GUILKEY, MARILYN. Rate Constancy: Another Look at Response Independence in Concurrent Schedules. (1972) Directed by: Dr. Richard L. Shull. Pp. 55.

The purpose of this study was to re-examine the question of response independence or response rate constancy in concurrent variable interval schedules of reinforcement. The results of an earlier study (Catania, 1963) indicated that responding in one schedule of a pair of concurrent variable interval schedules was not affected by the amount of time spent responding in the other schedule when a changeover delay (COD) was used. However, other data have suggested that high rates of responding during the COD may have been responsible for those results. In this study one group of three pigeons was run with a COD to assess the effects of COD responding in producing rate constancy or rate independence. A second group of birds was run with a fixed-ratio changeover (FR-CO) contingency to see if rate constancy would be obtained with a changeover contingency that did not involve a COD.

All the birds were food-deprived and grain was used as the reinforcer. Both groups were run on a series of concurrent schedules. One schedule remained constant while the other was varied. For each pair of schedules the procedure was to establish a baseline for rates of responding using a standard changeover-key method of programming the schedules. One modification of the standard concurrent scheduling procedures was used, in that when a reinforcement became available in one schedule, it had to be delivered before a reinforcement could

became available on the other schedule. After the baseline had been established the scheduling procedure was changed to a procedure in which reinforcements were signalled on the one of the keys. This was done by allowing the bird to changeover only when a reinforcement was available on the signalled schedule. In this manner the bird was forced to spend most of the session time in the unsignalled schedule, while still obtaining reinforcements on the signalled schedule. The unsignalled schedule was always VI (variable interval) 2-min. The other schedule was either VI 6-min, VI 2-min, VI .67-min or EXT (extinction). The COD value was two seconds and the fixed ratio changeover requirement was two responses.

The main results of the study was that overall response rates on the VI 2-min schedule increased during the signalling conditions for five of the six birds used. The overall rates for the sixth bird decreased during the COD. Since this bird was the only bird to respond at consistently high rates during the COD, his results provided some support for the idea that high rates during the COD cause a reduction in the local rates of responding during the signalling conditions which results in apparent overall rate constancy. The results of the other five birds did not support the idea that responding in one schedule oi a pair of concurrent schedules is independent of responding in the other schedule.

RATE CONSTANCY: ANOTHER LOOK AT RESPONSE INDEPENDENCE IN CONCURRENT SCHEDULES

by

Marilyn Guilkey

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Thesis Adviser

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 Richard L. Shull

Oral Examination Committee Members Richard L. Shull

Aaron J. Brownstein

Robert G. Eason
for Evelyn Segal

Date of Examination

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CHAPTER I

INTRODUCTION

Concurrent variable-interval schedules of reinforcement provide two (or more) independently programmed and continuously available variable-interval schedules of reinforcement. Two procedures are commonly used to arrange these schedules. In one, each scedule is assigned to a different response key and the subject moves between them. Reinforcements are delivered only for responses on the key assigned to that schedule. In the other procedure, both schedules are programmed on the same ("main") key and each schedule has a different stimulus, usually key color, correlated with it. Although the schedules operate continuously, only one schedule with its correlated stimulus is in effect at a time. A second response key, called the changeover key, is provided and responses on this key serve to switch the stimuli and the associated schedule on the main key.

A considerable amount of research has been devoted to examining the relation between responding and reinforcement in concurrent schedules. Herrnstein (1961) and Catania (1963) found that the relative rate of responding on each of two schedules was equal to the relative rate of reinforcement that the schedule provided. The relative rate of responding for one schedule is equal to the overall rate of responding (responses in that schedule/total session time) divided by the sum of the rates of responding for both schedules. Relative rate of reinforcement is calcuated analogously. Relative rates of responding reduce to the relative numbers of responses and relative rates of reinforcement reduce to relative numbers of reinforcement (Shull and Pliskoff, 1967).

This relationship has become known as the "matching rule." When relative responses or other relative measures of behavior are found to be equal to the relative rate of reinforcement, matching is said to occur.

Catania (1966) found that the relative amount of time spent in one schedule was equal to the relative rate of reinforcement. This result raised the issue of whether the critical factor in the matching relationship was the matching of responses or matching of time.

Herrnstein's original explanation of matching was in terms of the "overall" rates of responding, that is, responses in each schedule divided by the session duration. He reasoned that both schedules were continuously available for the entire session duration, although the organism could only respond in one at a time. Matching occurred because response rates were a "linear measure of response strength which was itself a linear function of the frequency of reinforcement." A variation of this view has been proposed by Revusky (1963) and discussed by Catania (1966). Revusky proposed that the animal distributed his responses in such a way as to maintain an equal number of responses per reinforcement on each key. Matching would then occur because the total output on a key would be some multiple of the number of reinforcements that key provided.

Another view of matching has been discussed by Brownstein and Pliskoff (1968) and by Baum and Rachlin (1969). This view assumes that responding occurs at a fairly uniform "local" rate on each key and that an animal allocates his time between schedules according to the relative value of the schedule. The distribution of responses would, in this view, be determined by the distribution of time spent responding on each key. If the local rates were the same in the presence of each schedule and relative time matched the relative rate of reinforcement, than the relative number of responses will also match the relative rate of reinforcement.

Because in the typical concurrent procedure, relative numbers of responses and relative time allocation have both been found to match the relative rate of reinforcement, the effects of the relative rate of reinforcement on the distribution of time and responses cannot be assessed separately. Brownstein and Pliskoff (1968) and Baum and Rachlin (1969) have reported conceptually similar experiments which offer some support for the time allocation model. In these two experiments a discrete response such as a key peck was not required, although a reinforcement contingency was in effect. In the Brownstein and Pliskoff study, the subjects (pigeons) were required to be in the presence of a certain stimulus correlated with the schedule in order to be reinforced in the schedule. In the Baum and Rachlin study the "response" was standing in one side or the other of the experimental chamber.

In the Brownstein and Pliskoff experiment two variable-interval schedules of food presentation were concurrently programmed; each schedule was correlated with a different colored house light which illuminated the experimental chamber when that schedule was in effect. Reinforcers programmed for each schedule could only be delivered in the presence of the stimulus light correlated with that schedule. The only response key available served to change the color of the light and the schedule that was in effect. Brownstein and Pliskoff found that the pigeons matched the relative time spent in the presence of each schedule to the relative rate of reinforcement that the schedule provided.

In the study by Baum and Rachlin (1969), each one of a pair of variable-interval schedules assigned reinforcements to food hoppers in opposite walls of the experimental chamber. The reinforcements provided by each schedule were delivered only if the pigeon was standing in the appropriate half of the chamber. Correcting for a consistent position bias, Baum and Rachlin found that the pigeons matched the proportion of time spent in each half of the box to the proportion of reinforcements obtained on that side.

The implication of these studies is that the matching of time may be the variable most directly affected by the relative rate of reinforcement while the distribution of responses may be a by-product of the distribution of time.

However, an earlier study by Catania (1963) does not appear to support a time-allocation model. Catania found that the total response output for a given concurrent schedule remained constant despite an increase in the amount of time spent in that schedule. The study was designed to investigate whether or not responding in one schedule interacted with or was independent of the rate of responding in the other schedule. First, three pigeons were run on a set of concurrent-schedule pairs, programmed according to the changeover-key method. Several pairs of schedules were used, with one schedule being held constant and the other being varied. Catania found that as the rate of reinforcement in the variable schedule increased, the rate of responding in that schedule increased, while the rate of responding in the schedule that was held constant decreased systematically. Catania found that the rate of responding in each schedule fit the following power function: $R_1 = Kr_1/(r_1 + r_2)\frac{5}{6}$. where "$R_1$" is the rate of responding in one schedule, "r_1" is the rate of reinforcement in that schedule, "r_2" is the rate of responding in the other schedule and "K" is a constant.

Notice that there is no term for the rate of responding for schedule two in the equation. Catania believed that the rates of responding in the two schedules were independent, that is, the rate in one schedule was not affected by the amount of time the subject spent in the other schedule. However, it could be argued that the rates of responding in the constant schedule decreased because the pigeon was spending more time responding on the variable schedule and could therefore emit fewer responses on the constant schedule.

To explore this possibility, Catania devised a procedure that allowed the subject to spend nearly the entire session responding on the constant schedule while still receiving the reinforcements that had been programmed on the variable schedule. This was accomplished by the use of a signalling procedure that signalled reinforcements on the variable schedule. Changeovers were allowed to be made to the signalled schedule only when a reinforcement became available on that schedule. During the rest of the session the bird remained in the constant schedule. The same pairs of schedules were used in the signalling condition as had been used in the first part of the study.

