

*A YOKED-CHAMBER COMPARISON OF CONCURRENT
AND MULTIPLE SCHEDULES: THE RELATIONSHIP
BETWEEN COMPONENT DURATION AND RESPONDING¹*

ALAN SILBERBERG AND JOHN SCHROT

THE AMERICAN UNIVERSITY AND WALTER REED ARMY INSTITUTE OF RESEARCH

Two experimental chambers were electrically connected so that the component selected by a pigeon confronting concurrent variable-interval schedules in one chamber could be successively presented as a multiple schedule to a second pigeon in the other chamber. Component duration was regulated by the use of a changeover delay, the value of which was systematically varied between 0 and 30 sec. It was found that the relative local response rates on the preferred key (absolute response rate to that component divided by the sum of the absolute response rates during both components) tended to increase with increasing component durations for the birds in the concurrent chamber, but decreased for the birds in the multiple chamber. These data support the interpretation that there are fundamental differences in the mode of responding to multiple and concurrent schedules. Based on these findings, it was concluded that previous demonstrations of matching on multiple schedules do not establish that response allocation is controlled by a process equivalent to that found on choice paradigms. It now appears that matching on multiple (but not concurrent) schedules is a consequence of selecting short component durations. The implications of these data for Herrnstein's (1970) and Rachlin's (1973) formulations of the relationship between multiple and concurrent schedules are examined.

In the presence of two concurrently available response keys and their associated variable-interval (*conc VI VI*) schedules, the function relating relative response rate (responses to a key/response total) to relative reinforcement frequency (reinforcements to a key/reinforcement total) has been demonstrated to be linear with a slope of 1.0 and a Y-intercept of 0.0 (e.g., Herrnstein, 1961). This "matching" function stands in contrast to the function obtained when the conditions of VI reinforcement are successive rather than simultaneous. In this latter paradigm, called a multiple variable-interval variable-interval (*mult VI VI*) schedule, this function frequently has a slope of less than 1.0 and a positive Y-intercept (e.g., Lander and Irwin, 1968).

Although concurrent operants can be studied under circumstances permitting simultaneous reinforcement of more than a single response alternative (e.g., Sidman, 1958), most

studies of choice behavior have used procedures ensuring that responding occurs successively. With regard to the pigeon's key peck, for example, the succession of choices is apparent because a pigeon cannot peck two spatially separated keys simultaneously. In view of the fact that behavior is usually successively ordered for reinforced alternatives on both concurrent and multiple schedules, the difference in the function relating relative response rates and reinforcement frequencies on these two paradigms may seem puzzling. There are, however, several procedural differences that may account for the different functions: (1) the tape readers assigning reinforcement operate synchronously on a *conc VI VI* schedule, but on a *mult VI VI* schedule, each reader is operative only when its associated component is present; (2) a changeover delay (COD) is frequently used to ensure that changeovers on *conc VI VI* schedules go unreinforced until the first response after a specified temporal interval (see Herrnstein, 1961), but a COD is usually not used on a multiple schedule; (3) obtained component duration: on choice paradigms, switching between keys (and hence, components) is usually quite frequent; e.g., with a COD of 1.75 sec,

¹This research was supported by NIMH grant 1 R01 MH2281-01, Alan Silberberg principal investigator. The authors wish to thank John Miller and Richard Wellins for their help in conducting the study and analyzing the data. Reprints may be obtained from Alan Silberberg, 321 Asbury Building, The American University, Washington, D.C. 20016.

Silberberg and Fantino (1970) found that pigeons would switch between keys up to four times per minute; in contrast to the high switching rates frequently observed on *conc* VI VI schedules, a typical duration for multiple schedule components is 3 min (e.g., Lander and Irwin, 1968; Reynolds, 1963); (4) component shifts are experimenter-controlled on multiple schedules and subject-controlled on concurrent schedules; hence, the different functions obtained under successive and simultaneous conditions of reinforcement may be due to the fact that only the concurrent procedure permits freedom of choice between components.

