently of responses, will function as an aversive event which rats will bar press to avoid. If it is assumed that response independent grain reinforcement also has aversive properties and the relation between the degree of aversiveness and the relative rate of response independent reinforcement is monotonically increasing then the VT component should be more aversive when 0.70 rather than 0.30 of the reinforcers are delivered independently of responses. Consequently the absolute size of the difference between the obtained and predicted VT times should be greater when 0.70 of the reinforcers are delivered in the VT component, i.e. during exposure to the conc VT 1.07-min VI 2.28-min RKI H.L. off schedule. The simplest assumption to make concerning the operation of such a bias factor is that proportionately less time should be allocated to the VT component during exposure to each of these schedules, conc VT 1.07-min VI 2.28-min RKI H.L. off and conc VT 2.28-min VI 1.07-min RKI H.L. off. It follows from this assumption that the absolute value of the difference between the predicted and obtained percentages of

time spent in the VT component should be a constant proportion of the
predicted VT time during exposure to each of these schedules. Thus,
the obtained time ratios for each of these schedules should be displaced
an equal distance below the matching line on logarithmic coordinates.
The resulting logarithmic function should be a straight line parallel
to and below the predicted matching diagonal. Because only two points,
0.70 and 0.30, were obtained the linearity or curvilinearity of the
relation is indeterminable. However even if the relation were linear
the straight line would not be parallel to the matching line because the
point corresponding to the conc VT 1.07-min VI 2.28-min RKI H.L. off
schedule is lower than the point corresponding to the conc VT 2.28-min
VI 1.07-min RKI H.L. off schedule. This implies that the ratio of the
absolute value of the difference between the obtained and the predicted
VT time to the predicted VT time was not constant for each of these
conditions. In addition, if this account of the obtained bias is
correct then the time ratios for R-3 should show a similar displace-
ment because R-3 was exposed to the same distribution of reinforcers.
The data for R-3 shown in Fig. 6 do not systematically support this
explanation because only the conc VT 1.07-min VI 2.28-min RKI point
falls below the matching diagonal. The time-ratio points shown in
Fig. 5 for R-1 and B-3 both of whom were exposed to the conc VT 1.5-min VI
1.5-min RKI schedule were also displaced below the matching line, however
since no additional points were collected for R-1 and B-3 and the displace-
ment is small these data can not be used to support or reject this account.
Although the data for R-3 do not systematically support the proposed

explanation of the bias as stated, if it is additionally assumed that R-3 and R-4 are differentially sensitive to both distributions, 0.70 and 0.30, of VT reinforcement the explanation becomes more probable.

A second and possibly more parsimonious and obvious explanation for the obtained bias is the condition of markedly reduced illumination during the VT component. Neuringer (1969), using a concurrent chain schedule, found that a preference for an FI terminal link was caused by a blackout occuring during the opposite FT terminal link. The argument here is identical to that involving response independent reinforcement as a possible cause for this bias, however only the assumption of aversive properties is necessary. That is if the relation between blackout length and degree of aversiveness is monotonically increasing then the VT component should be more aversive when 0.70 of the reinforcers are delivered during this component than when 0.30 of the reinforcers are obtained during this component. In addition it was observed for R-1 and B-3, both of whom were exposed to the conc VT 1.5-min VI 1.5-min RKI schedule and to an illuminated VT component, that when the houselight was inadvertently not turned on during one session both birds spent considerably more time in the VI component during this session than during the houselight on sessions immediately preceding or subsequent to the houselight off session. Again the simpliest assumption to make concerning the effect of the aversive properties of the blackout is that the magnitude of the decreased time spent in the VT component should be a constant proportion of the predicted VT time during exposure to both concurrent schedules, conc VT 1.07-min VI 2.28-min RKI H.L. off and conc VT 2.28-min VI 1.07-min RKI H.L. off. The unequal displacement of both points for these schedules again suggest a nonproportional

contribution of the blackout to the obtained bias. Since only one point
was obtained for R-1 and B-3 during exposure to the conc VT 1.5-min VI
1.5-min RKI schedule these data present no firm empirical or logical basis
for rejecting or supporting this account. An examination of the data and
the procedure does not readily suggest an explanation for this lack of
proportionality.

The bias of R-4 for the VI component was accompanied by variations
in the changeover rate, shown in Fig. 8, during exposure to each of the
schedules. The finding of Brownstein and Pliskoff (1968) and Herrnstein
(1961) that the changeover rate decreases with increasingly disparate
reinforcement distributions suggests that the changeover rate should
remain relatively constant for each bird across conditions because the
distribution of reinforcers was not changed within birds. For all birds
except R-4 this appears approximately the case. The changeover rate for
R-4 during exposure to the conc VT 1.07-min VI 2.28-min RKI H.L. off
schedule was approximately twice the rate which prevailed during the
terminal condition, conc VT 2.28-min VI 1.07-min RKI H.L. off. No obvious
explanation for this rate difference is evident from the data or the
procedure.