The results of the signalling procedure confirmed Catania's prediction that the rates of responding on the two schedules were independent of each other. The overall rate of responding (responses/session time) for the constant schedule of a given pair was the same whether or not the other schedule was signalled. Even though more time was spent in the constant schedule during the signalling conditions, no more responses were made on that schedule; rather the local rate (responses in the constant schedule/time spent in the constant schedule) declined during the signalling procedures. These results do not support the time-allocation model which postulates that the increased amount of time available for responding in the constant (unsignalled) schedule should have resulted in an increase in the total number of responses made in that schedule.

However, it may be argued that the drop in local rate on the constant (unsignalled) schedule in the signalling conditions could have been an artifact of the procedure that was used. In Catania's study, as well as in the majority of research on concurrent schedules, a changeover delay was used to restrict the number of changeovers and to separate in time responses on one schedule from reinforcements on the other schedule. The changeover delay (COD) specifies the minimum interval of time that must elapse following a changeover before a reinforcement can be delivered. Without a COD, as Herrnstein (1961) first found, pigeons tended to change over after every response, so that the response distribution remained at about 50 percent regardless of the schedule parameters. A COD of 1.5 to 2.0 seconds has generally been found sufficient to obtain matching.

Recently, Silberberg and Fantino (1970) have provided data that indicated that responding during the COD tended to occur at a higher local rate than responding after the COD has elapsed. They used a two-key procedure and a COD of 1.75 sec and measured separately the local rate of responding during the COD and after it had elapsed. They suggested that the high local rates during the COD resulted from a higher local probability of reinforcement immediately after the COD because a reinforcement that had become available during the COD or when responding was occurring on the other schedule was held until the COD had elapsed. Catania (1966) regarded the bursts of responding that occurred during the COD as "compensating" for the time spent responding on the other schedule so that a constant response output on the schedule was maintained. Pliskoff (1971) has provided a summary of these arguments.

It thus appears that responding during the COD tends to occur at a higher local rate than responding after the COD has elapsed. The significance of this finding for Catania's experiment is that during the first phase of the experiment which involved unsignalled concurrent scheduling the birds changed over frequently. If the COD rates were higher than the post-COD rates, then the local rates of responding would reflect the contribution of two distinct rates and would be a weighted average of these two rates. During the signalling conditions, few changeovers were made and the local rates would have been expected to consist almost entirely of the lower rate of responding characteristic of post-COD periods. Therefore, a lower local rate in the constant (unsignalled) schedule would result simply from the elimination of changeovers, and hence, COD "bursts" of high-rate responding.

Still, although the elimination of COD responding might account for the drop in local rate in the constant schedule during the signalling procedures, it does not account for the fact that the rate in the constant schedule during the signalling conditions dropped as the rate of reinforcement in the signalled schedule increased. A simple time-allocation model predicts that these local rates remain the same because the unsignalled schedule remained the same. It is possible that local rates as well as overall rates vary systematically as a function of the relative rate of reinforcement.

The purpose of the present study was twofold: First, to show that the apparent overall response-rate constancy Catania obtained could have been due to the effects of the COD upon local rates of responding and second, to see if response-rate constancy or response-rate independence would occur with a concurrent procedure that did not include a COD. The first part of the study constitued a systematic replication of the Catania study with different schedule parameters and with responses during and after the COD being separately recorded. In this way, it was possible to calculate separately local rates of responding during and after the COD so that the contribution of COD rate to the local rate could be assessed.

In the second part of the experiment, a fixed-ratio changeover contingency was used instead of a changeover delay. This procedure, which was first reported by Stubbs and Pliskoff (1969), requires that the subject complete a small fixed-ratio requirement on the changeover key to switch the schedule on the main key. The purpose of this procedure was to separate, as far as possible, the effects of the changeover contingency from those of the main key. This procedure, since it does not employ a changeover delay, should not generate COD bursts.

CHAPTER II

METHODS

Subjects

Subjects were four naive adult Silver King pigeons and two White King pigeons with brief experimental histories on multiple variable-interval schedules. At the beginning of the experiment all birds were at 80% of their free-feeding weights.

Apparatus

A standard-sized pigeon experimental chamber was used. The front wall, measuring 36 cm by 36 cm contained two 1.8 cm translucent Gerbrands pigeon keys and an opening for a mixed-grain feeder (Lehigh Valley Electronics). The keys were spaced 8 cm apart, center to center, and were mounted 25.5 cm from the floor of the chamber. The feeder opening was in the center of the panel below the left key. The response keys were adjusted to operate with a minimum force of 15 grams. A small relay mounted behind the front panel provided a feedback click for each effective key peck. A speaker in the ceiling of the chamber provided white masking noise and an exhaust fan provided ventilation. During the feeder operation the key lights were turned off and the feeder opening was illuminated.

Procedure

Sessions were conducted daily (with interruptions for vacations)and were run for 60 reinforcements. The reinforcer was always 3 sec operation of the feeder.

The four naive birds were hand-shaped and all birds were then run on variable-interval (VI) one-min for 14 daily sessions. The key color was alternated between red and green daily. Following VI training, all birds were run on concurrent VI 2-min VI 6-min with no changeover contingency for nine sessions. Then the first experimental condition was instituted. The basic procedure was to establish a baseline of rates of responding on each pair of unsignalled schedules, and then switch to a procedure in which reinforcements were signalled in one of the schedules. This was a departure from Catania's procedure as he ran all the signalled conditions consecutively after running a series of unsignalled concurrent schedules.

One of the schedules was always VI 2-min (30 reinforcements per hour) while the other schedule was varied among VI-6 min, VI 2-min, VI .67-min (corresponding to 10, 30, and 90 reinforcements per hour) and extinction. (Concurrent VI 2-min Ext sessions were run for 30 reinforcements). This produced relative rates of reinforcement for the constant schedule of .75, .50, .25 and 1.00. The VI schedules consisted of an arithmetic series of 13 intervals, with the smallest interval nominally zero sec and the longest interval twice the mean interreinforcement interval. The intervals were arranged in random order and punched on a continuous loop of 16 mm film.

Basic concurrent procedure. Catania's (1963) basic concurrent procedure was followed. Both VI schedules were programmed to run concurrently on the main (left) key. Responses on the other key, the changeover (CO) key, which was illuminated white, changed the schedule in effect on the main key. The CO-key was darkened and inoperative after every changeover until a main key response was made. Thus, the procedure required at least one main key response between each changeover. Reinforcements assigned by a schedule were delivered only when the appropriate schedule was in effect on the main key and were held until they were collected.

Each schedule was correlated with a different color on the main key. Red illumination of the main key was correlated with the constant VI 2-min schedule. The variable schedule was correlated with green illumination of the main key.

One important modification of the usual concurrent procedure concerned the independence of the two schedules. Following a procedure described by Stubbs and Pliskoff (1969), whenever a reinforcer was programmed by one of the VI schedules, the tape drives for both schedules stopped until the reinforcer was collected. This procedure insured that the obtained distribution of reinforcements was the same as the programmed distribution. Any confounding of the reinforcement distribution with the subject's distribution of his session time was thereby avoided.

Signalling procedure. The signalling procedure that was used was similar to Catania's, except that the changeover key was illuminated white instead of the same color as the signalled reinforcement schedule. Both schedules operated concurrently but the main key was illuminated red and the changeover key was dark and inoperative except when a reinforcement was programmed on the other schedule (the green schedule). At that time the changeover key was illuminated and the bird could changeover and obtain the reinforcer programmed by the green or signalled schedule. After the delivery of the reinforcer, the main key was again illuminated red and the changeover key was again dark and inoperative.

For a given pair of schedules the session duration and distribution of responses on each schedule were the same during both baseline and signalling procedures. The difference between the two conditions was the availability of the changeover key and access to the green schedule. In the baseline conditions changeovers were unrestricted; in the signalling conditions changeovers were limited to occasions when a reinforcer could be obtained in the green (signalled) schedule. Therefore, in the signalling conditions most of the session was spent in red; in the baseline conditions the time spent in the red schedule was determined by the subject.

Two groups of birds were run under all the baseline and signalling procedures with one of two changeover contingencies in the effect throughout.

Changeover delay procedure. Three birds (two naive and one experienced) were exposed to the baseline and signalling procedures with a changeover delay (COD) as the changeover contingency in the replication of Catania's procedure. The COD specifies the minimum interval of time that must elapse between a response on the changeover key and a reinforcement for a response on the main key. A reinforcement that became available while responding was going on the other main key schedule or during the COD was held until the COD elapsed. The COD was two sec in all the data reported. (A COD of three sec was used in a condition just previously to the first condition reported in the present study. This was done to see if better response matching could be obtained, but was not successful in this respect. The data did not differ in any systematic way from the data obtained with a two sec delay and were not included.) The COD was timed from a response on the changeover key.

