A YOKED-CHAMBER COMPARISON OF CONCURRENT AND MULTIPLE SCHEDULES[1]

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Pigeons were exposed to alternative pairs of variable-interval schedules correlated with red and green lights on one key (the food key). In one experimental chamber, responses on a white key (the changeover key) changed the color of the food key and initiated a 2-sec changeover delay. Pigeons in a second chamber obtained food by pecking on a colored key whenever the pigeons in the first (concurrent) chamber had obtained food for a peck on that key color. There was no changeover key in the second (multiple) chamber: changeover responses in the first chamber alternated the schedules and colors in both chambers. The pigeons in both chambers emitted the same proportion of responses on each of the variable-interval schedules, and mastered discrimination reversals at the same rate. The pigeons differed only in their absolute response rates, which were greater under the concurrent schedules. In a second experiment, changes in key color occurred automatically, with different proportions of time allocated to the two variable-interval schedules. Matching of relative response frequency to relative reinforcement frequency was affected by the relative amounts of time in each component, by rate of changeovers, and by manipulations of the variable-interval scheduling.

Catania (1966) noted that concurrent operants are most conveniently investigated if the two response classes cannot occur simultaneously, for otherwise it cannot be ensured that the reinforcement scheduled for one response does not strengthen a simultaneously occurring response from the other operant class: ". . . In order to maintain the independence of two topographically compatible operants, it is necessary to make them incompatible by programming explicit reinforcement contingencies that separate the two operants in time . . . when concurrent operants are incompatible in the first place, it is often necessary to program concurrent schedules in such a way that the operants become even more incompatible (Catania, 1966, pp. 215-216)."

But if the operants are separated in time, then concurrent schedules become formally equivalent to multiple schedules, with the control of component alternation left to the subject. This equivalence is especially obvious when concurrent schedules are arranged according to a "Changeover-Key", procedure (cf. Findley, 1958), in which the concurrent schedules are correlated with different stimuli and arranged on a single operandum; the organism may switch between the schedules by responding on a seperate operandum.

In light of the formal similarity between concurrent and multiple schedules (cf. Catania, 1969), it becomes important to ask what differences exist in the behaviors generated by these schedules and to what differences in the contingencies they are attributable. Behavior on concurrent schedules is typically quite sensitive to differences in the amount, frequency, immediacy, and quality of reinforcement provided by the schedules, while behavior on single-operandum schedules is typically insensitive to such differences (Catania, 1963). The number of operanda in the situation, however, may be less important than the frequency of shifting between reinforcement schedules. In single-operandum studies, the frequency of shift may range from zero ("between groups" methods) to infrequent ("within groups" methods) to moderately frequent (multiple schedules). In concurrent schedules, the frequency of shift is usually very high. Correlated with this increase in shift frequency is an increase in the sensitivity of the procedures (i.e., an increase in the proportion of the variance in the dependent variable that can be attributed to changes in the independent variable). The importance of shift

frequency was experimentally demonstrated by Shimp and Wheatley (1971), who systematically varied the component duration of multiple schedules. They found that as the component duration was shortened, the relative frequency of responding in a component approached a value equal to the relative frequency of reinforcement in that component.

It would be incorrect to conclude, given the formal similarities of concurrent and multiple schedules, and the apparent similarities of the behaviors engendered by those schedules when multiple component shift frequency is adequately high, that all differences between the schedules have been resolved. There is more involved in the arrangement of schedules than implied by formal definitions of those schedules, and there are many differences in the techniques actually used in arranging concurrent and multiple schedules. In concurrent interval schedules, for instance, both tape readers are kept operating until they have set up a reinforcer. In the case of multiple schedules, the tape reader for one component is turned off when the other component is in effect. This difference will bring about different distributions of reinforcement availability within the components of the two types of schedule. The use of a changeover delay (COD) will further affect reinforcement distributions. In concurrent schedules, animals have the continuous, reversible option of responding on one schedule or the other. This feature of concurrent schedules has contributed to their popularity as a device for studying choice behavior. In multiple schedules it is the experimenter, not the subject, that arranges component shifts. It would be surprising if this difference in the amount of control given the subjects was not reflected in the data, over and above the effects attributable to the resultant differences in component duration and shift frequency.