While the time data for R-1, B-3, and R-3 support the contention
of a close correlation between the distribution of time and reinforcers
with concurrent VI-VT response requirements, unequal local rates of respond-
ing, and equal and unequal distributions of reinforcers the local rate data
suggest that the VT reinforcers were coming into contact with behavior other
than key pecking and show that a reduction in the VI-key local response rate
for R-3 and R-4 occured during exposure to the conc VT 1.07-min VI 2.28

schedule. This decrease in the VI-key local rate, shown in Fig. 2, does not necessarily imply that a decrease in the total number of VI-key responses per se can account for the reduction in the local rate. Because the total session times for R-3 and R-4 were approximately constant during exposure to the conditions in which 0.70 of the programmed reinforcers were delivered in the red-key component, the relatively flat absolute rate function for R-4 during these conditions suggests that the total number of amber key responses was relatively invariant. Thus in the case of R-4 the increased time spent in the VI-key component during exposure to the conc VT 1.07-min VI 2.28-min schedule was the primary factor involved in the reduction in the VI-key local response rate. This increase in the VI-key time for R-4 is reflected in the decrease, from conc VI 1.07-min VI 2.28-min to conc VT 1.07-min VI 2.28-min, in the relative time function shown in Fig. 4. For R-3 a VI-key response reduction was more involved in the decrease in the VI-key local rate because the time spent in the VI-key component during exposure to the conc VT 1.07-min VI 2.28-min schedule was not extremely different from the time spent in the VI-key component during exposure to the conc VI 1.07-min VI 2.28-min schedule. In this case the similarity of the amount of time allocated to the VI-key component during exposure to both of these schedules is reflected in the position of the relative time functions shown in Fig. 4 for both conditions.

The decreases in the local rates during the VT condition suggest that the response independent reinforcers were strengthing behavior other than key pecking. The observational data for R-3 and R-4 show that this was indeed the case. For R-3 these behaviors included standing in front of the hopper while making pecking motions and turning counterclockwise

after reinforcement. For R-4 this class of not key pecking behavior in-
cluded pecking around the changeover key, turning his head, and walking
to the far back side of the experimental chamber. The pecking behavior
of R-3 and R-4 indicate that while main-key pecking was eliminated all
pecking was not. Since no quantative data on the frequency, duration or
regularity of occurence of these behaviors was collected these observations
can only show the nature of these behaviors.

Although the data shown in Fig. 3 for R-1 and B-3 and in Fig. 4
for R-3 support the contention that with concurrent VI-VT response re-
quirements, unequal local rates of responding, and equal and unequal dis-
tributions of reinforcers the distribution of time approximates the
reinforcement distribution both these data and the local response rate
data additionally suggest that pigeons do not prefer response independent
to response dependent reinforcement and the primary basis for preference
in a concurrent schedule of grain reinforcement is reinforcement frequency.
To the extent that the measure of preference in a concurrent chain schedule
is comparable to the measure of preference in the concurrent schedule and
concurrent changeover responding and main-key responding are respectively
comparable to concurrent chain initial link and terminal link responding
these results support the findings of Neuringer (1969) and Killeen (1968)
which suggest that in a concurrent chain schedule pigeons do not prefer
response independent to response dependent reinforcement and the primary
basis for preference is reinforcement frequency.

SUMMARY

The purpose of the present study was to assess the effects of concurrent VI-VT response requirements on time allocation. Using a changeover-key procedure the reinforcers were distributed equally between both concurrent components for two pigeons while two different pigeons were exposed to two unequal distributions of reinforcers, 0.70-0.30 and 0.30-0.70. To eliminate main-key pecking the houselight was turned on and the main key was made dark and inoperative during the VT component. Because pecking persisted for R-4 the houselight was also turned off, leaving the light from the changeover key as the only illumination during the VT component. For all birds exposed to the illuminated VT component, the relative time spent in the VT component closely approximated the corresponding relative rate of reinforcement. These subjects included both birds exposed to the equal distribution of reinforcers and one bird exposed to the unequal distributions of reinforcers. R-4 spent considerably more time in the VI component than would be predicted by the distribution of reinforcers. A probable explanation for this bias involves the condition of reduced illumination for R-4 during the VT component.

BIBLIOGRAPHY

Baum, W. M. and Rachlin, H. Choice as time allocation. Journal of the Experimental Analysis of Behavior, 1969, 12, 861-874.

Brownstein, A. J. and Pliskoff, S. S. Some effects of relative reinforcement rate and changeover delay in response-independent concurrent schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1968, 11, 683-688.

Catania, A. C. Independence of concurrent responding maintained by interval schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1962, 5, 175-184.