Fixed-ratio changeover procedure. Three birds were run with a fixed-ratio two contingency in effect on the changeover key instead of a COD. The purpose of this procedure was to see if the results of Catania's study could be obtained with a different changeover contingency. The fixed-ratio value selected was sufficient to limit changeovers and to produce matching.

Two pecks on the changeover key were required to complete each changeover. After the first response on the CO- key, the main key was darkened to prevent main-key responses during the changeover ratio. The second response completed the ratio requirement and changed the schedule and its correlated key color in effect on the main key and also darkened the CO-key. The changeover key was reilluminated by the first main-key peck following the changeover. During the signalling procedure, the changeover key was not reilluminated by the first main-key peck following a reinforcement in the signalled schedule.

In all the conditions both VI tape drives and main-key recording timers were stopped during fixed ratio changeovers. This was done to separate as far as possible changeover contingencies from main-key contingencies, That is, the rate of changeovers and the response rate during the changeover should not have affected the reinforcement contingencies. With the COD procedures, however, the tapes and timers continued to run during the COD in replication of Catania's (1963) procedure. (On one initial conditions the tapes did run during fixed-ratio changeovers, but the data did not differ systematically from the other conditions and so were not included.)

In Table 1 is listed the number of sessions run and the sequence of baseline and signalling conditions. Each condition was run for a minimum of 15 days and changes were made only when response rates in the red schedule showed no increasing or decreasing trends.

TABLE 1

Number of Sessions for Each Bird
and the Sequence of Conditions

Schedule in Green	Rft./hr. Green	Procedure	Bird Number COD 2	5	7	FR-CO 4	6	9
VI 6-min	10	Baseline	14	14	14	16	16	16
		Signalling	16	16	16	16	16	16
VI 2-min	30	Baseline	20	20	20	20	20	20
		Signalling	20	20	20	20	20	20
		Baseline	15	15	15	15	15	15
		Signalling	15	15	15	15	15	15
VI 0.67-min	90	Baseline	26	25	25	25	25	25
		Signalling	20	20	20	20	20	25
		Baseline	20	15	20	19	15	20
		Signalling	20	15	20	19	15	20
Ext	0	Baseline	26	25	25	25	25	25
		Signalling	24	25	25	20	25	25
VI 6-min	10	Baseline	35	35	35	35	36	46
		Signalling	25	25	25	25	35	49

CHAPTER III

RESULTS

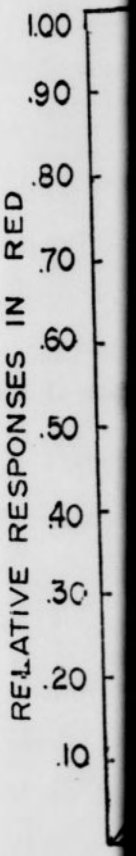
The data plotted in all figures were derived from the medians of the last five days of a condition, except for figures in which results from daily sessions are shown. Where two determinations of a condition were made, the average of the two medians was used.

Figures 1 and 2 show relative responses in the red schedule (VI 2-min) and relative time spent in red, respectively, as a function of the relative rate of reinforcement in that schedule. All but four points in Figure 1 fell within 8% of perfect response matching. The relative time measures more closely approximated matching, as all points without exception fell within 8% of perfect matching. Thus, all birds' performances were appropriate to concurrent schedules.

The aim of the study was twofold: first, to see if high rates during the COD could have been responsible for the results of Catania's study in which overall rate constancy was obtained with signalled reinforcement schedules, and second, to see if his results could be replicated when a fixed-ratio on the changeover key was the changeover contingency.

In general, constancy of overall response rate in the red schedule for a given pair of schedules was not obtained

Fig. 1- Relative Responses in Red as a Function of the Rate of Reinforcement in Red.



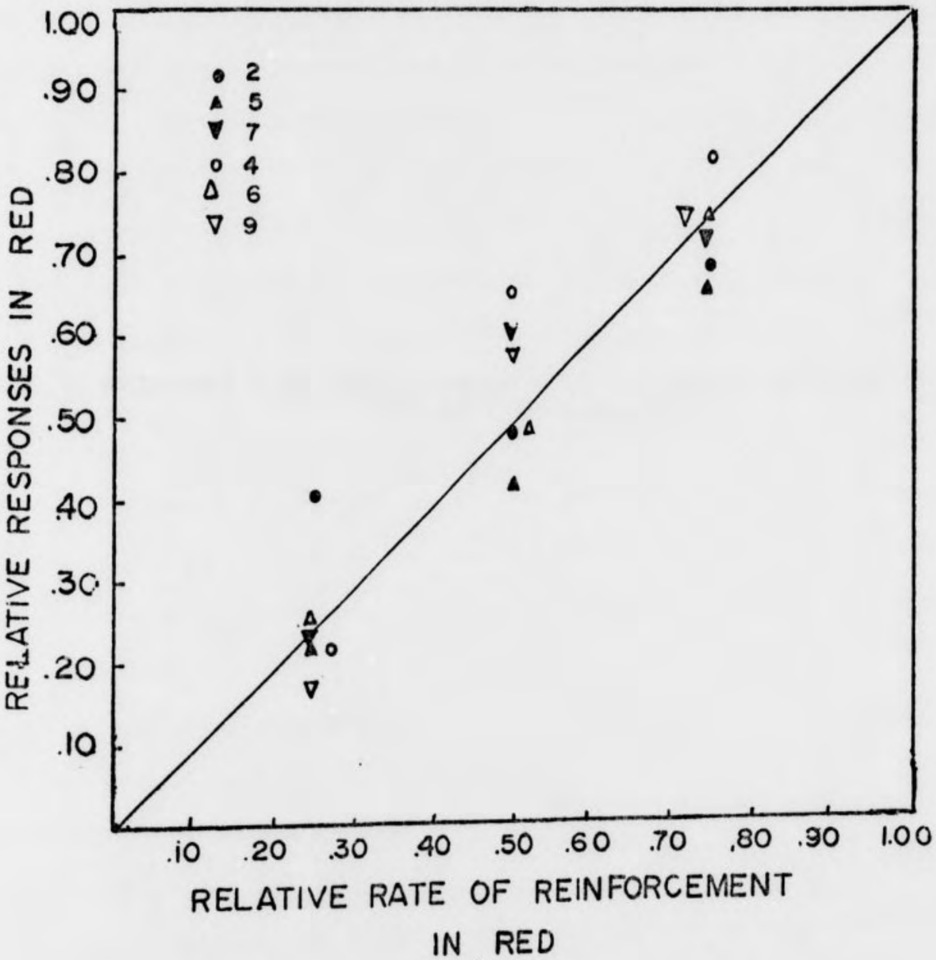
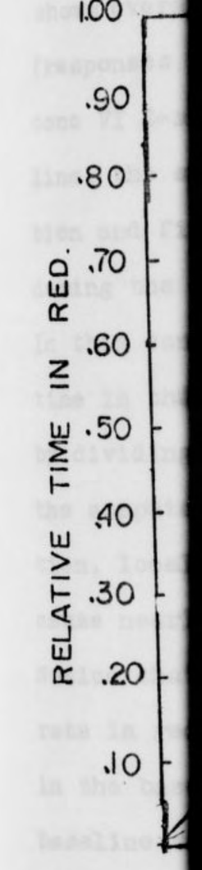
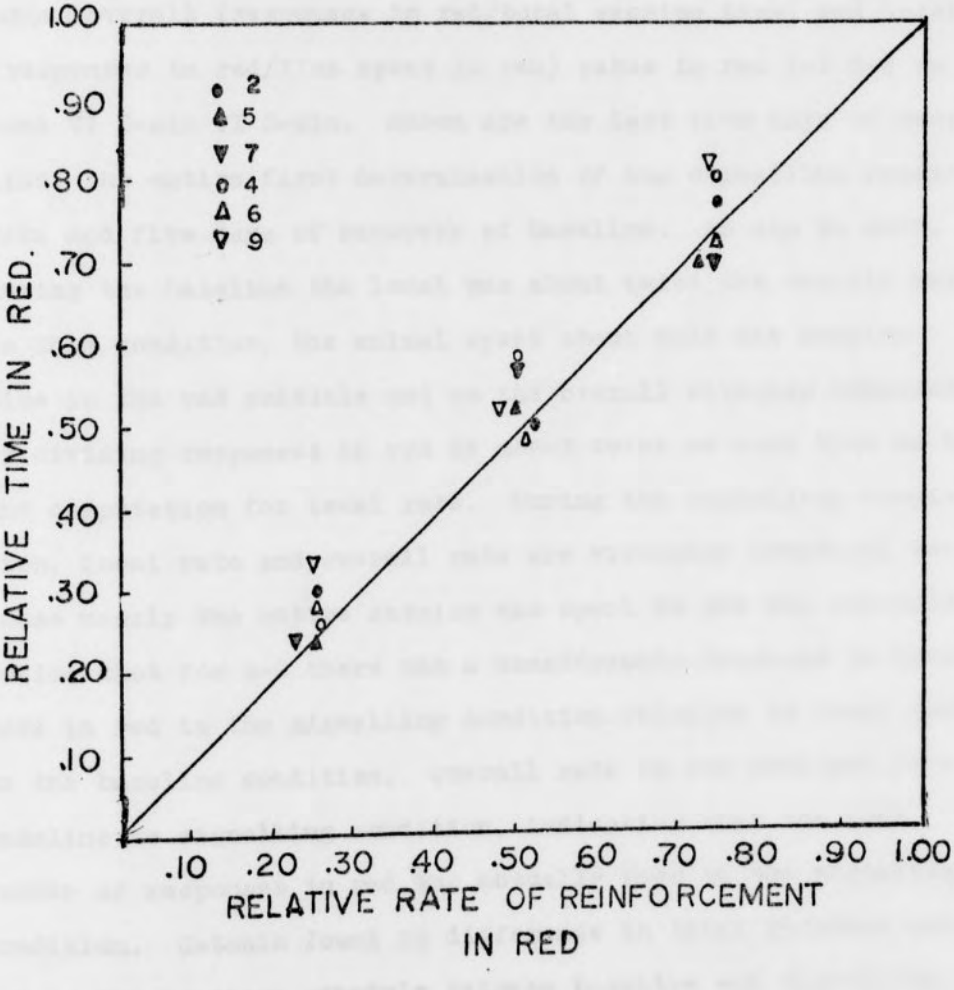