Catania (1966) suggested that a study of these distinctions be started by experimentally analyzing concurrent responding into multiple behavior, and switching, or choice behavior. The latter may be isolated by removing the response requirement on the multiple key, delivering reinforcers independently of responding in the presence of distinctive stimuli, yet permitting animals to switch between stimuli. Several investigators have pursued this line of inquiry (Baum and Rachlin, 1969; Brownstein, 1971; Brownstein and Pliskoff,

1968), and have found the relative amount of time pigeons spend in the presence of a stimulus to equal the relative amount or frequency of reinforcement in the presence of that stimulus. The multiple-component of concurrent performance may be studied by: " . . . removing the CO-key and programming the alternation of the schedules and their associated stimuli on the basis of the CO-key responding of either the same organism in preceding sessions or another organism in a second experimental chamber in which a COD-key procedure is programmed [Catania, 1966, p. 222]."

The following experiments begin that study.

METHOD

Subjects

Four male White Carneaux pigeons, all with previous experience in experiments with concurrent schedules, were maintained at 80% of their free-feeding weights.

Apparatus

Two experimental chambers were employed. The first was a picnic ice chest containing two Lehigh Valley response keys centrally located 4.75 in. (12 cm) apart, 4 in. (10 cm) above a feeder aperture. The left key was transilluminated by a white light, except during reinforcement and at the termination of the session. The right key could be transilluminated with red or green lights. The second chamber was a Lehigh Valley three-key box in which the left and center keys were dark and inoperative throughout the experiments. The right key was 5 in. (13 cm) above, and 3.5 in. (8 cm) to the right of, the center of the feeder aperture and could be transilluminated with red or green lights. A force of 0.1 N was required to activate the keys in both chambers. In both chambers, a darkening of the houselights signalled the onset of a 3-sec period during which mixed grain was available from the food magazine.

EXPERIMENT 1

Procedure

Part 1. A yoked comparison of concurrent and multiple schedules. In this experiment, two of the pigeons (31 and 36) were exposed to concurrent schedules in the first chamber and two (20 and 38) to the corresponding mul-

tiple schedules in the second chamber. The schedule in the second chamber was yoked to the schedule in the first chamber in that stimulus presentations and the availability of reinforcement were dependent on the behavior of the pigeons in the first chamber. In the first chamber, reinforcements were arranged according to a variable-interval (VI) 60-sec schedule when the right key was green, and according to a VI 30-sec schedule when the right key was red. These schedules were constructed according to the specifications of Fleshler and Hoffman (1962). Both interval schedules ran continuously until they set up a reinforcer, which could be obtained only by a response on the appropriately colored key. The pigeons in the first chamber could switch from one key color to the other by a single response on the left, white, changeover key. A 2-sec changeover delay was in effect, so that reinforcement could not occur within 2 sec of the last response on the changeover key.

The keylights in the second chamber were perfectly correlated with those in the first: whenever the pigeon in the first chamber changed the color of its key, say, from red to green, the lights in the second chamber would also change from red to green. When the first pigeon received a reinforcer, the next response by the second pigeon was reinforced if it occurred on the appropriately colored key. If the second pigeon failed to respond before the first again switched the key, the reinforcement was "saved" until the pigeon did respond on the correctly colored key, although it could not be obtained within 2-sec of a change of the key color. This safety factor was necessary only for some of the initial sessions, before the pigeons in the second chamber developed a steady pattern of responding.

Twenty-four daily sessions were conducted, each session terminating after 60 reinforcements. The pigeons that were initially in the first chamber were then assigned to the second chamber, and those initially in the second chamber were assigned to the first. The scheduling circuitry was left unchanged, so that those pigeons that had obtained their food on multiple schedules in the second chamber were now exposed to the concurrent schedules in the first chamber, and *vice versa*. After an erratic first session, responding stabilized rapidly enough to conclude this phase after 10 sessions.

Part 2. Replication and discrimination reversal. The same yoked technique was used as in Part 1. The schedules correlated with the red and green key colors were changed to VI 120-sec and VI 40-sec, respectively. These schedules were constructed according to the specifications of Fleshler and Hoffman (1962) for 12-interval VI schedules. Note that not only were the mean interreinforcement intervals of both schedules increased, but the shorter schedule was now associated with green, rather than with red as in Part 1.