The findings of Shimp and Wheatley (1971) support the interpretation that among the alternatives mentioned above, component duration may play an important role in producing the differences in the way animals partition their responses between components of multiple and concurrent schedules. These researchers varied the duration of the components from 2 to 180 sec on a *mult* VI VI schedule and found that pigeons had relative response rates that approximated the predictions of the matching function when component durations were 2 or 5 sec, but obtained the conventional finding of "undermatching" (i.e., relative response rates lower than relative rates of reinforcement) when component durations exceeded 5 sec.

The conclusion that can be drawn from Shimp and Wheatley's data—that possibly the variable controlling behavioral differences between multiple and concurrent schedules is component duration—is indirectly supported by the results of Killeen (1972). He presented a yoked comparison of concurrent and multiple schedules by electrically connecting two experimental chambers so that the component chosen by a pigeon confronting a concurrent schedule was simultaneously presented on a single key as a multiple schedule to a second pigeon in the other chamber. He found that pigeons in both chambers matched relative response rates to relative reinforcement frequencies. He concluded that "the proportion of responses emitted in the components of concurrent schedules is independent of an organism's freedom to shift between components" (page 20). In other words, choice *per se* did not seem to be an important variable in producing the matching function.

Despite Killeen's findings, there is some reason to suspect that his conclusions were premature. A large body of data suggests that the matching function is independent of component duration on concurrent schedules (e.g., Stubbs and Pliskoff, 1969), but is dependent on component duration on multiple schedules (Shimp and Wheatley, 1971; Todorov, 1972). Hence, relative response rate may be a function of component duration only for responding on multiple schedules; on concurrent schedules, however, some other factor, possibly the freedom to shift components, may be ensuring the invariance of the matching function regardless of component duration. With regard to the Killeen study, matching may have obtained for birds on both the concurrent and multiple schedules because the high rate at which birds switched components in the concurrent schedule (mean component duration during Experiment 1, Part 2 was 4.4 sec) permitted the yoked partners to be on a paradigm equivalent to Shimp and Wheatley's with short component durations. Based on the data of Stubbs and Pliskoff, lower switching rates would still have produced matching on concurrent schedules; with longer component durations, however, undermatching would have characterized the data of the yoked partners. Such a finding would suggest that choice *per se* is the factor ensuring the production of matching, not component duration.

The present experiment was similar to Killeen's except that it addressed the issue of how relative response rates vary in both the concurrent and multiple schedules as a function of component duration on two different types of choice paradigms: on the first paradigm, called the changeover-key (CO-key) procedure, both schedules and their associated exteroceptive stimuli are assigned to the same key (main key) and responses to a second key switch the schedule and stimulus in effect on the main key (see Findley, 1958); on the second paradigm, called the two-key procedure, each schedule and its associated stimulus is assigned to one of the two response keys (see Herrnstein, 1961). On both procedures, three of the four differences that usually distinguish multiple from concurrent schedules have been removed: for both the concurrent and multiple chambers, the VI tape readers operate synchronously, a COD is used, and component durations are equivalent. The only scheduled difference be-

tween chambers is that only the birds in the concurrent chamber can choose components.

The important manipulation that distinguishes the present study from Killeen's is that the value of the COD was systematically varied. As other researchers have noted (*e.g.*, Shull and Pliskoff, 1967), component duration on choice paradigms reliably increases with increasing COD values. If, as is anticipated, choice *per se* is a critical factor producing matching on *conc* VI VI schedules, matching should result independently of the obtained component durations only for the birds on the concurrent schedule; if, on the other hand, component duration is the common factor underlying matching on both *conc* and *mult* VI VI schedules, relative response rates for all birds should covary across different obtained component durations.

METHOD

Subjects

Eight experimentally naive White Carneaux pigeons, deprived to 80% of their free-feeding weights, served.

Apparatus

Two identical experimental chambers were connected electrically so that stimuli presented in one chamber (concurrent) could be presented simultaneously in the other (multiple). Each chamber's dimensions were 34.3 by 30.5 by 33 cm. Except for the metal response panel and the metal grid floor, all surfaces were white. The distances from the floor of the chamber to the hopper aperture, the midpoint of the center key and the houselight were, respectively, 9.5 cm, 25 cm, and 30.5 cm. The midpoints of each of the two side keys were displaced 7.6 cm from the midpoint of the center key. Gerbrands response keys, requiring a minimum force of 0.1 N for operation and transilluminated by Industrial Electronic Engineers multi-stimulus projectors, were used.

