CONCURRENT PERFORMANCES: REINFORCEMENT INTERACTION AND RESPONSE INDEPENDENCE¹

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When a pigeon's pecks on two keys were reinforced concurrently by two independent variable-interval (VI) schedules, one for each key, the response rate on either key was given by the equation: $R_1 = Kr_1/(r_1 + r_2)^{5/6}$, where R is response rate, r is reinforcement rate, and the subscripts 1 and 2 indicate keys 1 and 2. When the constant, K , was determined for a given pigeon in one schedule sequence, the equation predicted that pigeon's response rates in a second schedule sequence. The equation derived from two characteristics of the performance: the total response rate on the two keys was proportional to the one-sixth power of the total reinforcement rate provided by the two VI schedules; and, the pigeon matched the relative response rate on a key to the relative reinforcement rate for that key. The equation states that response rate on one key depends in part on reinforcement rate for the other key, but implies that it does not depend on response rate on the other key. This independence of response rates on the two keys was demonstrated by presenting a stimulus to the pigeon whenever one key's schedule programmed reinforcement. This maintained the reinforcement rate for that key, but reduced the response rate almost to zero. The response rate on the other key, nevertheless, continued to vary with reinforcement rates according to the equation.

Consider a pigeon pecking two response-keys. On each key, pecks are reinforced according to a variable-interval (VI) schedule, a schedule that arranges that a peck on a key is reinforced only after a variable period of time has elapsed since the preceding reinforcement for a peck on that key (Ferster and Skinner, 1957). When two of these schedules are programmed concurrently, one on each of two keys, the performance of a pigeon has the following characteristics: the total response output varies non-linearly with the total reinforcement; the pigeon matches the relative rate of pecking on a key to the relative rate of reinforcement for that key; and, as a result, the schedules on the two keys interact, *i.e.*, on each key the rate of pecking varies not only with the rate of reinforcement for that key, but also with the rate of reinforcement for the other key.

The first part of this paper is concerned with a quantitative account of these relation-

ships. Data from the first of two experiments presented here, together with data from other experiments in the literature, will be used to show that:

1. The total output on the two keys is proportional to the one-sixth power of the total reinforcement for pecks on the two keys. This may be written:

$$R_1 + R_2 = K(r_1 + r_2)^{1/6}, \quad (1)$$

where R is the rate of pecking, r the rate of reinforcement, and the subscripts 1 and 2 indicate the keys, key 1 and key 2. The constant, K , depends upon the units chosen for R and r and upon the absolute level of the response rates for a given pigeon.

2. The pigeon matches relative rates of pecking to relative rates of reinforcement. This may be expressed:

$$\frac{R_1}{R_1 + R_2} = \frac{r_1}{r_1 + r_2}. \quad (2)$$

The notation is the same as for equation (1). From these two equations, an equation for the pecking on one of two keys can be derived. Solving for R_1 in equation (2):

$$R_1 = \frac{r_1}{r_1 + r_2} (R_1 + R_2).$$

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Substituting from equation (1) for $(R_1 + R_2)$ in this equation:

$$R_1 = \frac{r_1}{r_1 + r_2} K(r_1 + r_2)^{1/6} = \frac{Kr_1}{(r_1 + r_2)^{5/6}} \quad (3)$$

Similarly, we can derive a symmetric equation for R_2 :

$$R_2 = \frac{Kr_2}{(r_1 + r_2)^{5/6}} \quad (3a)$$

When, in the first experiment, K was determined for a given pigeon, equation (3) predicted fairly closely the rate of pecking maintained by that pigeon on one of two keys in several concurrent VI schedules.

Equation (3) indicates that the rate of pecking on one key depends in part on the rate of reinforcement for pecks on the other key. In other words, the reinforcement schedules for the two keys interact in determining the response rate on either key. A further implication of equation (3) is that the response rates on the two keys are independent. That is to say, the rate of responding on one key does not determine the rate of responding on the other key. This implication is given by the fact that R_1 , the rate of pecking key 1, is expressed only in terms of r_1 and r_2 , the rates of reinforcement provided by the two keys. The term R_2 , the rate of pecking key 2, does not enter into the equation (although it enters into the derivation of the equation).