Catania, A. C. Concurrent performances: Reinforcement interaction and response independence. Journal of the Experimental Analysis of Behavior, 1963, 6, 253-263.

_____. Concurrent operants. In W. K. Honig (Ed.), Operant behavior: areas of research and application. New York: Appleton-Century-Crofts, 1966. Pp. 213-270.

Ferster, C. B. and Skinner, B. F. Schedules of Reinforcement. New York: Appleton-Century-Crofts, 1957.

Gilbert, T. F. Fundamental dimensional properties of the operant. Psychological Review, 1958, 65, 272-285.

Herrnstein, R. J. Relative and absolute strength of response as a function of frequency of reinforcement. Journal of the Experimental Analysis of Behavior, 1961, 4, 267-272.

Killeen, P. Response rate as a factor in choice. Psychonomic Science, 1968, 12, 34.

Neuringer, A. J. Delayed reinforcement versus reinforcement after a fixed interval. Journal of the Experimental Analysis of Behavior, 1969, 12, 375-383.

Reynolds, G. S. On some determinants of choice in pigeons. Journal of the Experimental Analysis of Behavior, 1963, 6, 53-59.

Steiner, S. S., Beer, B. and Shaffer, M. M. Escape from self-produced rates of brain stimulation. Science, 1969, 163, 90-91.

Stubbs, D. A. and Pliskoff, S. S. Concurrent responding with fixed relative rate of reinforcement. <u>Journal of the Experimental Analysis of Behavior</u>, 1969, 12, 887-895.

Wilkie, D. M. Variable-time reinforcement in multiple and concurrent schedules. <u>Journal of the Experimental Analysis of Behavior</u>, 1972, 17, 59-66.

APPENDIX

Table I

Experimental conditions, relative rate
of reinforcement in the red-key compo-
nent, and number of sessions exposure
to each condition for each bird. A
COD was in effect during all conditions.