Standard electromechanical equipment, housed in a separate room, was used to control the experiment and record the data.

Procedure

After being trained to eat reliably from the food magazine when it was presented unpredictably in time, the pigeons were placed on an autoshaping schedule (Brown and Jenkins,

1968) in which both side keys were transilluminated with white light 6 sec before the response-independent presentation of grain. Successive presentations of the lighted keys were separated by a variable intertrial interval of 30 sec, during which time only the houselight was illuminated. After two 50-trial sessions, during which reliable pecking was induced to both keys, the birds were randomly assigned to two groups, corresponding to the CO-key and the two-key procedures, of four birds each.

In the CO-key procedure, two pigeons were placed on the concurrent schedule paradigm (Birds 10838 and 9467) and two were placed on its multiple schedule equivalent in the yoked-control chamber (Birds 9905 and 11838). In the concurrent schedule, each response to the right, blue CO key switched the hue transilluminating the left, main key between red and green. Access to grain for both main-key components was assigned by a single, constant-probability VI 90-sec tape based on specifications of Fleshler and Hoffman (1962). Once the tape reader established that reinforcement was available on the main key, a probability generator assigned it with $p = 0.7$ to the red component and with 0.3 probability to the green component (see Stubbs and Pliskoff, 1969). Once a reinforcement was assigned, the VI tape was inoperative until that reinforcement was delivered. Each CO response started a COD clock. A reinforcement assigned to either main-key component could not be delivered until the occurrence of the first response to the appropriate component after that clock timed out.

Key colors in the yoked-control chamber were identical to the stimuli projected in the concurrent schedule chamber: whenever, for example, the bird on the concurrent schedule switched components from red to green, the left-key stimulus in the yoked-control chamber also changed from red to green. Blue-key responses in the yoked-control chamber did not switch main-key components as was the case in the concurrent schedule chamber; however, if a blue-key response did occur, it prohibited access to grain for a main-key response for a period equivalent to the COD value for the other chamber.

The delivery of grain in the yoked-control chamber was dependent on the delivery of grain to the partner on the concurrent schedule. In the

Table 1

Original data from which all calculations were made summed over last five sessions. C and M signify Concurrent and Multiple schedules respectively.

(1) Bird # (Condition)	(2) COD Value (Sec)	(3) Sessions	(4) Red Key Time (Min)	(5) Green Key Time (Min)	(6) Red Key Responses	(7) Green Key Responses	(8) Red Key Reinforce- ments	(9) Changeovers (Both Keys)
EXPERIMENT 1 PRE-REVERSAL								
10838(C)	0	25	323.79	144.74	6383	4940	205	16774
9905(M)					14842	6668		
9467(C)	0	25	233.55	224.36	11306	10464	205	14201
11838(M)					10385	7890		
10838(C)	2	36	340.70	132.37	27697	16287	199	3623
9905(M)					8907	5499		
9467(C)	2	37	357.14	114.90	31626	10344	214	2404
11838(M)					9532	5240		
10838(C)	10	25	435.88	118.70	25589	10584	200	768
9905(M)					10389	3309		
9467(C)	10	25	398.69	126.98	30285	8318	210	771
11838(M)					10723	6470		
10838(C)	30	26	599.07	160.23	30963	7598	204	363
9905(M)					6125	3905		
9467(C)	30	37	535.86	107.30	47729	5865	206	232
11838(M)					7674	4251		
POST-REVERSAL								
9905(C)	30	25	500.14	221.94	7605	4212	206	421
10838(M)					20897	8481		
11838(C)	30	25	626.21	122.94	21693	3531	231	498
9467(M)					50314	4742		
9905(C)	0	25	319.75	142.55	5716	2527	207	4901
10838(M)					16193	4890		
11838(C)	0	25	386.50	139.48	10198	4979	229	4300
9467(M)					31347	5684		
EXPERIMENT 2 PRE-REVERSAL								
9908(C)	0	25	324.47	134.79	9197	8549	197	7453
11917(M)					14476	4128		
10502(C)	0	25	361.64	101.06	16779	5333	218	9146
10868(M)					20309	4470		
9908(C)	2	32	385.94	99.08	22038	7640	211	2098
11917(M)					28401	7964		
10502(C)	2	32	320.28	147.49	28327	13573	225	4109
10868(M)					21571	10959		
9908(C)	10	31	372.65	187.24	8637	7050	202	851
11917(M)					33897	12531		
10502(C)	10	38	409.37	134.74	22968	6069	212	989
10868(M)					22642	11424		
9908(C)	30	25	645.11	231.02	9869	5666	212	538
11917(M)					54151	14798		
10502(C)	30	25	620.94	125.07	26874	4824	212	467
10868(M)					25442	5724		
POST-REVERSAL								
11917(C)	30	25	706.76	119.00	59543	8235	210	292
9908(M)					9796	4787		
10868(C)	30	25	541.58	121.88	22061	7188	224	373
10502(M)					12593	7024		
11917(C)	0	25	366.34	94.10	31737	6549	203	10513
9908(M)					3196	773		
10868(C)	0	25	314.68	137.57	23662	11443	226	14010
10502(M)					11659	4658		