The second experiment is devoted to an experimental demonstration of this independence of the response rates on the two keys. A change in schedule that held constant the rate of reinforcement for one key but changed the rate of pecking on that key did not affect the rate of pecking on the other key. The rate of pecking on the other key continued to be determined by the reinforcement rates on the two keys according to equation (3).

EXPERIMENT 1: REINFORCEMENT INTERACTION

Apparatus

The experiments were conducted in a standard experimental chamber, similar to one described in a previous paper (Catania, 1961). Two translucent response-keys were located on one wall. A feeder for briefly presenting grain (reinforcement) was located below the keys and centered between them.

The key on the left could be illuminated from behind by either red or yellow light, and that on the right by green light. During reinforcement, the feeder was lit and the key-lights were off.

Subjects

Three adult, male, White Carneaux pigeons, maintained at about 80% of free-feeding body weight, served in daily experimental sessions. Each had a history of pecking under various schedules of reinforcement.

Procedure

The concurrent scheduling used here is described in Findley (1958). Each of two independent VI schedules operated continuously, and each was associated with a different color of the left key. Pecks on the left key produced the reinforcements programmed by one schedule when this key was red and produced those programmed by the other schedule when this key was yellow. The pigeon changed over from one schedule to the other by pecking the right, or changeover, key. Each peck on the changeover key (which was always green) changed the color of the left key.

Findley has shown this "changeover-key" concurrent procedure to be functionally equivalent to a two-key concurrent procedure, a procedure in which two independent schedules are programmed, one for pecks on one key and the other for pecks on the second key. In both procedures, each of two schedules are continuously available. The only difference between them is in the changeover from one schedule to the other: in the two-key procedure, the pigeon does this simply by moving from one key to the other, while in the changeover-key procedure, it pecks the changeover key.

The equivalence of the procedures permits the schedules for the red and yellow colors on the left key in the present experiments to be referred to as the schedules for key 1 and key 2 respectively. Each color, with its associated schedule, is equivalent to one key, with its associated schedule, in the two-key concurrent procedure.

Because the two schedules are available continuously, response rates in this paper will refer to responses per minute (resp/min) over sessions, rather than to resp/min in the presence of a given schedule's color. In addi-

tion, the VI schedules will be specified in terms of the rate of reinforcement they can provide in a session. For example, a VI schedule that reinforces a peck 3 min, on the average, after a preceding reinforcement can provide up to 20 reinforcements per hour (when the pigeon obtains each reinforcement immediately after it is programmed), and will be called here a VI 20-rft/hr schedule.

During most sessions, a changeover delay (COD: cf. Herrnstein, 1961; Catania, 1962) was in effect. The COD, timed from each peck on the changeover key, was 2 sec: pecks that occurred within less than 2 sec after a peck on the changeover key could not produce reinforcement. The COD prevented one schedule of reinforcement from exerting accidental control over the changeover-key pecking and the pecks maintained by the other schedule (cf. Catania and Cutts, in press).

The schedules are summarized in Table 1. Each is described by the rate of reinforcement it provided, in rft/hr. The schedule 0, 40 in the table, for example, is a concurrent EXT VI 40-rft/hr schedule.

Table 1

Sequences of Concurrent VI Schedules, in rft/hr.

Sequence	Key 1 (Red)	Key 2 (Yellow)	Sessions
A. COD 2-sec	20	20	14
	30	10	24
	15	25	10
	35	5	9
	0	40	14
	20	20	7
B. No COD	20	20	8
	10	30	8
	15	25	8
	5	35	10
	40	0	14
C. COD 2-sec	0	20	9
	20	20	10
	40	20	9
	10	20	12
	30	20	10

Each session ended after 60 reinforcements. Session duration, therefore, varied with the total reinforcement rate provided by the two VI schedules.