Bird	Condition	Relative rate of red-key reinforcement	Number of sessions exposure
R-1	conc VI 1.5-min VI 1.5-min	0.50	20
	conc VT 1.5-min VI 1.5-min	0.50	30
	conc VT 1.5-min VI 1.5-min RKI	0.50	20
	conc VI 1.5-min VI 1.5-min	0.50	11
B-3	conc VI 1.5-min VI 1.5-min	0.50	17
	conc VT 1.5-min VI 1.5-min	0.50	30
	conc VT 1.5-min VI 1.5-min RKI	0.50	15
R-3	conc VI 1.07-min VI 2.28-min	0.70	33
	conc VT 1.07-min VI 2.28-min	0.70	40
	conc VT 1.07-min VI 2.28-min RKI	0.70	15
	conc VT 2.28-min VI 1.07-min RKI	0.30	21
R-4	conc VI 1.07-min VI 2.28-min	0.70	31
	conc VT 1.07-min VI 2.28-min	0.70	42
	conc VT 1.07-min VI 2.28-min RKI	0.70	10
	conc VT 1.07-min VI 2.28-min RKI H.L. off	0.70	25
	conc VT 2.28-min VI 1.07-min RKI H.L. off	0.30	21
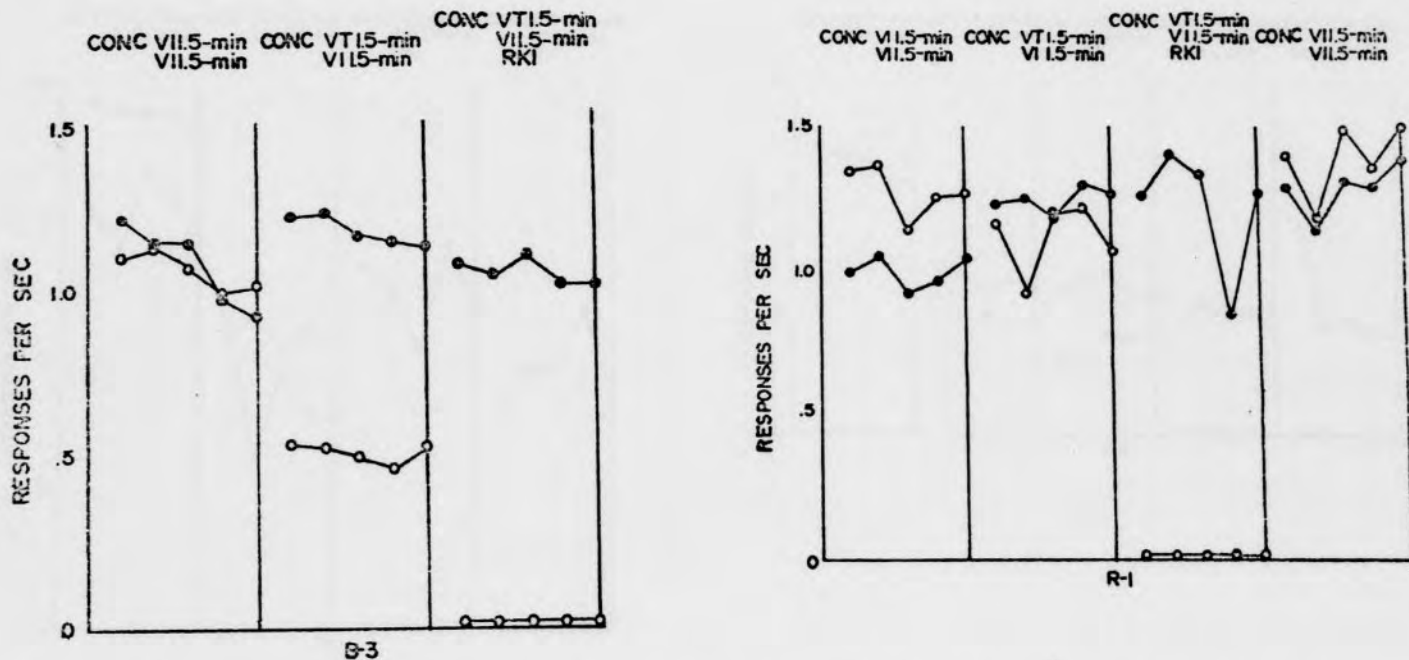