1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
RELATIVE RESPONSES IN RED
● 2
▲ 5
▼ 7
○ 4
△ 6
▽ 9
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
RELATIVE RATE OF REINFORCEMENT
IN RED

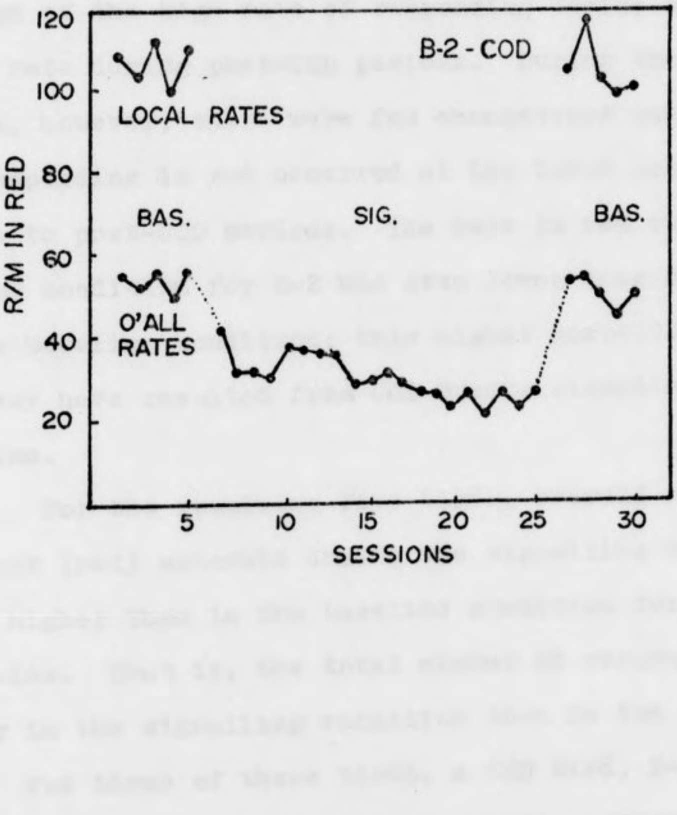
Fig. 2- Relative Time Spent in Red as a Function of the Rate of Reinforcement in Red




● 2
▲ 5
▼ 7
○ 4
△ 6
▽ 9
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
RELATIVE TIME IN RED.
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
RELATIVE RATE OF REINFORCEMENT
IN RED

for any of the birds for all pairs of schedules. For one bird the overall rate in the constant (red) schedule was always lower during the signalling condition than during the immediately preceding baseline condition. To illustrate the typical result that was obtained for this bird, B-2, Figure 3 shows overall (responses in red/total session time) and local (responses in red/time spent in red) rates in red for B-2 on conc VI 2-min VI 2-min. Shown are the last five days of baseline, the entire first determination of the signalling condition and five days of recovery of baseline. As can be seen, during the baseline the local was about twice the overall rate. In this condition, the animal spent about half the session time in the red schedule and so the overall rate was computed by dividing responses in red by about twice as much time as in the computation for local rate. During the signalling condition, local rate and overall rate are virtually identical because nearly the entire session was spent in the red schedule. Notice that for B-2 there was a considerable decrease in local rate in red in the signalling condition relative to local rate in the baseline condition. Overall rate in red declined from baseline to signalling condition, indicating that the total number of responses in red was actually less in the signalling condition. Catania found no difference in total response output in the constant schedule between baseline and signalling conditions.

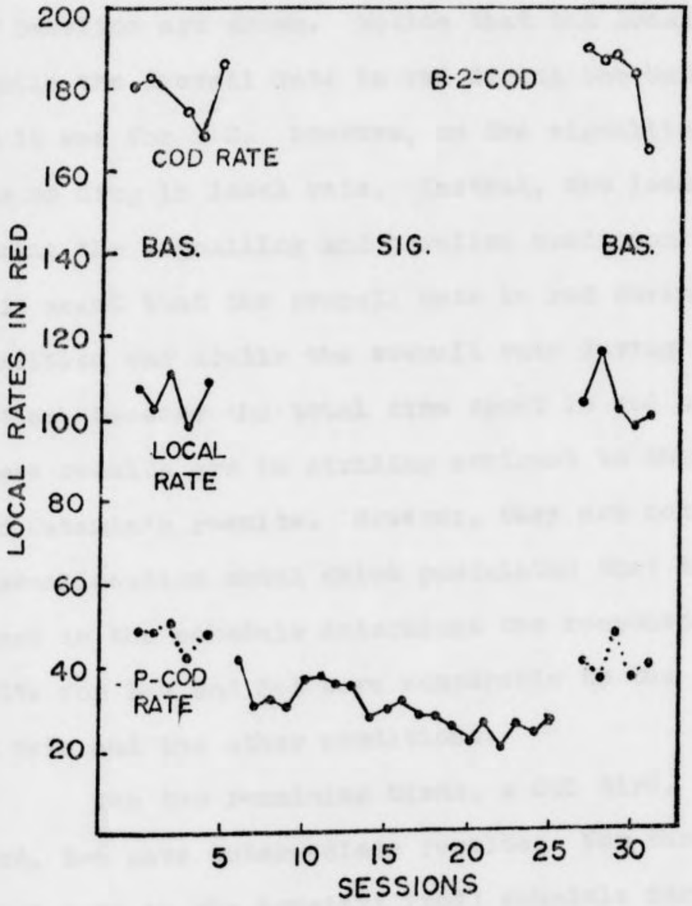
Fig. 3- Local and Overall Response Rates in Red on Concurrent VI 2 VI 2 for B-2.


120
100
80
60
40
20
R/M IN RED
B-2 - COD
LOCAL RATES
BAS.
SIG.
BAS.
O'ALL RATES
5
10
15
20
25
30
SESSIONS

The results of B-2 can be demonstrated to be due to the fact that B-2 responded at a high rate during the COD and at a much lower rate after the COD had elapsed. Figure 4 shows local rate in red over the same sessions as Figure 3, but here local rate during the baseline condition has been separated into the rate that occurred during the COD and after the COD elapsed. Local rate in red during the baseline condition was a weighted average of the high rate of responding during the COD and the lower rate during post-COD periods. During the signalling condition, however, there were few changeovers and thus virtually all responding in red occurred at the lower local rate appropriate to post-COD periods. The rate in red during the signalling condition for B-2 was even lower than the post-COD rate of the baseline condition; this higher post-COD rate in baseline may have resulted from COD bursts extending into the post-COD time.

For the remaining five birds, overall rate in the constant (red) schedule during the signalling condition tended to be higher than in the baseline condition for each pair of schedules. That is, the total number of responses in red was higher in the signalling condition than in the baseline condition. For three of these birds, a COD bird, B-5, and two FR-CO birds, B-4 and B-9, this increase occurred because there was little or no drop in the local rate of responding in red (responses in red/time spent in red) during the signalling condition as compared to the preceding baseline condition and

Fig.4- COD and Post-COD Local Rates in Red on Concurrent VI 2 VI 2 for B-2.