Results and discussion

Derivation of the equation. Equation (1) in the introduction states that the total output on two keys is proportional to the one-sixth

power of the total reinforcement rate provided by the two keys. This function is a power function, and plots as a straight line in logarithmic coordinates ($y = kx^n$ is equivalent to $\log y = \log k + n \log x$). The slope of the straight line gives the exponent of the power function. In Fig. 1, the data from four experiments have been plotted in these coordinates.

Fig. 1. Total response rate as a function of total reinforcement rate, in log-log coordinates: data from four experiments. Functions have been displaced along the ordinate to avoid crowding.

The data from Herrnstein (1955) and from a paper in preparation by Catania and Reynolds are for pigeons pecking at a single key on various VI schedules. For the present purposes, a single-key procedure may be taken as equivalent to a two-key procedure with EXT as the schedule for one of the keys. The evidence supporting this assumption will be presented in Fig. 2.

The data from Findley (1958) and from the present experiment are for pigeons pecking at two keys. For Pigeon 4, the total reinforcement rate was varied with the VI schedules for the two keys held equal. For the other five pigeons, the total reinforcement rate was varied by varying the schedule for one key while holding the schedule for the other key constant (for Pigeons 117, 243, and 294, see sequence C, Table 1). The atypical data for Pigeon 5 may be due to the absence of a COD in Findley's procedure.

With the exception of Findley's Pigeon 5, the data are in fair agreement: a power func-

tion with an exponent of about $\frac{1}{6}$ appears to describe the relationship between total output and total reinforcement rate (the exact value of the exponent is not critical for the present development). It must be added, however, that a logarithmic function ($y = k \log x + c$) also fits the data fairly well. There are two principal reasons, one logical and one practical, for choosing the power function: first, the power function does not make the unlikely prediction that low reinforcement rates generate negative rates of responding, whereas the logarithmic function does; second, and probably more important, the power function permits a simpler mathematical development for the present analysis than does the logarithmic function.

For equation (1) to hold, it is necessary to show also that the total output maintained by a given total reinforcement rate does not vary with changes in the distribution of reinforcement across the keys. A given reinforcement rate shared equally by the two keys or programmed for only a single key should maintain a constant total output.

Fig. 2. Total response rate as a function of the difference in the reinforcement rates provided by two concurrent VI schedules. Except for Findley's Pigeon 2 (see text), all points were obtained with concurrent VI schedules that provided a total of 40 rft/hr.

In Fig. 2, total output (in resp/min) is plotted against the absolute difference (in rft/hr) between the reinforcement rates for the two keys. The figure shows no systematic relationship between total output and the distribution of reinforcement rates across the

two keys. This is not only a necessary condition for equation (1), but also justifies the inclusion of the single-key data in Fig. 1.

Data from the present experiment (sequence A, Table 1) and from Herrnstein (1961) are for concurrent VI schedules that provided a total of 40 rft/hr. One point for Herrnstein's Pigeon 055 (indicated by the arrow) is off the graph. The data for Findley's Pigeon 2 are from concurrent VI schedules that provided a total of 20 rft/hr.

Fig. 3. Relative rate of responding on each key as a function of the relative rate of reinforcement for responding on that key, with and without COD. The diagonals represent perfect matching. Data from sequences A and C in Table 1 are indicated by upright triangles and by circles respectively.

The evidence for equation (2) is shown in Fig. 3. The equation is plotted as the diagonal lines in each graph, which represent perfect matching of relative response rate to relative reinforcement rate. The relative response rate on a key is the resp/min on that key divided by the total resp/min; the relative reinforcement rate is the rft/hr for the key divided by

the total rft/hr. With the COD (sequences A and C, Table 1), each pigeon matched accurately. Without the COD (sequence B, Table 1), extreme deviations from matching sometimes occurred. The COD appears to be critical because it separates in time responses on one key and subsequent reinforced responses on the other, and therefore prevents the schedule for one key from obtaining accidental control over the responding on the other.

Matching of relative response rate to relative reinforcement rate in pigeons has been obtained also by Herrnstein (1961) in a two-key concurrent experiment and by Reynolds (in press) in a three-key concurrent experiment.