After seven sessions consisting of 60 reinforcements each, the correlation between schedule and color was again reversed. Sessions were reduced to 30 reinforcements, and two sessions were conducted daily, about 4 hr apart. It was hoped that collection of data in these smaller blocks would permit a finer analysis of the fairly rapid discrimination learning. After eight of these shorter sessions, the correlation was again reversed, and another eight short sessions were conducted, followed by 12 sessions consisting of 60 reinforcements. After Parts 1 and 2 of Experiment 2 (reported below), Pigeons 31 and 36 were assigned to the yoked chamber, and Pigeons 20 and 38 to the main chamber, for another replication of the basic yoked comparison of concurrent and multiple schedules. Sixteen daily sessions were conducted, using the VI 120-sec and VI 40-sec schedules. To summarize: three discrimination reversals were conducted, and the pigeons were maintained on the last reversal several additional sessions for the collection of asymptotic data. After an interlude in which other experiments were conducted, conditions were reversed for the first and second groups of pigeons, and additional asymptotic data were collected.

RESULTS AND DISCUSSION

Part 1. Table 1 gives the mean data from the last five sessions at each condition. The grand means across pigeons seem representative of individual performances. The most important dependent variable in concurrent studies has traditionally been the proportion of responses emitted on each of the schedules. Table 1 shows that the proportions of responses emitted on the VI 30-sec (responses on VI 30/responses on VI 30 plus responses on VI 60) were the same for the pigeons exposed to the concurrent schedules and the pigeons exposed

Table 1

Average data from the last five sessions of Parts 1 and 2 of Experiment 1. All proportions
are calculated with the data from the shorter schedule in the numerator. All rates exclude
the time occupied by reinforcement. "C" stands for pigeons exposed to concurrent sched-
ules, "M" for pigeons exposed to yoked-multiple schedules.

Pigeon		Prop. of Responses		Prop. of Time	Local Response Rate (Responses per Min)				Prop. of Rf.	Local Rf. Rate (Rf. per Min)	
C	M	C	M		C		M				
Part 1					VI 30	VI 60	VI 30	VI 60		VI 30	VI 60
31	20	0.57	0.60	0.61	88	107	62	64	0.64	2.68	2.34
20	31	0.63	0.60	0.64	70	71	39	48	0.65	2.57	2.40
36	38	0.66	0.63	0.68	97	109	47	61	0.66	2.46	2.75
38	36	0.63	0.66	0.65	61	71	46	43	0.67	2.50	2.30
Average		0.62	0.62	0.65	79	89	49	54	0.65	2.55	2.45
Part 2					VI 40	VI 120	VI 40	VI 120		VI 40	VI 120
31	20	0.72	0.75	0.74	78	88	62	51	0.77	1.72	1.57
20	31	0.67	0.69	0.74	67	80	48	51	0.72	1.89	1.75
36	38	0.71	0.74	0.71	77	78	65	49	0.77	1.82	1.44
38	36	0.74	0.77	0.75	53	57	44	40	0.75	1.76	1.74
Average		0.71	0.74	0.73	69	76	55	48	0.75	1.80	1.63

to the multiple schedules. Both groups emitted
62% of their responses on the schedule with
more frequent reinforcement.

The proportion of time animals spend in
the presence of one of the components of a
concurrent schedule (time keylight A is on/
time keylight A is on plus time keylight B is
on) is often found to equal the proportion of
reinforcers they receive in that component
(reinforcements in component A/reinforce-
ments in component A plus reinforcements in
component B). Table 1 shows that this is also
the case in the present experiment, with both
proportions equal to 0.65.

Because the pigeons spent almost twice as
much time in the component that delivered
twice as many reinforcers, the local rate of
reinforcement (reinforcements in A/minutes
in A) should be about the same for both com-
ponents. Table 1 shows this to be the case,
with the animals receiving about 2.5 reinforce-
ments per minute in each component. This
high and equal local rate of reinforcement
was possible only because the VI schedules
were being arranged concurrently, with each
schedule setting up reinforcers even while the
animals were in the alternate components.