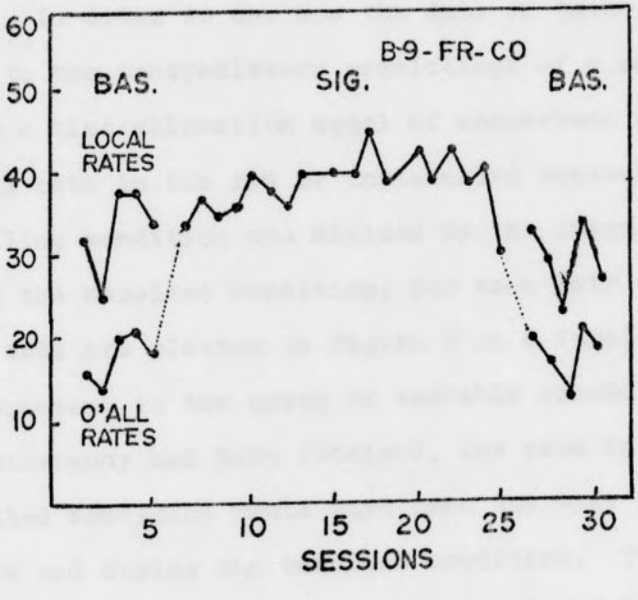

B-2-COD
COD RATE
BAS.
SIG.
BAS.
LOCAL RATE
P-COD RATE
LOCAL RATES IN RED
200
180
160
140
120
100
80
60
40
20
5
10
15
20
25
30
SESSIONS

because the time spent in red during the signalling condition was always greater than during the baseline condition (except during _conc_ VI 2-min Ext.)

Figure 5 shows daily sessions on _conc_ VI 2-min VI 2-min for B-9. The last five days of baseline, the first determination of the signalling condition and five days of recovery of baseline are shown. Notice that the local rate in red is double the overall rate in red during the baseline condition, as it was for B-2. However, on the signalling condition, there was no drop in local rate. Instead, the local rate in red during the signalling and baseline condition were the same. This meant that the overall rate in red during the signalling condition was double the overall rate during the baseline condition, because the total time spent in red about doubled. These results are in striking contrast to the results of B-2 and Catania's results. However, they are consistent with a time-allocation model which postulates that the amount of time spent in the schedule determines the response output. The results for B-4 and B-5 were comparable to the results of B-9 on this and the other conditions.

The two remaining birds, a COD bird, B-7 and a FR-CO bird, B-6 gave intermediate results. For these birds the local rate in the constant (red) schedule during the signalling condition was always lower than in the baseline condition, but the drop in local rate that occurred was not enough to

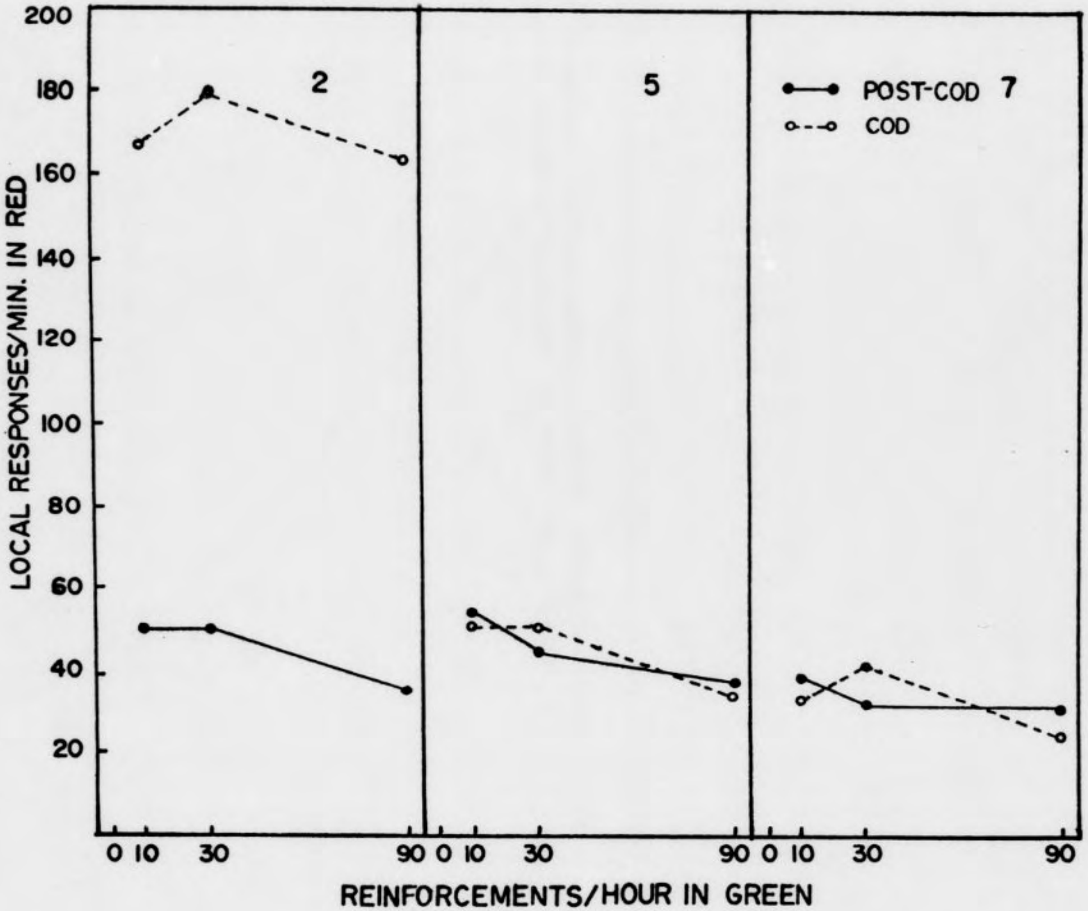
Fig. 5- Local and Overall Rates in Red on Concurrent VI 2 VI 2 for B-9.


B-9-FR-CO
BAS.
SIG.
BAS.
LOCAL RATES
O'ALL RATES
R/M IN RED
60
50
40
30
20
10
5
10
15
20
25
30
SESSIONS

maintain constancy of overall rate in red (i. e., a constant response output in red.) Why the drop in local rate occurred was not clear. For B-7 it could have been attributed to the elimination of high-rate COD responding. However, for this bird, as well as B-5, the local rate during the COD in red was not higher than the post-COD rate as Figure 6 shows. Why the drop in local rate in red for B-6 occurred was not clear.

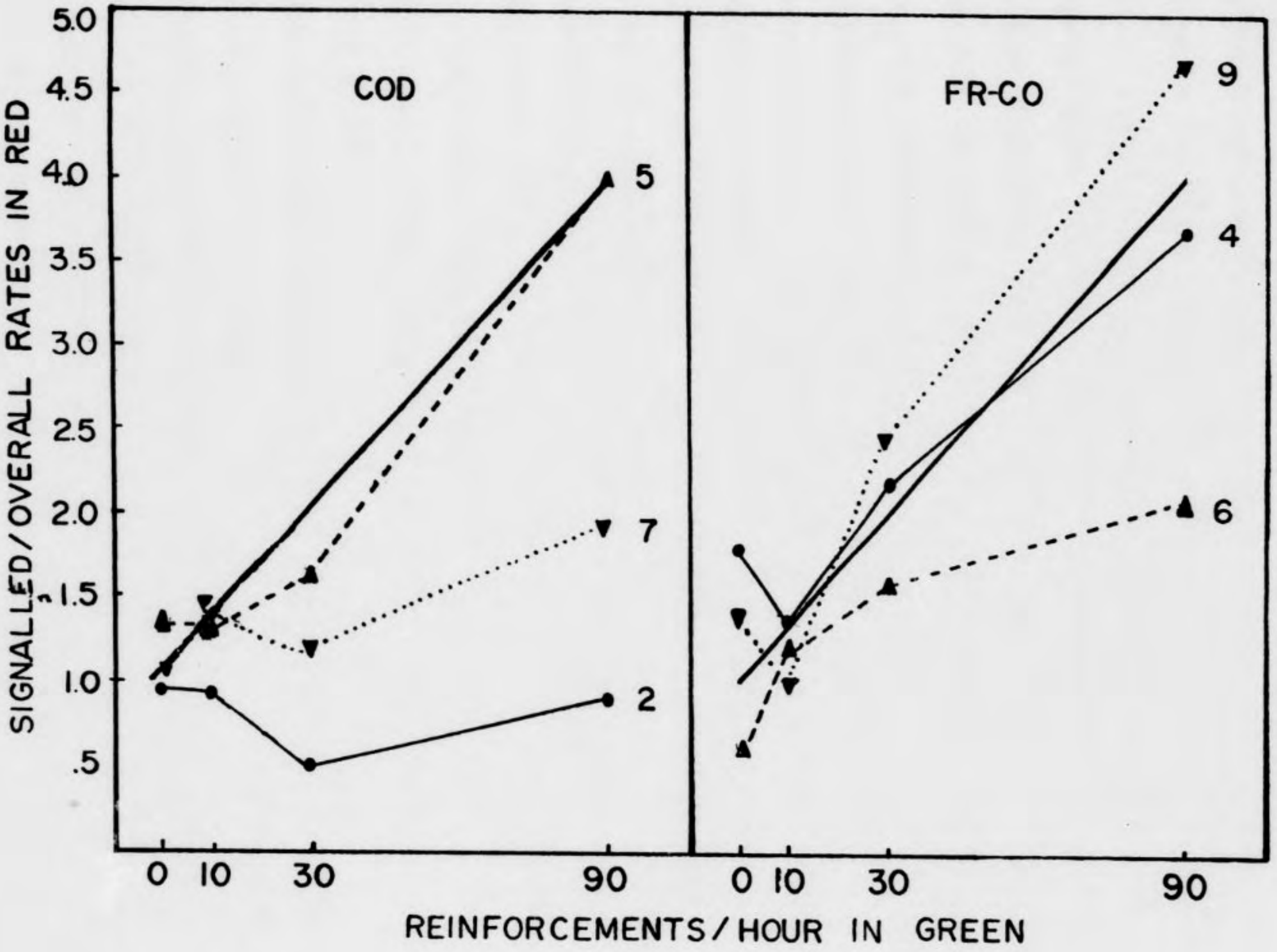
In order to see how the data of these six birds compared to the contradictory predictions of a rate-independence versus a time-allocation model of concurrent responding, the overall rate in the red or unsignalled schedule during the signalling condition was divided by the overall rate in red during the baseline condition, for each pair of schedules. These data are plotted in Figure 7 as a function of the rate of reinforcement in the green or variable schedule. If overall rate constancy had been obtained, the rate in red during the signalled condition would have been the same as the overall rate in red during the baseline condition. The ratio of these rates would then have been equal to 1.0 for each pair of schedules. If, however, the overall rates were dependent upon the time spent in the schedule the ratios would always have been greater than 1.0 since more time was available for responding in red during the signalling conditions than during the baseline conditions, except during the extinction (in green) when no increase in overall rates in red was expected as the birds usually spent the entire baseline sessions in the red schedule. The heavy solid line in Figure 7 is the function that would