event that components were switched before the bird on the multiple schedule received grain, grain was delivered for the first post-COD response once that component had returned.

On the two-key procedure, two pigeons were placed on the concurrent schedule paradigm (Birds 9908 and 10502) and two were placed on its multiple schedule equivalent in the yoked-control chamber (Birds 11917 and 10868). In the concurrent schedule chamber, each of the two operant-schedule pairs was assigned to a separate side key. Reinforcements were assigned to side-key responses in the same manner as on the CO-key procedure: a single VI 90-sec tape assigned reinforcement with $p = 0.7$ for left, red-key responses and $p = 0.3$ for right, green-key responses. A COD, which began with a CO response to either key, delayed grain delivery until the first post-COD response given that the tape reader had assigned a reinforcement to that key.

Key colors and their positions in the yoked-control chamber switched with each CO response made by the bird on the concurrent schedule; if, for example, this bird switched from responding to the left, red key to the right, green key, that CO response turned off the red light associated with the left key in the yoked-control chamber and illuminated the right key with green light. Thus, the stimuli for the bird on the multiple schedule were presented on separate keys, requiring it to switch its locus of responding whenever the bird on the concurrent schedule changed keys. Access to grain for the bird on the multiple schedule was dependent on the bird on the concurrent schedule having received reinforcement. In the event that components switched before obtaining grain, reinforcement was saved until the first post-COD response had occurred on that schedule.

The effects of component duration on responding were assessed for both procedures by varying COD values. All subjects first confronted an ascending series of CODs (0, 2, 10, and 30 sec), and then a descending series (30 and 0 sec). Before starting the descending series, birds that had been yoked controls were placed on the concurrent schedule procedure and, conversely, birds on the concurrent schedule of the ascending series served as yoked controls during the descending series.

Both experiments were conducted daily with

sessions terminating after 60 reinforcements of 4-sec access to grain. A given COD value remained in effect for 25 sessions unless the relative response rates on both the concurrent and multiple schedules had not been stable by a visual criterion for the last five sessions.

RESULTS

Table 1 presents the original data summed over the last five sessions under each experimental condition. All calculations were made from those five-day sums.

The top two rows of Figure 1 present the relative response rates for the red key (responses to the red key/response total) for the concurrent and multiple schedules as a function of COD value; the bottom row presents relative time (time in the presence of the red key/session time) which must be the same for both concurrent and multiple schedules. The panels from the left side of the figure are from the CO-key procedure, and the right-side panels are from the two-key paradigm. Each pair of animals in the concurrent and multiple condition is grouped at each COD value by a bracket along the abscissa. The dashed lines parallel to the abscissa at 0.70 on the ordinate signify the scheduled relative reinforcement frequency. The noteworthy feature of these data is that relative response rate and relative time tend to increase gradually, if irregularly, as COD value increases for both groups of birds on both the CO-key and two-key paradigms, and this trend appears more pronounced in the relative frequency measures of the concurrent schedule group than their yoked controls.