The local response rates (responses in A/
minutes in A) were slightly greater during the
VI 60-sec schedules than during the VI 30-sec
schedules. The most marked difference in the
table is found when the absolute response
rates are compared. The pigeons exposed to

concurrent schedules emitted half again as
many responses as the pigeons exposed to
multiple schedules (83 *vs.* 50 responses per
minute, when averaged over components).
Since the concurrent schedules were always ar-
ranged in the first chamber and the multiple
schedules in the second, it is possible that the
differences in rate were simply a function of
the different experimental chambers. Data
from Experiment 2 will make this interpreta-
tion unlikely.

Part 2. Figure 1 shows the changes in the
proportion of responses emitted on the red key,
and the proportion of time spent in the pres-
ence of the red key, throughout the course of
the three discrimination reversals. The pigeons
exposed to the multiple schedules appear to
have learned the discrimination reversals at
about the same rate as the pigeons exposed to
the concurrent schedules. If the pigeons in the
yoked chamber had not attended to the key
colors but had responded at the same rate in
each component, the curves depicting their
proportion of responses on the red key would
have been superimposed on the "proportion
of time" curves. This did not usually happen:
the differences in the local response rates dur-
ing the first four sessions of each reversal were
significantly different from zero (all t's > 10.,
3 df., $p < 0.005$) on the first and third reversals
for Pigeon 20 and on the first and second
reversals for Pigeon 38. This difference in re-
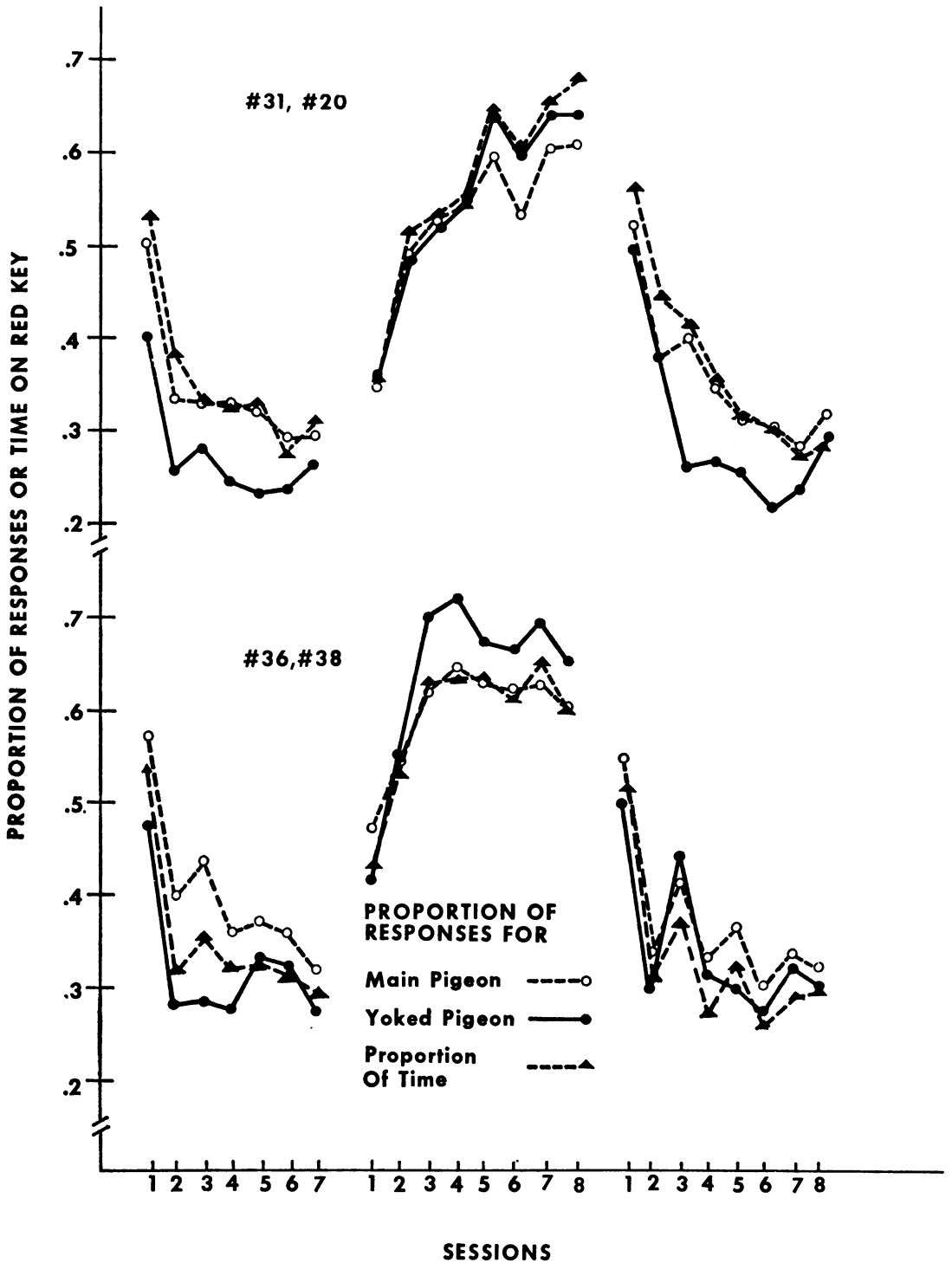sponse rates indicated that the key colors