Fig. 1. Responses per sec for both the red key (open points) and amber key (closed points) during the terminal 5 sessions exposure to each concurrent schedule. The schedule for the red-key component was changed from a VI to a VT following exposure to the conc VI 1.5-min VI 1.5-min schedule. Both R-1 and B-3 were exposed to the conc VT 1.5-min VI 1.5-min schedule.
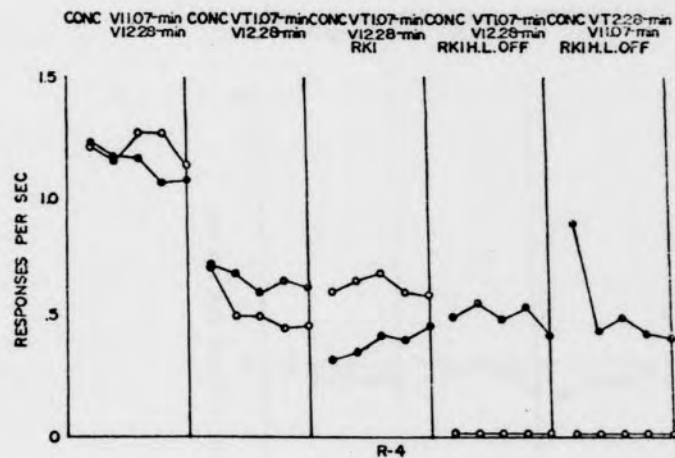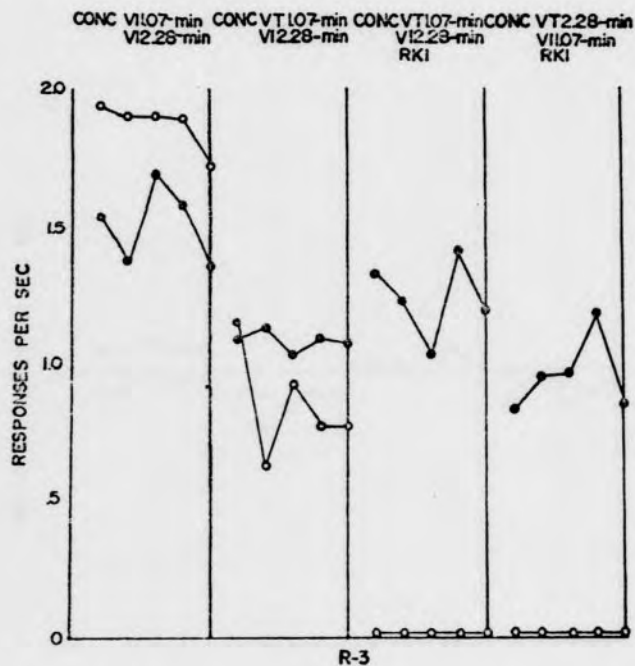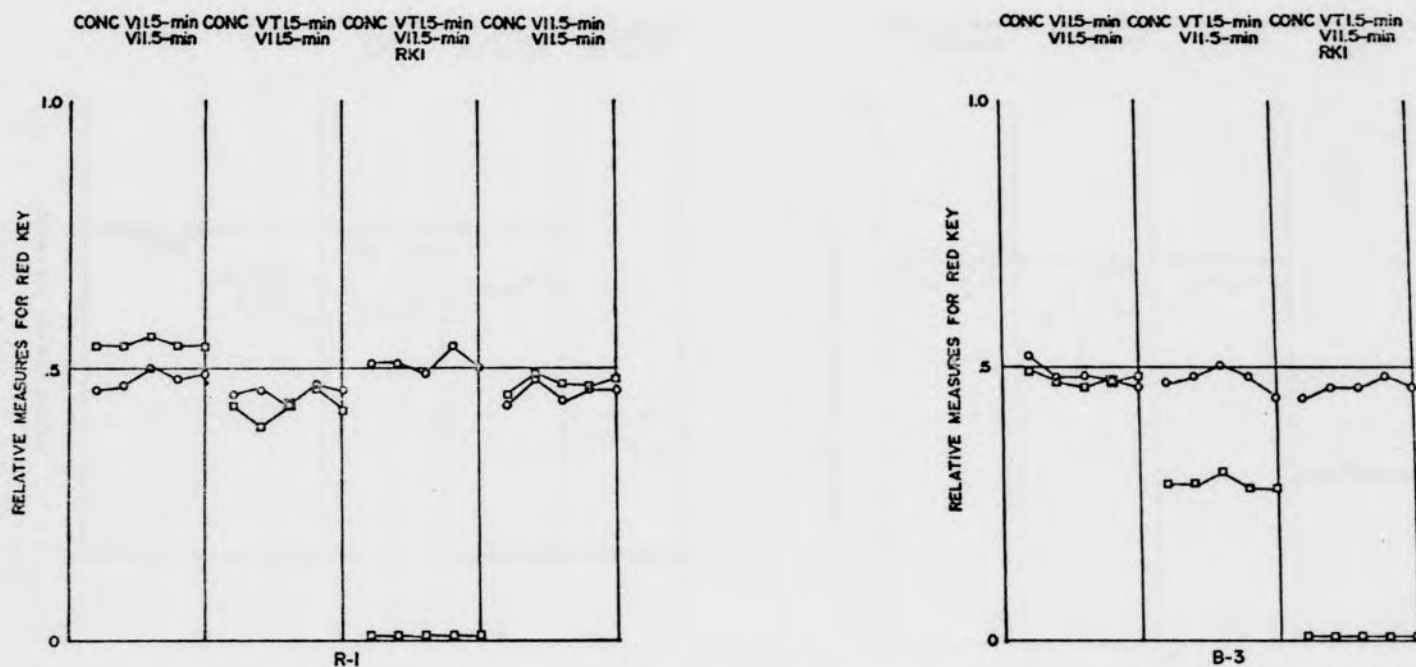
Fig. 2. Responses per sec for both the red key (open points) and amber key (closed points) during the terminal 5 sessions exposure to each concurrent schedule. The schedule for the red-key component was changed from a VI to a VT following exposure to the conc VI 1.07-min VI 2.28-min schedule. Both R-3 and R-4 were exposed to the conc VT 1.07-min VI 2.28-min schedule.
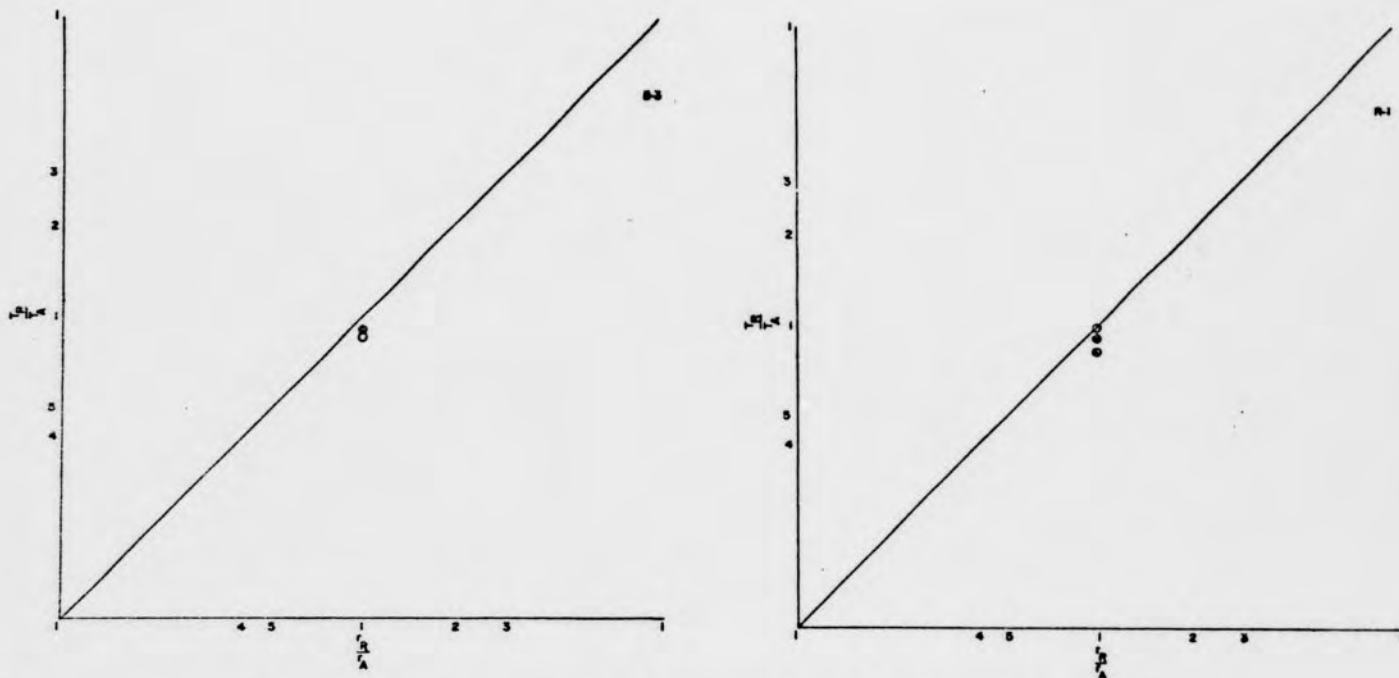