Verification of the equation. Having demonstrated that equations (1) and (2) provide a reasonably accurate description of concurrent VI responding in the pigeon, it should now be possible to show that equation (3) holds, because this equation is derived from equations (1) and (2). In Fig. 4, the response rates on each key are shown for the schedule sequences C and A (Table 1). Each point is the average rate of responding on a given key over the last three sessions of each schedule.

The left column of graphs is from sequence C, in which the schedule for key 1 was varied and the schedule for key 2 was VI 20-rft/hr. The unfilled circles show responding on key 1, and the filled circles reflect responding on key 2, both as a function of the rft/hr for key 1. For each pigeon, the response rate on key 1 increased and the response rate on key 2 decreased as the rft/hr for key 1 increased.

The smooth curves are fits of equation (3) to these data [Equation (3) was used to predict response rates on key 1. Equation (3a), the equivalent for key 2, was used to predict response rates on key 2. Because these equations are symmetric, there is no need to distinguish between (3) and (3a) here]. The fit required only the determination of K . For each pigeon, the total response rates for the five concurrent VI schedules in sequence C were averaged. The average for the same schedules was taken also for the predictions, with an arbitrary K , from equation (3). By taking the ratio between these averages as equal to the ratio between the pigeon's unknown K and the known arbitrary K , each pigeon's K was computed. Equa-

tion (3), with K so determined, agreed fairly well with the obtained data.

The right column of graphs in Fig. 4 shows data from sequence A, in which the total reinforcement rate across the two keys was held constant (40 rft/hr). The rate of responding maintained on each key is plotted against the rate of reinforcement for that key. For each pigeon, the response rate on each key was approximately a linear function, passing through the origin, of the reinforcement rate for that key. The same relationship was obtained by Herrnstein, for a similar set of schedules, in the two-key experiment previously cited.

Fig. 4. Rate of responding on each key as a function of reinforcement rates. The data from sequence C are shown on the left, those from sequence A on the right (cf. Table 1). The smooth curves are based on equation (3); details in text.

The straight lines through the present data are predictions from equation (3), using the value of K determined, for each pigeon, from

sequence C. The predictions are not far from least-squares fits. Once K has been determined for a given pigeon with one sequence of schedules, therefore, it may be used to predict response rates in a second sequence of schedules.

Implications of the equation. Having examined the evidence for equation (3), we may now turn to some of its implications. Four special cases are of interest. We would like to know how the rate of pecking on key 1 varies when:

1. r_1 varies while r_2 is held constant (key 1 in sequence C);
2. r_1 is held constant while r_2 varies (key 2 in sequence C);
3. $(r_1 + r_2)$, the total rft/hr for the two keys, is held constant and the distribution of reinforcement across the two keys varies (sequence A and Herrnstein, 1961);
4. the ratio between r_1 and r_2 is held constant while $(r_1 + r_2)$ varies.

Let us take these cases in turn.

When r_2 equals a constant, C , then, substituting in equation (3):

$$R_1 = \frac{Kr_1}{(r_1 + C)^{5/6}} \quad (4)$$

When $C = 20$ rft/hr, equation (4) describes the smooth curve through the unfilled circles in Fig. 4. When $C = 0$ (EXT for key 2), equation (4) becomes:

$$R_1 = Kr_1^{1/6}, \quad (5)$$

the power function for VI responding on a single key (cf. Fig. 1).

In Fig. 5, equation (3) has been plotted as a surface in three dimensional coordinates, with K chosen arbitrarily as 30. Equation (4) is represented, for several values of C (rft/hr for key 2), by the lines that run from left to right along the surface. The heavy line against the rear wall is equation (5).

Equation (4) says, then, that the response rate on key 1 is a monotonically-increasing,

Fig. 5. A surface describing the rate of responding on key 1 as a joint function of the reinforcement rates for responses on key 1 and for responses on key 2. Points were determined from equation (3), with K arbitrarily set equal to 30. Details in text.

negatively-accelerated function of the rft/hr for key 1 when the rft/hr for key 2 is held constant. The larger the rft/hr for key 2, the less the curvature of this function.