Fig.6- COD and Post-COD Local Rates in Red for each COD Bird.



200
180
160
140
120
100
80
60
40
20
LOCAL RESPONSES/MIN. IN RED
2
5
7
POST-COD
COD
0
10
30
90
REINFORCEMENTS/HOUR IN GREEN

Fig. 7- Normalized Overall Rates in Red for Each Bird as a Function of Rate of Reinforcement in Green.


COD
FR-CO
SIGNALLED/OVERALL RATES IN RED
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
5
7
2
9
4
6
0
10
30
90
0
10
30
90
REINFORCEMENTS/HOUR IN GREEN

be obtained if the bird time-matched on each condition and if his local rate in red was the same in the signalled condition as in the baseline condition for each pair of schedules. Note that, except during the extinction condition, all points are greater than 1.0, indicating that the overall rate in red during the signalling conditions would always be higher than the overall rate in red during the baseline conditions. Since session time remained approximately constant within the baseline and signalling conditions of a given pair of schedules, this increase means that the total response output in red during the signalling conditions would always be higher, than the overall rate in red during the baseline conditions. This increase is the result of the increase in the amount of time that is available for responding in red during the signalling conditions, since the local rate of responding in red remains constant. The amount of increase in the response output in red during the each signalling condition, which is reflected in the ratio of overall rates in red during the signalling and baseline conditions, is directly proportional to the increase in the amount of session time spent in the red schedule during each signalling condition. For example, if half the session time during the baseline condition were spent in the red schedule, then the increase in the amount of time spent in the red schedule during the signalling condition should result in a doubling of the total response output in the signalling condition so that the ratio of rates in red during the signalling and baseline conditions should be equal to 2.0. When less than half of the baseline condition session time is spent in the red schedule, a large increase in the total response output in the signalling condition is expected; when a large portion of the session time is spent in red during the baseline condition, a smaller increase will result. That is, the increase in the total response output in red that is expected in the signalling condition is inversely proportional to the proportion of the total session time spent in the red schedule during the baseline condition. The amount of time that is spent in the red schedule is, in turn, dependent upon the relative rate of reinforcement in red. As the rate of reinforcement in the green schedule increases along the X-axis of Figure 7, both the relative rate of reinforcement in red and the relative time spent in red decrease. Therefore, the predicted time-allocation function increases as an inverse function of the relative rate of reinforcement in the red schedule.

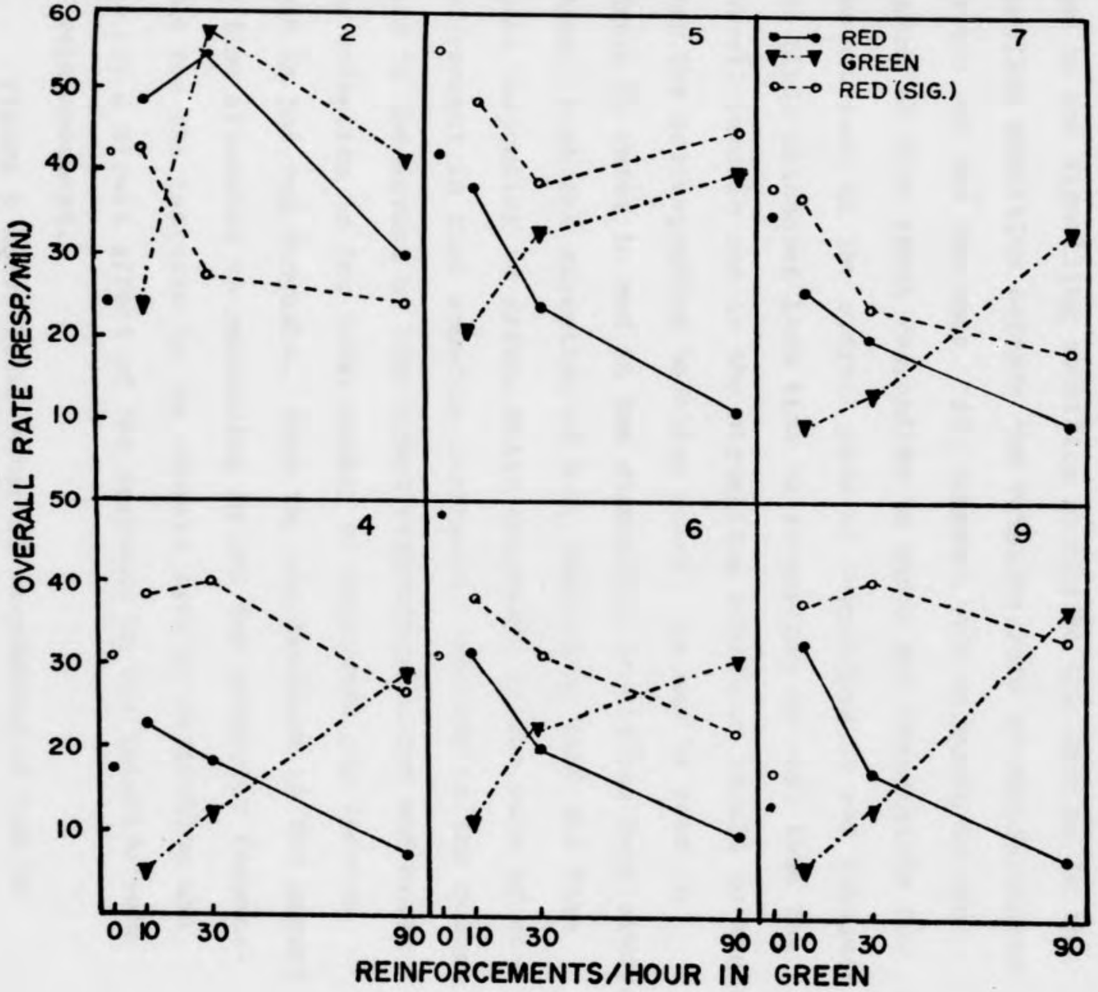
Comparing the results for each bird with the predicted time-allocation function in Figure 7, note that B-2 was the only subject whose data points were consistently equal to or less than 1.0. For this bird, the rate in red during the signalling conditions was less than or equal to the overall rate in red in the baseline conditions for all schedule values. The data points for the other birds all showed increasing functions.

For B-5 (COD), B-4 and B-9 (FR-CO) the functions closely approximated the predicted time-allocation function. That is, for these birds there was little tendency for local rate to decrease during the signalling conditions so that the response output in red during the signalling condition was always greater than the response output in red during the baseline condition for each pair of schedules. (B-5 showed a marked drop in the local rate of responding in red during 30 reinforcements per hour in green, but the normalized rate is clearly above 1.0 in Figure 7.)