Fig. 3. The relative time spent in the red-key component (round points) and relative red-key response rate (square points) for the terminal 5 sessions exposure to each concurrent schedule. The heavy black horizontal line is the obtained relative rate of reinforcement. The schedule of reinforcement during the red-key component was changed from a VI to a VT following exposure to the conc VI 1.5-min VI 1.5-min schedule. Both R-1 and B-3 were exposed to the conc VT 1.5-min VI 1.5-min schedule.
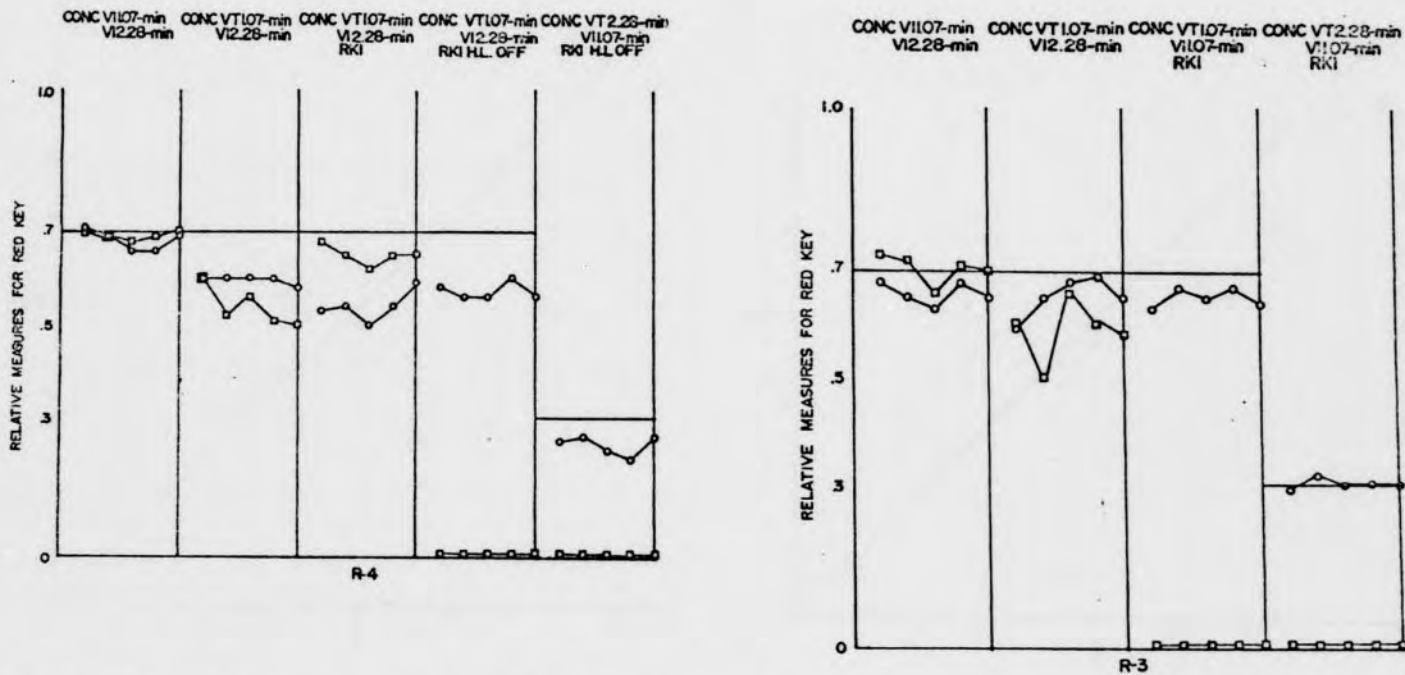
Fig. 4. The relative time spent in the red-key component (round points) and relative red-key response rate (square points) for the terminal 5 sessions exposure to each concurrent schedule. The heavy black horizontal line is the obtained relative rate of reinforcement. The schedule of reinforcement during the red-key component was changed from a VI to a VT following exposure to the conc VI 1.07-min VI 2.28-min schedule. Both R-3 and R-4 were exposed to the VT 1.07-min VI 2.28-min RKI schedule.