When r_1 equals a constant, C , equation (3) becomes:

$$R_1 = \frac{KC}{(C + r_2)^{5/6}}. \quad (6)$$

When $C = 20$ rft/hr, equation (6) describes the smooth curve through the filled circles in Fig. 4. When $C = 0$ (EXT for key 1), $R_1 = 0$. This is reasonable: EXT for key 1 implies no responding on key 1. As C becomes large relative to r_2 , equation (6) approaches: $R_1 = KC^{1/6}$, that is to say, the responding on key 1 does not vary with the rft/hr for key 2.

Equation (6) is represented in Fig. 5 by the curved lines that run from front to rear along the surface. These functions show that when the rft/hr for key 1 is held constant the response rate on key 1 decreases as the rft/hr for key 2 increases. The larger the rft/hr for key 1, the smaller the effect of the rft/hr for key 2.

Equations (4) and (6) make explicit the reinforcement interactions implied by equation (3). Perhaps the most interesting effect of these reinforcement interactions is for the special case of equation (3) in which the total rft/hr, $r_1 + r_2$, equals a constant, C . In this case:

$$R_1 = \frac{Kr_1}{C^{5/6}} = kr_1, \quad (7)$$

where $k = K/C^{5/6}$. Equation (7) says that the function relating the response rate on key 1 to the rft/hr for key 1 is a linear function that passes through the origin (*e.g.*, the straight lines predicting the data for both keys in Fig. 4). Furthermore, k , the slope of the function, decreases as C increases. Equation (7) is represented in Fig. 5 by the straight lines that run diagonally along the surface from the lower left to the upper right.

The linear function obtained by Herrnstein has already been cited. Herrnstein's experiment satisfied the conditions for equation (7): the total rft/hr for the two keys was held constant. In addition, Reynolds, in the three-key experiment cited, obtained a comparable linear function for the responding on each of three keys, and a second linear function with a steeper slope when the total rft/hr was

decreased by discontinuing reinforcement for one of the keys.

When the ratio between the rft/hr for the two keys is held constant ($nr_1 = r_2$), equation (3) becomes:

$$R_1 = \frac{Kr_1}{(r_1 + nr_1)^{5/6}} = \frac{Kr_1^{1/6}}{(n+1)^{5/6}} = kr_1^{1/6}, \quad (8)$$

where $k = K/(n+1)^{5/6}$. That is to say, the response rate on a key remains proportional to the one-sixth power of the rft/hr for that key, and only the constant, k , is affected by changes in the ratio between r_1 and r_2 . When $n = 0$, then $r_2 = 0$ and $k = K$, the constant of equation (5), the single-key power function.

Equation (8) is represented by the dashed lines in Fig. 5, which are, from top to bottom, for n 's equal to $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, and 4 respectively. The equation agrees with the data for Findley's Pigeon 4 (Fig. 1), for which the reinforcement rates for the two keys were held equal ($n = 1$) and the response rates on the two keys were about equal. The data for a single key can be obtained approximately, therefore, by dividing the total output and the total rft/hr by 2. In the coordinates of Fig. 1, this amounts simply to moving the entire function for Pigeon 4 down and to the left. The slope, and therefore the exponent of the power function, is unaltered.

We have seen that when responding on one key is reinforced according to a VI schedule, the response rate on the key is determined by the rft/hr for that key and the rft/hr for a second key by the equation: $R_1 = Kr_1/(r_1 + r_2)^{5/6}$. The fact that the total output on two keys behaves like the total output on a single key (Fig. 1 and 2) implies that r_2 in the equation can represent the sum of the rft/hr for two or more keys. The equation therefore generalizes easily to n keys: $R_1 = Kr_1/(r_1 + r_2 + \dots + r_n)^{5/6}$. For three keys, the data presented by Reynolds appear to be consistent with this.