A comparison of the relative response rates on the concurrent and multiple schedules may not be the best means of assessing the effects of component duration on responding. This is because the relative response rate of a subject in the yoked control group will vary as a function not only of its own local response rate (responses to a key/time in presence of that key), but also as a function of the relative time in the presence of a component—a factor controlled by its concurrent schedule partner. Thus, changes in the relative response rate of a yoked-control subject may reflect changes not in its mode of responding, but rather, changes in how the experimental bird is partitioning relative time. In order to study re-

sponse rate unencumbered by such unintended, alternative factors, local response rate measures shall be the basic datum in comparisons between groups. Since the local response rate measure is insensitive to relative time in the presence of a component, between-animal comparisons can be made with a behavioral measure solely under the control of the subjects being compared.

Figure 2 presents the relative local response rates for the concurrent and multiple schedules for individual birds (top two panels) and for the summed data (bottom two panels) as a function of the mean obtained component durations. Relative local response rate is defined as:

$$\frac{R_R/T_R}{R_R/T_R + R_G/T_G} \quad (1)$$

where R and T denote, respectively, responses and time, and the subscripts R and G refer to the red and green keys. Data from the ascending and descending series are signified respectively by solid and dashed lines.

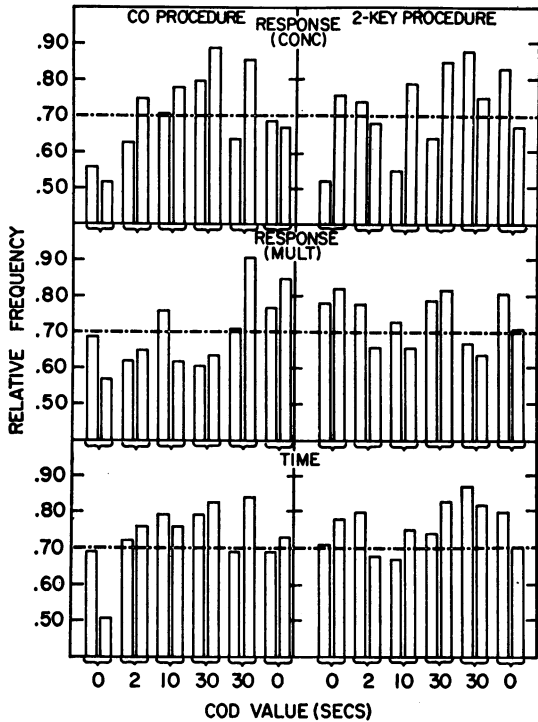


Fig. 1. Relative red-key frequency measures for the birds on the concurrent and multiple schedule as a function of COD value in seconds. Top two rows of data present the relative red-key response rates for the concurrent and multiple schedules respectively. Bottom row presents the relative time in the presence of the red key. Panels from the left- and right-side columns are from the CO-key and two-key procedures respectively. Data from each of the two animals under the concurrent and multiple schedule condition are grouped at each COD value by a bracket along the abscissa. The dashed line parallel to the abscissa at 0.70 on the ordinate signifies the scheduled relative red-key reinforcement frequency.