Fig. 5. The ratio of time spent in the red-key component over time spent in the amber-key component as a function of the corresponding reinforcement ratio for the conc VI 1.5-min VI 1.5-min schedule (closed point) and the conc VT 1.5-min VI 1.5-min RKI schedule (open point). In both Fig. 5 and 6 each time ratio consists of the median red and median amber times selected from the terminal 5 sessions exposure to the corresponding reinforcement schedules. The dotted open point for R-1 is the baseline redetermination point. The heavy black diagonal represents the perfect correlation between the corresponding time and reinforcement ratios.
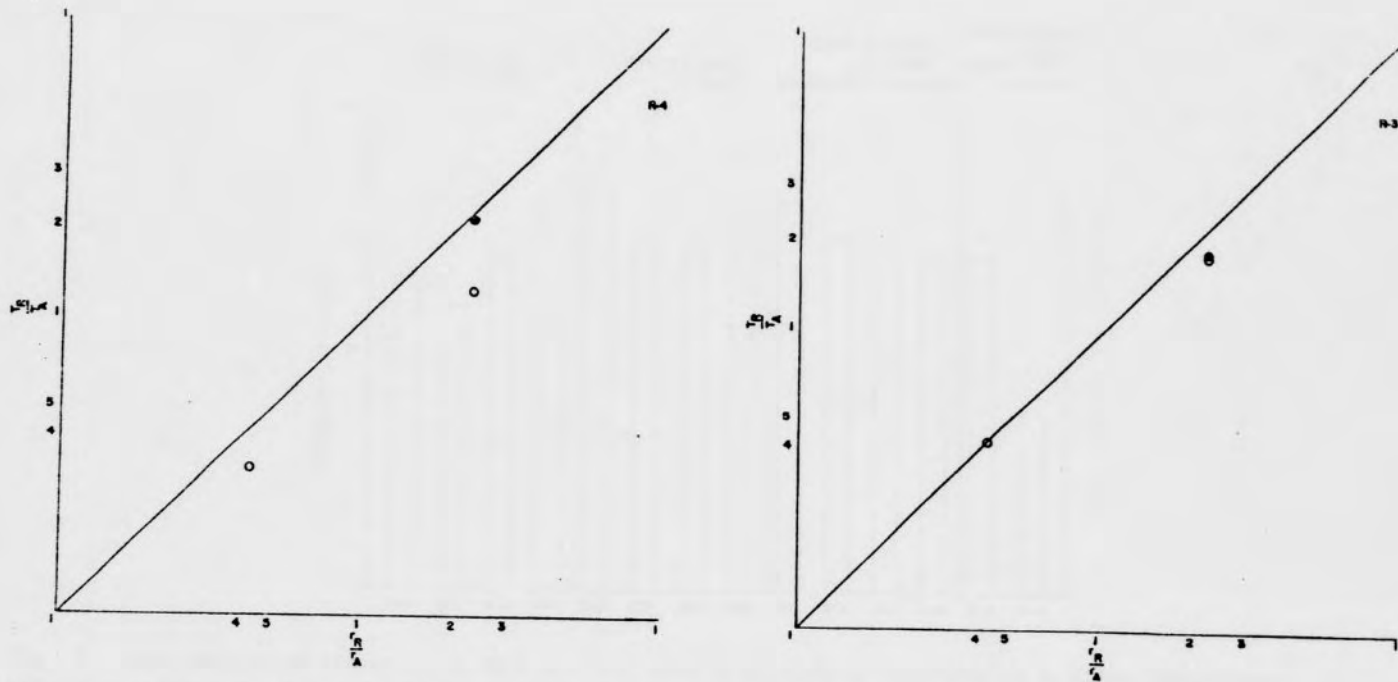
Fig. 6. The ratio of time spent in the red-key component over time spent in the amber-key
component as a function of the corresponding reinforcement ratio for the conc VI 1.07-min
VI 2.28-min schedule (closed point) and the conc VT 1.07 (or 2.28)-min VI 2.28-min (or
1.07-min) RKI (house light off for R-4) schedules. The heavy black diagonal represents
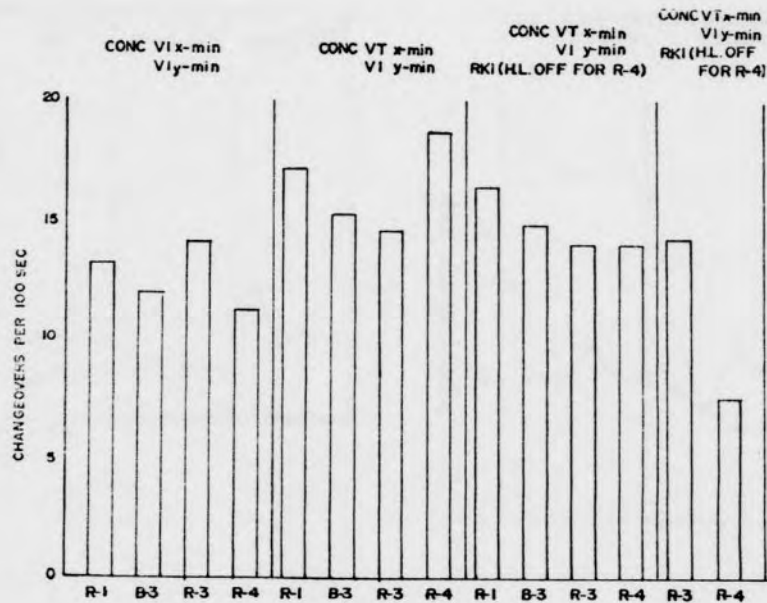the perfect correlation between the corresponding time and reinforcement ratios.