Fig. 1. Relative number of responses emitted on red key, or relative time spent in the presence of the red key, during three discrimination reversals. The first set of curves was collected over seven sessions consisting of 60 reinforcements. The remaining two sets were each collected over eight sessions consisting of 30 reinforcements.

exerted some control over the responding of the pigeons in the yoked chamber. The nature of this control will be investigated in the subsequent experiments; here it is sufficient to note that the similarity of the performances on multiple and concurrent schedules is not due simply to the inattention of the pigeons exposed to the multiple schedules.

The second part of Table 1 gives the mean data from the last five sessions of stable performance on the VI 120-sec, VI 40-sec schedules. The picture shown by these data is not substantially different from that seen in the first part of this experiment. The relative amount of time spent in each component matches the relative number of reinforcers obtained in each component. The proportion of responses emitted in each component is about the same for pigeons exposed to concurrent and multiple schedules, and the former continue to respond at a faster rate than the latter (71 *vs.* 53 responses per minute, averaged over components). The pigeons made 14.6 changeover (CO) responses per minute, on the average, in Part 1 and 13.6 per minute in Part 2.

EXPERIMENT 2

The first experiment demonstrated more similarities than differences between concurrent and multiple behavior, both during acquisition and during asymptotic performance. The schedules for the pigeons in the yoked-chamber were different in several important ways from typical multiple schedules. The shift between components of the yoked-multiple schedule was produced by pigeons responding on concurrent schedules, and thus was correlated in some unknown way with the delivery of reinforcers. The amounts of time spent in each of the components were unequal, and the frequency of shifting between components was much greater than that normally occurring in multiple schedules. These differences were investigated in the following experiment, where the yoked procedure was retained as a matter of scheduling convenience.

METHOD

The subjects, apparatus, and VI schedules were as in Part 2 of the preceding experiment. Each part of the experiment comprised 12 daily sessions of 60 reinforcements each.

Procedure

Part 1: automatic CO, component durations unequal. Alternations between components were automatic, with the VI 120-sec schedule in effect for exactly 6.4 sec, alternating with exactly 2.4 sec of the VI 40-sec schedule. This alternation did not stop during reinforcement. The pigeons thus spent 73% of their time in the VI 40-sec component, excluding the time for reinforcement. Responses to the white key in the first chamber initiated the 2-sec delay, but did not change the schedules. The automatic changeovers were not accompanied by a delay. The component durations used in this part of the experiment approximated the values obtained in Part 2 of the preceding experiment. Those values (in seconds), and the pigeons that generated them, were: 6.4, 2.3 for 31; 6.7, 2.7 for 36; 6.2, 2.6 for 20; 6.3, 2.1 for 38.

Part 2: automatic CO, component durations equal. This procedure was the same as Part 1, except that the components were automatically switched once every 4.5 sec.

Part 2 of the first experiment, and Parts 1 and 2 of this experiment, were conducted with Pigeons 31 and 36 in the first chamber and Pigeons 20 and 38 in the second. After Part 2 of Experiment 2, Pigeons 20 and 38 were assigned to the first chamber and 31 and 36 to the second chamber, and these three phases were replicated.

