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THE FOLLOWING SCHEDULE OF REINFORCEMENT AS A FUNDAMENTAL DETERMINANT OF STEADY STATE CONTRAST IN MULTIPLE SCHEDULES

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Two experiments investigated whether steady-state interactions in multiple schedules depend exclusively on the following schedule of reinforcement. Experiment 1 used a four-component multiple schedule in which two components were associated with the same constant schedule of reinforcement, and where rate of reinforcement was varied in the component that followed one of these. Contrast effects were reliable only in the component that preceded the point of reinforcement variation, although some contrast did occur otherwise. In those instances where contrast other than the following-schedule effect did occur, it was accounted for by the effect of the preceding schedule, an effect for which there were consistent individual differences among subjects, and which varied with component duration. Experiment 2 used a three-component schedule, in which reinforcement rate was varied in the middle component. The results were consistent with Experiment 1, as the following-schedule effect was the only consistent effect that occurred, although an effect of the preceding schedule did occur for some subjects under some conditions, and was especially evident early in training. The conclusion from both experiments is that there is no general effect of relative rate of reinforcement apart from the sum of the effects of the preceding and following schedules, and that the following-schedule effect is the fundamental cause of steady-state interactions.

Key words: contrast, multiple schedules, component duration, VI schedules, matching, signaled reinforcement, pigeons

Behavior in one component of a multiple schedule is a function not only of its own rate of reinforcement, but also of the rate of reinforcement in the surrounding components. Such effects of the "context of reinforcement" have been the subject of a large amount of empirical research (cf. de Villiers, 1977; Schwartz & Gamzu, 1977) and have led to several competing theoretical formulations (e.g., Herrnstein, 1970 vs. Rachlin, 1973). As yet, however, there is little agreement about the mechanisms underlying such effects.

At least two different approaches to the study of multiple schedules can be distinguished. Several investigators have provided extensive parametric manipulations of relative rates of reinforcement, which in turn have led to quantitative formulations of the relation between that variable and measures of response rate (e.g., Herrnstein, 1970; Lander & Irwin, 1968; Nevin, 1974). Other investigators have assumed that the molar effects of relative rate of reinforcement can be decomposed into several separate effects and have attempted to differentiate the controlling variables for those separate effects (e.g., Farley, 1980; Malone, 1976; Williams, 1976a, 1979). Although these two approaches should be complementary, at present the relation between them is unclear. For example, if a simple quantitative function adequately describes the relation between relative rate of reinforcement and relative rate of responding, it is difficult to see how the molar measure of relative rate of responding can be considered an aggregate of several different effects that are functionally independent. This difficulty is most evident with the phenomenon of matching in short-component multiple schedules (Shimp & Wheatley, 1971), where the 1:1 relation between relative response rate and relative reinforcement rate seems to leave little doubt that a single mechanism underlies the interactions that have been observed.

The apparent discrepancy between the two approaches to multiple schedules can be reconciled in either of two ways. First, it may be that the adequacy of existing quantitative formu-

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lations has been overstated, so that there is sufficient error in the quantitative description to allow several different mechanisms to operate simultaneously. Similarly, it is by no means clear that matching is a general phenomenon in multiple schedules, nor even that it is the limit of the relation between relative rate of reinforcement and relative rate of responding (cf. Nevin, 1974). Resolution of these issues depends upon some meaningful criterion of what constitutes an adequate quantitative description, and existing data do not permit the issue to be settled one way or the other.

An alternative resolution is to acknowledge the existence of several different sources of interactions in multiple schedules, but to assume that only one type of interaction occurs universally, which can be isolated from the other effects by appropriate training procedures. For example, some forms of behavioral contrast are known to be transitory (e.g., Bloomfield, 1966; Terrace, 1966), and thus become unimportant in steady-state comparisons where subjects are given extensive training. Still other forms of contrast can be traced to ideosyncratic procedural features such as the choice of stimuli, the number of stimuli, and the type of prior training (cf. Malone, 1976), all of which may produce reliable contrast under some conditions, but none of which need be operating in steady-state procedures designed for quantitative description of the effects of relative rate of reinforcement. Accordingly, previous quantitative descriptions may be limited in their application, but it is just their restricted domain of application that is of greatest interest in understanding the mechanisms underlying the general effects of relative rate of reinforcement, and in relating such effects with multiple schedules to those found in other situations (e.g., concurrent schedules).