A second extension of the present analysis is to variables other than rate of reinforcement. For example, a paper by Catania (in press) showed that reinforcement duration had almost no effect on the response rate maintained by a VI 30-rft/hr schedule for a single key, but that, with a conc VI 30-rft/hr VI 30-rft/hr schedule in which the total reinforcement duration for the two keys was held constant, response rate was a linear function,

passing through the origin, of reinforcement duration. The absence of an appreciable effect of reinforcement duration on single-key responding may indicate that response rate is a power function of reinforcement duration, but that the exponent of the power function is very small. An equation analogous to equation (3) could hold for reinforcement duration, therefore, given that the VI schedules for the two keys are equal:

$$R_1 = Kd_1/(d_1 + d_2)^{1-n},$$

where *d* is reinforcement duration, and *n* is a small positive fraction. Also, it should be possible to compare directly such variables as reinforcement rate, reinforcement duration, and reinforcement quality, simply by varying these in the schedule for one key, while holding the schedule for the other key constant.

Finally, it should be pointed out that the present account deals with concurrent VI schedules, schedules that are programmed simultaneously on two keys. It does not apply to VI schedules that are programmed successively on a single key, each in the presence of a different color of the key (multiple schedules). A detailed account of the interactions within these schedules has been presented by Reynolds (1961, in press). For these, the matching function, equation (2), does not hold.

EXPERIMENT 2:
RESPONSE INDEPENDENCE

As stated briefly in the introduction, equation (3) describes the response rate on one key only in terms of the reinforcement rates for each key; the response rate for the other key does not appear in the equation. It may be argued, however, that this comes about because of an effect the response rate on one key has on the response rate on another. In Fig. 4, for example, the response rate on key 2 (VI 20-rft/hr) decreased as the rft/hr for key 1 increased, but with the rft/hr for key 1, the response rate on key 1 increased also. This means that the response rate on key 2 may have decreased primarily because the pigeon spent more time in responding on key 1 and, therefore, less in responding on key 2. Such an analysis attributes the present results to response interference: because the pigeon cannot respond on both keys at the same time, any increase in the rate of responding on one

key necessarily produces a decrease in the rate of responding on the other.

Experiment 2 shows, however, that the rate of responding on one key is independent of the rate of responding on the other, as is suggested by equation (3). Experiment 2 repeated sequence C (Table 1), but with a stimulus correlated with each occasion for reinforcement on key 1. Under these conditions, the pigeon did not peck on key 1 in the absence of the stimulus, and so the response rate on key 1 was held near zero as the reinforcement rate for key 1 was varied. There was, therefore, virtually no interference between the responses on key 1 and those on key 2. Nevertheless, the response rate on key 2 continued to vary with the rft/hr for key 1 as it had in Experiment 1.

Method

Two independent VI schedules were programmed, one for each of the two colors of the left key, with the illumination of the changeover key correlated with the schedule for key 1 (red). Between programmed reinforcements for key 1, the left key was yellow (key 2) and the changeover key was dark. During this time, pecks on the changeover key had no effect. When reinforcement was programmed for a peck on key 1, the changeover key lit and, as in Experiment 1, each peck on this key changed the color of the left key. These conditions held until the key-1 reinforcement was delivered, after which the left key returned to yellow, the key-2 color, and the changeover key again became dark. Thus, while the rate of reinforcement for key 1 was varied as indicated in Table 2, the overall rate of responding on key 1 was held near zero, because the pigeon had only brief periods of access to this key.

Concurrent with each stimulus-correlated VI schedule for key 1, pecks on key 2 were

Table 2
Sequence of Stimulus-Correlated VI Schedules for Key 1, in rft/hr, Programmed Concurrently with VI 20-rft/hr for Key 2.

Schedule	Sessions
30	14
0	8
40	7
20	7
10	9

reinforced on a VI 20-rft/hr schedule (*cf.* sequence C, Table 1). When the schedule for key 1 was EXT (O), the left key was continuously yellow and the changeover key was continuously dark. All sessions included the 2-sec COD and ended after 60 reinforcements.