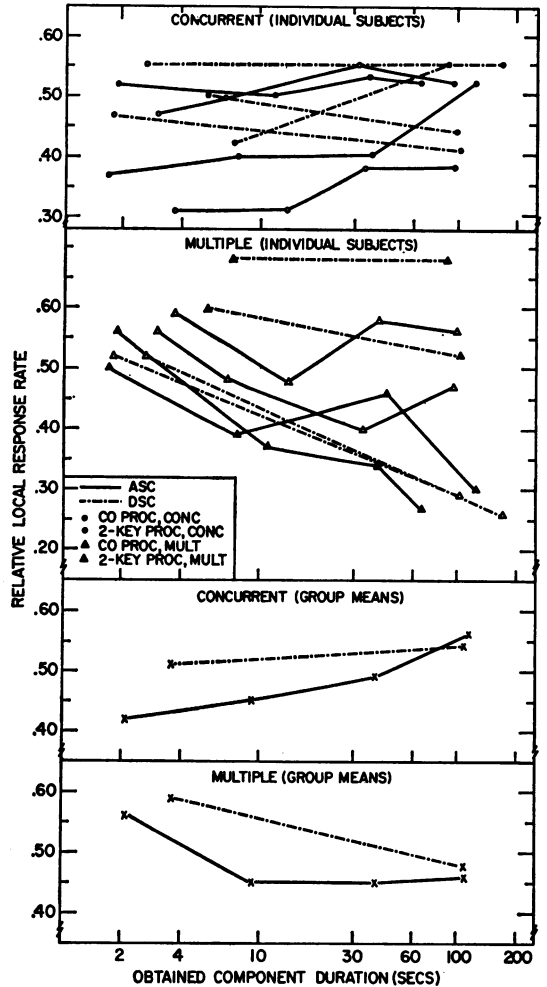


Fig. 2. Relative local response rates (see text for definition) for the birds on the concurrent and multiple schedules both individually (top two panels) and based on the summed data for both the CO-key and the two-key procedures (bottom two panels) as a function of the mean obtained component duration in seconds. Data from the ascending and descending series are signified respectively by solid and dashed lines. Circles and triangles present data points from the concurrent and multiple schedule groups; closed points represent the CO-key procedure, and open points represent the two-key paradigm.

It is noteworthy that the slopes of the relative local response rate curves do not have similar trends for birds on the concurrent and multiple schedules. With regard to the birds on the concurrent schedule, relative local response rates, whether based on individual or group data, appear to have a slightly positive slope, while the curves from the birds on the multiple schedule have a negative slope. The fact that these curves do not have similar slopes demonstrates that the effect of different component durations (induced by changes in COD value) on relative local response rate differs between birds on the concurrent schedule and birds on its yoked, multiple schedule equivalent.

DISCUSSION

The degree of matching obtained in the present study did not approach that found on the choice paradigm (Stubbs and Pliskoff, 1969) from which its procedures were adopted (see Figure 1). This procedure was used because it assures the equivalence of scheduled and obtained relative reinforcement frequencies. Despite the discrepancies between the matching prediction and the relative response rates obtained in the present study, the issue of the degree of matching is not critically important to the purposes of this experiment: it was mainly designed to assess whether there are differences in relative response rates between concurrent and multiple schedules, not to provide a replication of the matching phenomenon itself.

Our major finding was that the slopes of the relative local response rate curves differed for the concurrent and multiple schedules (see Figure 2). Based on the frequent finding that relative response rate and relative time covary independent of component duration (e.g., Shull and Pliskoff, 1967), zero slopes might have been expected for these curves for birds in the concurrent chamber. Nevertheless, the positive slopes that actually obtained are consistent with the findings of Todorov (1971), although his choice procedure differed considerably from the present one. The decreasing curves found with the multiple schedule also conform with earlier findings: Shimp and Wheatley (1971) and Todorov (1972) showed that longer component durations generate lower relative local

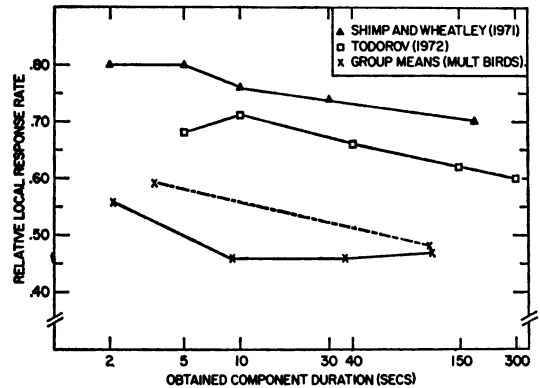


Fig. 3. Relative local response rate as a function of obtained component duration in seconds. Xs reference the group data of the birds on the multiple schedule during the ascending (solid lines) and descending (dashed line) series. The triangles and squares signify the Shimp and Wheatley and Todorov data respectively.

response rates. This point is clearly illustrated in Figure 3, which presents relative local response rates as a function of component duration for the birds on the multiple schedule in the present study as well as for the Shimp and Wheatley and Todorov (1972) experiments. Since the slopes of the multiple schedule's curves are similar to those found on other multiple schedules, and since the birds on the concurrent schedule differed from their yoked partners in that only the former group was free to choose its components, these data support the conclusion that choice *per se*, and not component duration, is the critical factor underlying the matching phenomenon.