Fig. 7. The number of changeovers/100 sec for each bird during exposure to a given concurrent schedule. The rate for all birds was computed from the median number of changeovers and the median total session time selected from the terminal 5 sessions of exposure to a given schedule. For R-1 and B-3 the x and y schedule values were 1.5-min while for R-3 and R-4 whose values were either 1.07-min or 2.28-min. During the last condition shown for R-3 and R-4 the schedule in effect was conc VT 2.28-min VI 1.07-min RKI (houselight off for R-4). The changeover rates while the red key was inoperative were obtained for R-4 with the houselight off.
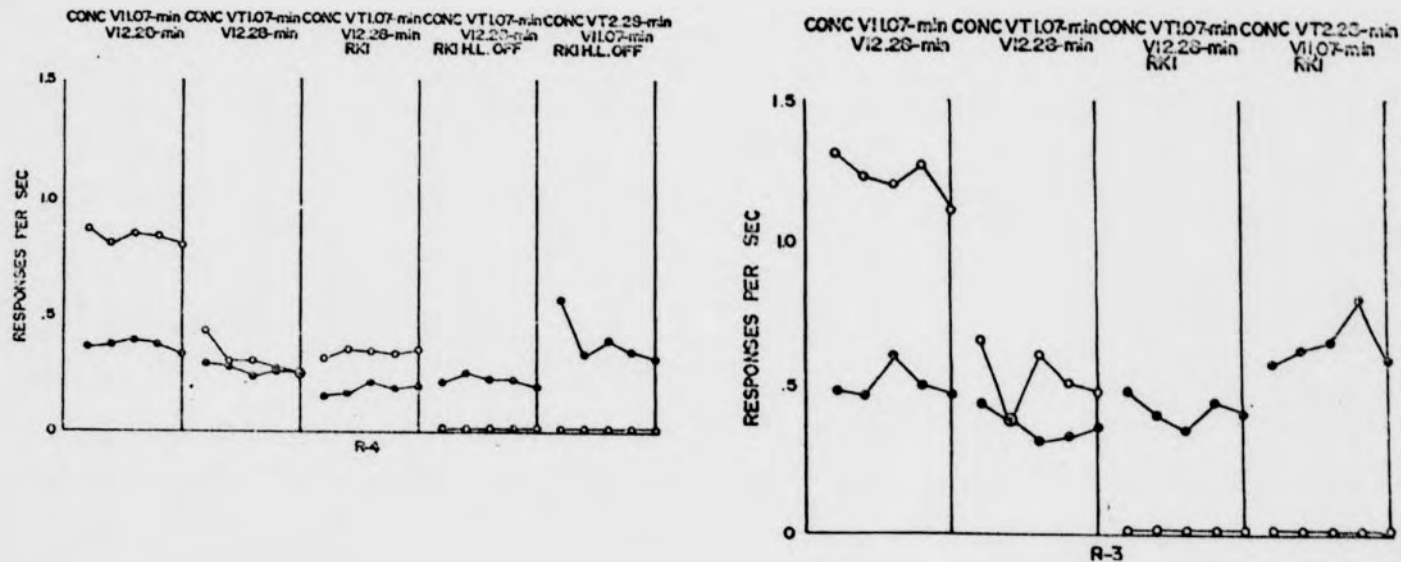
Fig. 8. Responses per sec for both the red (open points) and amber key (closed points) during the terminal 5 sessions exposure to each concurrent schedule. The schedule for the red-key component was changed from a VI to a VT following exposure to the conc VI 1.07-min VI 2.28-min schedule. The time base for computing these rates was the total session time (T_t).