The functions for B-7 (COD) and B-6 (FR-CO) are increasing which indicates that the response output in red tended to increase during the signalling conditions, but the lower slopes of these functions mean that the local rate in red dropped during the signalling condition. Although the results for these two birds do not fit the time-allocation function, it is clear that they are not consistent with response rate constancy either.

Figure 8 shows overall rate in both schedules during the baseline conditions, and rates in red during the signalling conditions for each bird. Notice that, with the exception of B-2, the rates in red for each bird decreased systematically as the rate of reinforcement in green increased. (The extinction data for B-2, B-4 and B-9 are also exceptions.) Correspondingly, the rates in green increased as the rate of

Fig.8- Overall Rates of Responding in Red for Each Bird as a Function of the Rate of Reinforcement in Green.

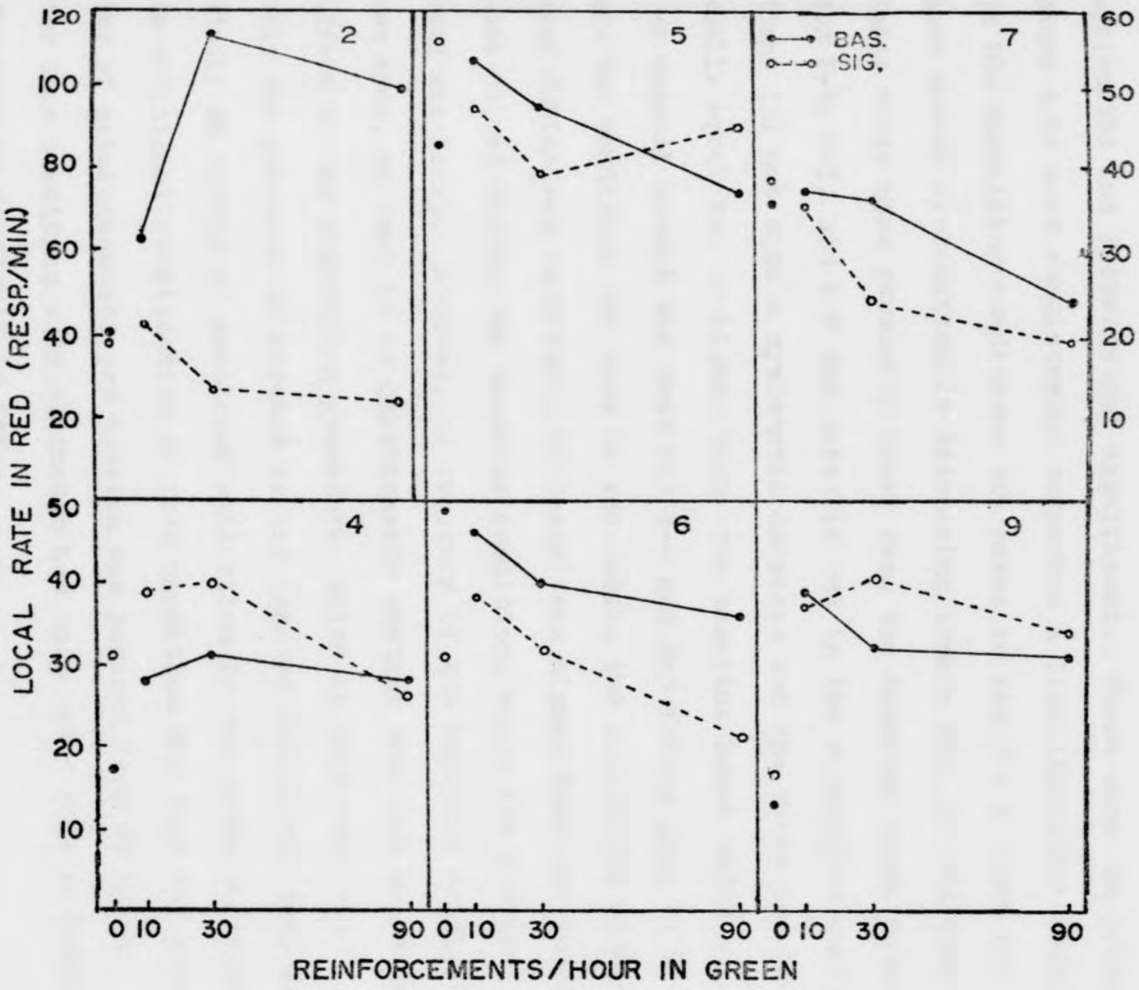

OVERALL RATE (RESP./MIN)
REINFORCEMENTS/HOUR IN GREEN
RED
GREEN
RED (SIG.)
2
5
7
4
6
9
60
50
40
30
20
10
50
40
30
20
10
0
10
30
90
0
10
30
90
0
10
30
90

reinforcement in green increased. If the decrease in overall response rate in red was due solely to the change on the relative rate of reinforcement in green, the overall rates in red in the signalling condition should be the same as in the baseline condition because the relative rate of reinforcement in the red was the same. If, however, the increase in the amount of time spent responding in green was responsible for the decrease in the overall rate of responding in red (because the birds allocated less time to responding in red) then the overall rate in red in the signalling condition should be higher than the corresponding baseline rates. As can be seen in Figure 8, rates in red in the signalling conditions were always higher, with the exception of B-2, indicating that the time spent responding in green, which increased as the rate of reinforcement in that schedule increased, resulted in the reduction in the amount of time spent responding in red and hence the reduction in the total number of responses per session made in the red schedule. That is, the decrease in the amount of time allocated to responding in red was primarily responsible for the decrease in the overall rate of responding and was not a direct effect of the decrease in the relative rate of reinforcement.

Figure 9 shows local rates of responding in red in baseline and signalling conditions. Notice that the baseline local rates in red tended to decrease slightly as a function of the increase in the rate of reinforcement in the green

Fig. 9- Local Rates of Responding in Red for Each Bird as a Function of the Rate of Reinforcement in Red.

rd
n Red.


LOCAL RATE IN RED (RESP./MIN)
REINFORCEMENTS/HOUR IN GREEN
BAS.
SIG.
2
5
7
4
6
9
120
100
80
60
40
20
60
50
40
30
20
10
50
40
30
20
10
0 10 30 90
0 10 30 90
0 10 30 90

schedule, although the rate of reinforcement in red remained the same. For B-4 and B-9, the decline in local rate was not systematic and probably not significant. These were the birds whose data most consistently supported a time-allocation model. In the signalling conditions the rates in red for B-7 and B-6 also showed systematically decreasing trends and, in addition, these rates were generally lower than the baseline local rates. For B-4, B-5, and B-9 the rates in red in the signalling conditions did not show a systematic decrease and the rates are generally equal to, or higher than, the baseline local rates. One unusual result was that for B-4 and B-5 during conc VI 2-min Ext condition the rate in red during the signalling condition (which was in effect, VI 2-min) was higher than the local rate in red during the baseline condition, while for B-6 the rate was lower. However, no recovery of the baseline condition was made, so that it is questionable whether this was an actual effect of the signalling procedure, which in this case was only the presence or absence of the lighted changeover key, or simply an effect of continued extinction in the green schedule. An additional complication of this condition was that the number of reinforcements per session was reduced from 60 to 30 for this condition only, although how this could have affected the data is difficult to say.

The overall rates of responding for B-2 (Figure 8) did not decrease systematically as a function of the rate of reinforcement in the green schedule. Part of the irregularity of these rates was due to changes in the local rate of responding in red across conditions and part was due to "overmatching" in red; that is, the proportion of responses made in the red schedule was larger than the proportion of reinforcements obtained on that schedule. The increase in the local rate in red that occurred when reinforcements were 30 and 90 per hour in the green schedule as compared to 10 reinforcements per hour was due to an increase in the proportion of responses made during the COD in red. The proportion of the total responses made in red increased from 30% in 10 reinforcements per hour in green to 77% in 30 reinforcements per hour in green and to 83% in 90 reinforcements per hour in green. Since responding during the COD occurred at such a high local rate, the large proportion of responding red during the COD greatly increased the local rate of responding in red. In Figure 9, for B-2 only, the post-COD local rates in red did, however, decline as a function of the rate of reinforcement in the green schedule, as did the rates in red during the signalling condition. The large drop in these rates was a function of the large difference between COD responding and post-COD responding. These results were clearly unusual and reflect the control that seemingly minor aspects of the scheduling procedure may acquire.

CHAPTER IV

DISCUSSION

The variety of results obtained in the present study attest to the complexity of the relations among the controlling variables in concurrent scheduling. However, the general conclusion to be drawn, that the rate of responding in one schedule of a pair of concurrent schedules is not independent of the amount of time spent responding in the other schedule, is well supported by the data of 5 of 6 birds run under two different changeover procedures, a COD and a fixed-ratio changeover contingency.