Part 3: VI schedules stopped during alternate components. Throughout the previous experiments, both VI schedules were continuously operative, except when a reinforcer was set up or being delivered. This technique makes reinforcement probability greatest after a changeover. In Part 3 of Experiment 2, a VI schedule was operative only when the stimulus correlated with that schedule was in effect. This technique is more similar to that typically used in arranging multiple schedules. To maintain the same rate of reinforcement as in Parts 1 and 2, the VI schedules were changed to VI 60-sec and VI 20-sec by halving the intervals on both VI tapes. Otherwise, scheduling was the same as in Part 2, with changeovers occurring every 4.5 sec.

Part 4: reduced CO frequency. This procedure was the same as that of Part 3, except that changeovers were automatic, once every 45 sec, rather than every 4.5 sec.

Table 2

Average data from last five sessions of Parts 1 and 2 of Experiment 2. All proportions are calculated with the data from the shorter schedule in the numerator. All rates exclude the time occupied by reinforcement. "1" stands for pigeons in the first chamber, "2" for pigeons in the second chamber.

Pigeon		Prop. of Responses		Local Response Rate (Responses per Min)				Prop. of Rf.	Local Rf. Rate (Rf. per Min)	
1	2	1	2	1		2				
				VI 40	VI 120	VI 40	VI 120		VI 40	VI 120
Part 1										
31	20	0.65	0.69	49	70	51	60	0.73	1.85	1.78
20	31	0.78	0.73	61	53	53	54	0.73	1.86	1.82
36	38	0.73	0.73	64	62	50	50	0.74	1.87	1.71
38	36	0.64	0.70	41	62	40	45	0.74	1.83	1.70
Average		0.70	0.71	54	62	49	52	0.74	1.85	1.75
Part 2										
31	20	0.48	0.56	57	57	53	41	0.73	2.71	0.953
20	31	0.49	0.59	64	66	60	38	0.72	2.87	1.02
36	38	0.61	0.60	73	44	56	35	0.73	2.77	0.933
38	36	0.61	0.58	53	31	41	28	0.73	2.73	0.956
Average		0.55	0.58	62	50	53	36	0.73	2.77	0.966

RESULTS AND DISCUSSION

Table 2 gives the mean data from the last five sessions of Parts 1 and 2. Part 2 of Experiment 1 was similar to Part 1 of Experiment 2, except that in the latter, changeovers were arranged by a clock, rather than by a pigeon. This procedure removes all variability from component durations and alternates the components independently of reinforcement set-up or occurrence. By comparing the relevant parts of Tables 1 and 2, however, it may be seen that these changes had relatively little effect on behavior. The proportion of responses emitted on the VI 40-sec schedule decreased by 1% for the pigeons in the first chamber, and by 3% for the pigeons in the second chamber. These decreases might be accounted for by the 2% decrease in the proportion of reinforcers received on that schedule. "Choice" may thus be removed from concurrent schedules with very little effect on the typical measure of choice behavior. The response rates of the pigeons in the second chamber, averaged over components, decreased from 53 to 50 responses per minute. The largest change is seen in the average response rate of the pigeons in the first chamber, which went from 71 responses per minute in Experiment 1 to 56 responses per minute in this experiment, a 21% decrease. This decline in response rate after removal of the opportunity to switch between schedules is consistent with the data of the first experiment, where concurrent schedules maintained a much higher response rate than the corresponding multiple schedules.

It cannot be argued that the reduced variability of component duration was responsible for the decrease in response rate in the present experiment, because the same reduction in variability had little effect on the response rate of the pigeons in the second chamber. Similarly, the pigeons in the second chamber are a control for differences in the correlations among component alternations, reinforcement delivery, and changeover delays. This last factor, the removal of changeover delays, should have had a profound effect on behavior. A 2-sec delay in a component that averages 2.4 sec severely affects the distribution of reinforcements in that component. While the pattern of responding within components might have been affected by removal of the delay, the average response rate of the pigeons in the second chamber showed little change. It seems fair to conclude that it was the removal of the opportunity to switch between schedules that was responsible for the decreased response rates of the pigeons in the first chamber.