Results

Figure 6 compares the data from this experiment (circles) with those from Experiment 1 (dashed lines) and predictions from equation (3) based on the constants previously determined for each pigeon (solid curves). Despite the fact that the rate of responding on key 1 was negligible in the present experiment, the rate of responding on key 2 varied with the rft/hr for key 1 in the same way as in Experiment 1, and agreed with the predictions from equation (3). An exception was Pigeon 294, but even for this pigeon, the response rate on key 2 decreased as the rft/hr for key 1 increased.

Details of the performances are illustrated in Fig. 7, which shows cumulative records of the responding of Pigeon 117 in Experiments 1 and 2. In each record, the recording pen was displaced downward when the schedule for that key programmed a reinforcement, and returned to the initial position when the reinforcement had been delivered.

The first pair of records (A) shows a full session from sequence C, Experiment 1. The major characteristic of the record for each key was the steplike grain, which indicated that the overall rate of responding on the key was an average over brief periods of no responding (while the pigeon was responding on the other key) and brief periods of responding at a high local rate.

The second pair (B) shows a session of the equivalent schedule in Experiment 2. There was little responding on key 1; the pigeon was able to change over from key 2 to this key only when the changeover key was lit. It then responded on key 1 until the COD was satisfied and a response was reinforced, and returned automatically to key 2 after this reinforcement. The grain of the key-2 record was relatively smooth, indicating that responding was continuous, but at a local rate lower than that during the brief periods of responding in A. The overall response rate on key 2 here was somewhat lower than that in A (*cf.* Fig. 6).

Fig. 6. Rate of responding on key 2 as a function of the rft/hr provided by the stimulus-correlated VI schedule for key 1. The solid lines are based on equation (3); the dashed lines show the data for the equivalent schedules in Fig. 4.

Fig. 7. Cumulative responses for Pigeon 117 during sessions of three concurrent schedules. The pen for each key was displaced downward when reinforcement was scheduled for a peck on that key.

The dashed lines through the key-2 record in B are extensions of the key-2 response rate immediately after the return from a key-1 reinforcement. The pigeon responded briefly at a high local rate on key 2 after the key-2 responding was interrupted for a key-1 reinforcement.

Record C shows a portion of a session of responding on key 2 during EXT for key 1. The grain of this record resembled that in B, but the overall rate of responding was higher by a factor of about 2 (*cf.* Fig. 6).

In summary, the overall response rates on key 2 were similar in A and B, but the local characteristics of the performances differed (periods of responding at a high local rate broken by periods of no responding, as opposed to relatively continuous responding at a lower local rate), whereas in B and C, the overall response rates differed considerably, but the local characteristics of the performances were similar. With a constant rft/hr for key 1, therefore, the responding on key 1 affected the local characteristics of the key-2 performance, but not the overall response rate on key 2. This means that the response rate on key 2 was determined directly by the rft/hr for key 1, *i.e.*, the effect was not mediated by response interference.

Discussion

It has been shown previously that the local characteristics of a concurrent performance can vary considerably while the general characteristics remain constant (Catania, 1961, 1962). The overall rate of responding maintained by a given VI schedule, for instance, did not vary with the frequency of changeovers to a key for which a second schedule was programmed. The inference drawn from these results was that the response rate maintained by a given schedule is determined by the context of schedules within which it is programmed, but is independent of the characteristics of the responding maintained by the other schedules. A similar inference may also be drawn from Reynolds' three-key experiment, cited above, in which general measures such as absolute and relative response rates behaved in a more orderly way than local measures such as probabilities of changeovers

among the three keys. Experiment 2 provides further support for the above inference, within the context of a quantitative account of the reinforcement interactions among schedules.

In addition to showing that the absence of R_2 in equation (3) has empirical significance, Experiment 2 suggests that the equation is more general than those from which it was derived, *i.e.*, equations (1) and (2). Neither equation (1), the power function for total output, nor equation (2), the matching function for relative response and reinforcement rates, can hold when the responding on one of the keys is made negligible by correlating reinforcements for one of the two VI schedules with a stimulus. It appears, therefore, that these equations apply to the concurrent VI schedules in Experiment 1 because equation (3) holds, and not vice versa.

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