The results of B-2, while inconsistent in several respects, demonstrate that high rates during the COD tend to "inflate" local rates of responding in the baseline conditions. The elimination of these bursts by the signalling procedure resulted in a lower rate of responding in the unsignalled schedule during the baseline conditions, so that the total response output in red remained constant or decreased in comparison with the baseline rates. Thus, if high local rates during the COD occurred in Catania's (1963) study, apparent overall rate constancy would have been obtained. Catania (1972) has, in fact, concluded that a COD does tend to increase response rates and may be necessary for rate constancy to occur.

That high local rates during the COD were not consistently obtained for the other two birds run with a COD (B-5 and B-7) was an unexpected result in light of the observations of Catania (1963), 1966) that COD rates tend to be higher than rates after the COD has elapsed, and the quantitative evidence of Silberberg and Fantino (1970) that COD rates were higher on a two-key procedure. However, the scheduling of the COD in the Catania study which was the same as the procedure used in the present study does not require that any responding take place during the DOD. This is due to the fact that the COD is timed from a response on the changeover key so that the first response on the main key is eligible for reinforcement if the COD has elapsed between the changeover and the first main key response. Thus, this procedure may lend itself to the development of idiosyncratic behavior patterns during the COD which may or may not include responding on the main key. In the signalling procedure used by Silberberg and Fantino (1970), the COD was timed from the first response on the "main" key following a response on the other "main" key, so that the first peck on a main key was never reinforced. Casual observation of B-5 and B-7 in the later conditions of the experiment indicated that they tended to pause during the COD in red. COD response rates in green for B-5, however, tended to remain high throughout the experiment, while those of B-7 fluctuated.

As a result of the rate constancy obtained in his 1963 experiment and in a later replication, Catania (1969) concluded that the rate of responding in one schedule of a pair of concurrent schedules was not affected by the rate of responding in the other schedule, but varied as a function of the rate of reinforcement provided by the other schedule. He proposed that reinforced responding was reduced or inhibited by reinforcement in another schedule. This accounts for the inverse relationship that has been found between responding in one schedule and the rate of reinforcement in the other schedule. However, the results of the present study indicate that the relative rate of reinforcement determined the overall response rate or response output in two ways. First, the relative rate of reinforcement determined the amount of time spent responding on a schedule (according to the matching rule, relative time equals relative rate of reinforcement). When the distribution of time is externally fixed, as it was in the signalling conditions, the response output in the unsignalled schedule increased because the amount of time spent in that schedule increased. Secondly, the relative rate of reinforcement affected the local rates of responding. As the rate of reinforcement in the green schedule increased, the local rate of responding in the red schedule tended to decrease, although the rate of reinforcement in the red schedule remained the same. This effect was more evident in the signalling conditions where the effects of the birds' distribution of time were eliminated. The overall response output in a given schedule is a product of the local rate of responding and the time spent responding in the schedule: $P_1 = (P_1/t_1)(t_1)$ where P_1= pecks in schedule one, t_1= time spent in schedule one. Both of the terms on the right-hand side of the equation seem to be determined to some extent by the relative rate of reinforcement.

These results can be interpreted within the framework of a time-allocation model of concurrent performances. This view has been proposed and discussed by Baum and Rachlin (1969), Brownstein and Pliskoff (1968), and Shull and Pliskoff (1967). According to this view, the animal distributes his response time between the two schedules in proportion to the relative values, which are determined by the rate, amount, or delay of reinforcement. The local rates are assumed to be the same for both schedules, so that the distribution of responses tends also to match the distribution of time and reinforcement rate.

The assumption of equal local response rates in each schedule that Baum and Rachlin (1969) made was based in part on data obtained in single schedule experiments by Catania (1961) and Blough (1963) which indicated that birds tended to respond at a "base rate" of 2 to 3 responses per second and that variations in overall rates on a simple schedule were a result of periods of responding at this base rate alternated with periods of not responding. Presumably, the animal is continually engaging in some sort of behavior and the time spent in these other activities is controlled by the values of the other sources of reinforcement that are available in the experimental situation. Even a simple schedule is therefore, in reality, a concurrent schedule, but one in which the alternative sources of reinforcement are not programmed by the experimenter. Concurrent shcedules of reinforcement make the alternation between two reinforced classes of behavior more explicit, although, as Herrnstein (1970) has pointed out, still other, unprogrammed reinforcers should be considered as operating in a concurrent situation as well.

The assumption of equal local rates was not borne out in the present study, however, over variations in the green schedule even though the red schedule itself remained constant. The drop in local rates (Figure 9) in red as a function of the rate of reinforcement in green was probably not significant for B-4 and B-9 in the baseline conditions or for B-5 and B-9 in the signalling conditions, but for B-6 and B-7 the decrease was systematic in both baseline and signalling conditions (Figure 9). This suggests that the rate of reinforcement in the green schedule did affect the local rate of responding in the red schedule. Assuming that while the bird is in the red schedule, he is actually allocating his time between responding on the key and engaging in "other" behaviors. The proportion of the time spent in red which is actually allocated to these other activities is assumed to be determined by the relative value of these activities to the programmed reinforcer.

If the relative proportion of time in the red schedule which is actually devoted to these other behaviors increases, then the local rate in red will decrease. This is because fewer key-pecking responses will be made in the time that is spent in the red schedule.

This increase in the proportion of time devoted to other behaviors implies that the relative value of these other behaviors increases as the relative rate of reinforcement in red decreases. This requires the assumption that these other activities are not affected by changes in the relative rate of reinforcement in the same way as the programmed reinforcer.

The drop in local rates that occurred in the signalling conditions as a function of the rate of reinforcement in the other schedule is consistent with two other experiments in which a signalling procedure was used. In the first of these, Rachlin and Baum (1969) used concurrent schedules in which the duration of the reinforcer on the signalled schedule was varied while the unsignalled schedule remained constant. They found that the rate of responding in the unsignalled schedule varied inversely as a function of the duration of the reinforcer in the signalled schedule. In the second study (Hughes, 1970) reinforcements were signalled in one component of <u>mult</u> VI VI schedule while the other schedule remained constant. While the rate of responding in the unsignalled schedule was higher when responses were signalled on the other schedule than when they were not, the rate of responding in the unsignalled schedule varied inversely with the rate of reinforcement in the other schedule.

CHAPTER V

SUMMARY

The present study was conducted (1) to assess the effects of the changeover delay in producing overall rate constancy in a concurrent VI VI procedure where reinforcements are signalled in one schedule, and (2) to determine whether response-rate constancy would be obtained when a fixed-ratio changeover contingency was used. The results of the study indicated that overall response-rate constancy was generally not obtained with a fixed-ratio changeover procedure or with a COD when the response rate during the COD was not higher than the rate after the COD had elapsed. The results for one bird whose rate during the COD was high suggests that this may have been responsible for the rate constancy that was obtained in an earlier study (Catania, 1963). A modified time-allocation model of concurrent responding was suggested to account for the data.

BIBLIOGRAPHY

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

Blough, D. S. Interresponse time as a function of continuous variables: a new method and some data. *Journal of the Experimental Analysis of Behavior*, 1963, *6*, 237-246.

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

Catania, A. C. Behavioral contrast in a multiple and concurrent schedule of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1961, *4*, 335-344.

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

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

Catania, A. C. Concurrent performances: inhibition of one response by reinforcement of another. *Journal of the Experimental Analysis of Behavior*, 1969, *12*, 731-744.

Catania, A. C. Concurrent performances: synthesizing rate constancies by manipulating contingencies for a single response. *Journal of the Experimental Analysis of Behavior*, 1972, *17*, 139-146.

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

Herrnstein, R. J. On the law of effect. *Journal of the Experimental Analysis of Behavior*, 1970, *13*, 243-266.

Hughes, R. The effects of signalled reinforcements in multiple schedules of reinforcement. Unpublished Masters thesis, University of North Carolina at Greensboro, 1970.

Rachlin, H. C. and Baum, W. H. Response rate as a function of amount of reinforcement for a signalled concurrent response. Journal of the Experimental Analysis of Behavior, 1969, 12, 11-16.

Revusky, S. H. A relationship between responses per reinforcement and preference during concurrent VI VI. Journal of the Experimental Analysis of Behavior, 1963, 4, 518.

Shull, R. L. and Pliskoff, S. S. Changeover delay and concurrent performances: some effects on relative performance measures. Journal of the Experimental Analysis of Behavior, 1967, 10, 517-527.

Silberberg, A. and Fantino, E. Choice, rate of reinforcement and the changeover delay. Journal of the Experimental Analysis of Behavior, 1970, 13, 187-197.

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