Why should the transition from concurrent to multiple schedules result in a reduced rate of responding? In multiple schedules, no time is spent making changeover responses, so that response rates on the main schedules should, if anything, be greater than in concurrent

schedules. The obtained difference makes sense, however, when one remembers that preference and response rates usually covary. While there are exceptions to such a correlation, especially when contingencies differentially reinforce high or low response rates, animals generally choose frequent reinforcement over infrequent, and respond faster in the former case; they prefer immediate to delayed reinforcement, and respond faster for immediate reinforcement, and so on. If such a relation exists in concurrent schedules, animals will tend to keep themselves in the schedule where their response rates are highest by switching when the preference for (and response rate in) one of the schedules decreases. Under multiple schedules, animals cannot switch to other reinforcement schedules. They are "locked" into schedules that may occasionally command less than maximal response rates. If switching does occur, it must be to behaviors that are not recorded and for which reinforcers have not been explicitly arranged. Such switching could only result in further decrements in recorded response rates.

In Part 2 of this experiment, the components switch at about the same rate, but each component lasted for exactly 4.5 sec. This seemingly minor change in the component durations had major effects on the pigeons' performance. Local response rates increased during the VI 40-sec and decreased during the VI 120-sec. These rate changes were not proportionately as great as the change in the proportion of the time spent in the VI 40-sec component (from 73% to 50%), so that there was a decrease in the proportion of responses emitted on the VI 40-sec schedule. (Since one-half of the session time was spent in the VI 40-sec component but more than one-half of the reinforcers were obtained there, there was slightly less time available for responding during that component. Had the clock that scheduled component alternations stopped during reinforcement, this bias would have been avoided, and the proportions of responses in that component would have been about 2% greater.)

It was noted in this part of the experiment that almost all of the responding in the VI 120-sec component occurred during the first few seconds of that component. This is consistent with the results of Silberberg and Fantino (1970), who found response rates to be higher immediately after changeovers than

at any other time in concurrent schedules. Since both schedules of a concurrent pair are continuously operative, the probability of reinforcement for responses soon after switching is quite high and may be largely responsible for the non-homogeneous response rates. Reducing these probabilities, either by arranging long CODs (Shull and Pliskoff, 1967) or by stopping the schedules in alternate components (Findley, 1958), reduces or eliminates switching. In typical multiple schedules where the schedules are nonoperative during alternate components, the reinforcers are more homogeneously distributed. This distinction was investigated in Part 3.

In Part 3, the component VI schedules were stopped while the alternate components were in effect. Table 3 gives the average data from the last five sessions of this condition. The proportion of responses emitted on the VI 20-sec schedule increased to 70%, a value approximating the proportion of reinforcers received on that schedule. The proportion of responses on the same schedule in Part 1 of this experiment was also about 70%, but there the pigeons were responding at about the same rates in each component and spending more time in the component with the briefer VI. In Part 3, component durations were equal, but the pigeons responded at a faster rate on the VI 20-sec schedule and at a slower rate on the VI 60-sec schedule than in any other part of these experiments.

In Part 4, the frequency of alternation between components was decreased to once every 45 sec. This decrease in the shift frequency brought about a 4% decrease in the proportion of responses emitted on the VI 20-sec schedule. The obtained proportion was 6% below the "matching" value of 72% and is thus quite consistent with the data collected by Shimp and Wheatly (1971) for component durations of 30 and 60 sec.

GENERAL DISCUSSION

The success of experimental analyses of complex phenomena depends upon the independence of the parts that are dissociated for study. Experiment 1 demonstrated that the proportion of responses emitted in the components of concurrent schedules is independent of an organisms' freedom to shift between components, while the absolute response rate

Table 3

Average data from last five sessions of Parts 3 and 4 of Experiment 2. All proportions are calculated with the data from the shorter schedule in the numerator. All rates exclude the time occupied by reinforcement. Since each pigeon was exposed to Parts 3 and 4 only once and since the reinforcement schedules were the same in both chambers, the data from these chambers are not treated separately.