The notion that different processes control response allocation on concurrent and multiple schedules has also been espoused by Rachlin (1973). According to his formulation, subjects on concurrent schedules choose so as to equalize the time rate of reinforcement (reinforcements/time) across components. The consequences of this equation are that matching obtains and the local response rates across components are equal. He noted that matching also may occur on short-component multiple schedules such as those used by Shimp and Wheatley. But here, matching cannot be the product of equating time rate of reinforcement across both components because component duration is not subject controlled; rather, matching is the product of unequal local response rates generated by the differential time rate of reinforcement across components.

Why, then, do pigeons match on concurrent and short-component multiple schedules despite differences in the properties of their behavior? Rachlin argued that matching is derivative rather than fundamental: it is a consequence of equalizing the relative reinforcing value of the two alternatives. Matching obtains on choice paradigms because the subject can adjust component durations (which support equal local response rates) to equate the time rate of reinforcement; on multiple schedules, matching obtains not through the adjustment of component durations, but through the generation of additional, possibly non-operant pecks to the richer component (see also Gamzu and Schwartz, 1973). In both cases, matching represents an equation of behavior to relative reinforcing value.

Although the present findings are in general agreement with Rachlin's conclusions, they do not support the notion that differences in the time rate of reinforcement between components account for the unequal local response rates obtained on multiple schedules. To the extent that the birds on the concurrent schedule matched relative time to relative reinforcement frequency, the components of the birds on the multiple schedule were adjusted so as to equalize time rate of reinforcement across components. Despite this equation, the relative local response rate of the birds on the multiple schedule decreased both absolutely and relative to the birds on the concurrent schedule (see Figure 2) as component duration increased. Further, the rate of decrease for the birds on the multiple schedule was similar to that found by Shimp and Wheatley (1971) and Todorov (1972), even though the present study equalized time rate of reinforcement per component and the latter two studies did not (see Figure 3). Since these differences between responding on concurrent and multiple schedules were maintained in the absence of differences in the time rate of reinforcement, Rachlin's appeal to the notion of differential local reinforcement rates alone cannot explain differences between responding on concurrent and multiple schedules.

One conclusion reached by Rachlin and supported by the present data—that different modes of responding characterize behavior on concurrent and multiple schedules—is inconsistent with a response-strength model advanced by Herrnstein (1970). His model would

predict that no differences would obtain between a bird on a concurrent schedule and a bird confronting the yoked, multiple schedule equivalent in terms of the slopes of their relative response rate curves. This prediction follows directly from how relative response rate is defined:

$$\frac{P_1}{P_1 + P_2} = \frac{\frac{kr_1}{r_1 + mr_2 + r_0}}{\frac{kr_1}{r_1 + mr_2 + r_0} + \frac{kr_2}{r_2 + mr_1 + r_0}} \quad (2)$$

where P_1 and P_2 equal response rates to the first and second components; r_1 and r_2 equal the reinforcement rates for first- and second-component responses; r_0 equals the reinforcement rate for alternatives other than responding to the first and second components; k is a constant equal to P_1 or P_2 when r_0 and either r_2 or r_1 are zero; and m equals a constant representing the interaction between components. Since m , r_1 , and r_2 are the same for birds on both the concurrent and multiple schedules, only individual differences between birds in k and r_0 can account for differences in relative response rates. Although these between-subject differences will produce different curves for equation 2, the slopes of these curves should be the same, because k and r_0 should not vary with changes in component duration.

Figure 4 compares the relative response rates between the experimental and yoked chambers in the present study by showing how relative

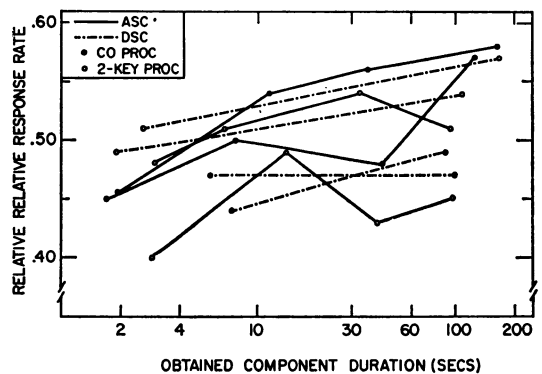


Fig. 4. Relative relative response rates (see text for definition) as a function of mean obtained component duration in seconds. Data from the ascending and descending series are signified respectively by solid and dashed lines. Closed and open data points represent, respectively, data from the CO-key and two-key procedures.

relative response rates (relative response rate of each bird on the concurrent schedule/same measure plus the relative response rate of its yoked control) varied as a function of obtained component duration. If the slopes of the relative response rate curves of the birds on the concurrent and multiple schedules covaried as the Herrnstein model predicts, a zero slope would obtain; based on the data of Figure 4, however, it is apparent that seven of eight curves have a positive slope. Therefore, these data do not conform with the predictions of Herrnstein's model.

Herrnstein's model also makes a testable prediction with regard to the local response rate (P_1) within a component of a multiple schedule; namely that

$$P_1 = \frac{kr_1}{r_1 + mr_2 + r_0} \quad (3)$$

Since the value of m varies inversely with component duration on multiple schedules (see Herrnstein, 1970, p. 259), the local response rate to a component should increase as component duration increases (and m decreases). Although it is possible to determine whether the yoked controls' local response rates reliably increase with increasing component durations as the model predicts, such an assay would be confounded by response rate discontinuities induced by changing COD values (see Silberberg and Fantino, 1970). A better test of this formulation is based on Todorov's (1972) experiment, in which component durations of *mult* VI 30-sec VI 90-sec schedule were varied between 5 and 300 sec without the use of a COD. Table 2, which is adapted from his data, shows that the local response rates averaged across both components (column 2) do not change with increasing component durations (column 1), although relative response rates do (column 3). Although the decreasing relative response rates obtained with increasing component durations are consistent with the predictions of Herrnstein's model, the invariance of the local response rates is not—a finding obviously incompatible with the Herrnstein formulation.

It was found in the present experiment that responding on choice paradigms differed from responding on multiple schedules: on concurrent schedules, the relative local response rate increased somewhat with increases in obtained component duration; on equivalent multiple

Table 2
Data From Todorov (1972)

Column (1): component duration; column (2): average of mean response rate for three birds in responses per minute across both components (response total to both components/session time); column 3: average of mean relative response rates.

(1) Component Duration	(2) Response/min	(3) Relative Response Rate
5	42.7	0.69
10	41.1	0.70
40	39.9	0.66
150	42.6	0.63
300	39.6	0.59

schedules, this measure decreased with increases in the component duration. These findings support the interpretation that choice *per se* and not component duration is fundamental in producing matching on concurrent schedules. Although matching can be found on multiple schedules, it now appears to be the consequence of selecting short-component durations. Instances of matching on multiple schedules are, according to this interpretation, unlikely to reflect a source of response allocation shared in common with matching on concurrent schedules.

REFERENCES

- Brown, P. and Jenkins, H. M. Auto-shaping of the pigeon's key-peck. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 1-8.
- Findley, J. D. Preference and switching under concurrent scheduling. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 123-144.
- Fleshler, M. and Hoffman, H. S. A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 529-530.
- Gamzu, E. and Schwartz, B. The maintenance of key pecking by stimulus-contingent and response-independent food presentation. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 65-72.
- Herrnstein, R. J. Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 267-272.
- Herrnstein, R. J. On the law of effect. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 243-266.
- Killeen, P. A yoked-chamber comparison of concurrent and multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 13-22.
- Lander, D. G. and Irwin, R. J. Multiple schedules:

- effects of the distribution of reinforcements between components on the distribution of responses between components. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 517-524.
- Rachlin, H. Contrast and matching. *Psychological Review*, 1973, 80, 217-234.
- Reynolds, G. S. Some limitations on behavioral contrast and induction during successive discrimination. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 131-139.
- Shimp, C. P. and Wheatley, W. L. Matching to relative reinforcement frequency in multiple schedules with a short component duration. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 205-210.
- Shull, R. L. and Pliskoff, S. S. Changeover delay and concurrent schedules: some effects on relative performance measures. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 517-527.
- Sidman, M. By-products of aversive control. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 265-280.
- 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 rate of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 887-895.
- Todorov, J. C. Concurrent performances: effect of punishment contingent on the switching response. *Journal of the Experimental Analysis of Behavior*, 1971, 16, 51-66.
- Todorov, J. C. Component duration and relative response rates in multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1972, 17, 45-50.

Received 8 October 1973.

(Final Acceptance 1 March 1974.)