Pigeon	Chamber	Prop. of Responses	Local Response Rate (Responses per Min)		Prop. of Rf.	Local Rf. Rate (Rf. per Min)	
Part 3			VI 20	VI 60		VI 20	VI 60
20	1	0.65	86	46	0.74	3.06	1.03
31	2	0.71	80	33	0.74	3.06	1.03
38	1	0.74	83	28	0.72	2.80	1.10
36	2	0.72	66	24	0.72	2.80	1.10
Average		0.70	79	33	0.73	2.93	1.07
Part 4							
20	1	0.58	86	62	0.72	3.13	1.16
31	2	0.69	89	44	0.72	3.13	1.16
38	1	0.71	76	31	0.72	3.10	1.07
36	2	0.67	58	29	0.72	3.10	1.07
Average		0.66	77	42	0.72	3.12	1.12

is not independent of that freedom. This is not to say that the actual pattern of shifting does not affect the response proportion. The pattern of shifting determines component durations, which, in their turn, have a profound effect on response proportions. But when the component durations are set at values that approximate those the pigeon would choose (*e.g.*, are chosen by another pigeon), response proportions are the same whether or not the organism itself does the switching. Experiment 2 investigated just how good those approximations must be to leave behavior invariant. It was found that component alternation does not have to be correlated with reinforcement, and the average component durations may be substituted for the range selected by the pigeons. Changes in the relative durations of the components, however, do affect the proportion of responses in each component, as do changes in the frequency of alternation between components.

In Experiment 1, the proportion of time that pigeons spent in one component of a multiple schedule equalled the proportion of reinforcers they obtained in that component. Since the local response rates were about equal, the proportion of responses emitted in one component also matched the proportion of reinforcers obtained there. Response matching also occurs in multiple schedules with high shift frequencies (Experiment 2, Part 3), but

there, the matching is generated by proportional differences in local response rates.

Why should local response rates be similar in concurrent schedules and different in multiple schedules? Certainly part of the answer lies in the similarity of the local reinforcement rates in the components of concurrent schedules and the difference of those rates in the components of multiple schedules. But we cannot conclude that local response rates will always be proportional to local reinforcement rates. In concurrent schedules, response rate is greatest immediately after a changeover and decreased in some fashion throughout the remainder of the component. It would be surprising if, in general, the ratio of the averages of these nonhomogeneous rates were directly predictable from the ratios of the reinforcement rates. But concurrent schedules in which the animals partition their time in proportion to the distribution of reinforcers are a special case. Not only are the local rates of reinforcement in the components equal, but the probabilities of reinforcement immediately after a changeover are also equal. If, for instance, an animal averages 3 sec on a VI 60-sec schedule and 6 sec on a VI 30-sec schedule, the probability that a response will be reinforced upon switching into the longer schedule is 0.5(6/60), and the probability that it will be reinforced upon switching into the shorter schedule is 0.5(3/30). Whenever pigeons diverge from

temporal matching, these probabilities diverge from equality. (This analysis ignores CODs, which not only delay the reinforcement, but add a constant to the numerators of both fractions.) The importance of these probabilities of reinforcement soon after a changeover can be seen in the data of Silberberg and Fantino (1970). Analysis of their data shows that the proportion of responses on each of two concurrent VI schedules immediately after a changeover was negatively correlated with the overall proportion of reinforcements on each schedule, but was positively correlated ($r = 0.499$) with the relative probability of reinforcement immediately after a changeover.

In Part 2 of Experiment 2, component durations were changed from 6.4 and 2.4 sec to 4.5 sec. If response rate is highest in the beginning of a component, shortening the duration of the VI 40-sec component should have increased the local response rate in that component, and lengthening the VI 120-sec component should have decreased response rate in that component. Inspection of Table 2 shows that this did indeed happen.

In Part 3 of this experiment, the VI schedules were stopped in the alternate components, and response matching was approximated once again. In this part of the experiment, the probability of reinforcement after a changeover was the same the the probability of reinforcement at any other time in the component. But if the pigeons match local response rates to local reinforcement rates here, why should they not have done so in Part 2? In that part of the experiment, not only were the reinforcement ratios 3 to 1, but the probabilities of reinforcement for post-changeover responses were also 3 to 1: $(4.5/40)/4.5/120)$. There may be a ceiling effect on response rate, so that post-changeover responses just could not stay proportional to post-changeover reinforcement probabilities. In any case, the failure to get matching here underlines the problems implicit in comparing the averages of non-homogenous processes, except in those felicitous cases when the data to be compared are equal, as in the typical concurrent schedules.

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