Even if steady-state interactions are under unitary control of a single variable, the best characterization of that variable is by no means certain. Contrary to early formulations that treated relative rate of reinforcement as a molar entity (e.g., Herrnstein, 1970; Lander & Irwin, 1968; Nevin, 1974), there is now reason to believe that the full effects of the context of reinforcement cannot be captured at that level of analysis. Instead, a major role is played by the transitions between components, so that a major issue is how the local effects of schedule transitions are related to the molar effects of relative rate of reinforcement (e.g., Farley, 1980).

Emphasis on local transitions in the density of reinforcement has of course played an important role in previous theories of contrast. For example, frustration theory (Amsel, 1962; Terrace, 1966) assumes contrast to result from the energizing effects of a decrease in reward from its previous level, and such effects are assumed to decline with the time since schedule transition. Similarly, some versions of additivity theory (Rachlin, 1973; Spealman, 1976) assume the mechanism of contrast is elicited pecking to the discriminative stimulus, which occurs whenever the *onset* of the stimulus is associated with an increase in rate of reinforcement. Thus, the eliciting effects of the stimulus also decline with time since presentation of the preceding schedule. But both of these accounts are restricted to the effects of the preceding schedule, and are silent with respect to a second type of transition: that to the following schedule. Support for the importance of this second type of transition comes from a variety of studies that have demonstrated that response rate is inversely related to the value of the reinforcement schedule that follows the opportunity to respond (Buck, Rothstein, & Williams, 1975; Farley, 1980; Pliskoff, 1961, 1963; Williams, 1976a, 1976b, 1979; Wilton & Gay, 1969). Moreover, the effect of the following schedule appears to be more general than that of the preceding schedule, as it occurs in steady-state procedures where reliable effects of the preceding schedule do not occur (Williams, 1979).

Given that the preceding-schedule effect and the following-schedule effect appear to be functionally independent (Farley, 1980; Williams, 1979), and that both types of schedule transition have been shown to play an important role, the issue is whether there are any effects of relative rate of reinforcement independent of the separate transitional effects. If no such independent effect occurs, the implication is that the molar effects of relative rate of reinforcement can be reduced to some more elementary mechanism(s), so the major issue becomes how the phenomena ascribed to the molar effects of relative rate of reinforcement (e.g., the power-law relation between relative rate of responding and relative rate of reinforcement; matching with short-component schedules) are related to the mechanisms underlying the transitional effects.

There is good reason to doubt that the molar effects of relative rate of reinforcement can be reduced in any significant way to the effect of the transition from the preceding schedule. This is true because there have been numerous demonstrations of persistent contrast even after the effects of the preceding schedule have disappeared (e.g., Malone, 1976; Nevin & Shettleworth, 1966; Williams, in press). But it is unclear whether there are effects of relative rate of reinforcement independent of the following-schedule effect. Previous work (Williams, 1979) suggests they are not independent, as the following-schedule effect has been found to persist in steady-state situations, and to play a major role in determining the effects of component duration. However, the results of Williams (1979) do not resolve the issue because that study investigated the following-schedule effect without changes in the overall relative rate of reinforcement. The independent variable in that study was the reinforcement rate following some target component, but the overall relative rate of reinforcement with respect to the target component was held constant. Thus, it is possible that variation in relative rate of reinforcement will produce changes in response rate independent of the following-schedule effect.

Experiment 1 can be viewed as an extension of Williams (1979). The same subjects as used in that study were continued on the same four-component multiple schedule, as shown in Figure 1. Of major interest are the rates of responding in the circle and lines components, which are associated with identical VI 3-min schedules. Both are preceded half the time by VI 1-min and by EXT, but they differ with respect to the schedule in the following component: the circle is always followed by EXT, the lines are always followed by VI 1-min. The following-schedule effect is demonstrated by a higher rate during the circle than during the lines.

Using the sequence shown in Figure 1, the present study manipulated the reinforcement schedule (and sometimes the stimulus condition) that occurred following the lines. Most frequently, this was to change the VI 1-min schedule to EXT, so that both the circle and the lines were then followed by EXT. At issue is whether this change in the relative rate of reinforcement would increase the rate of responding during both the circle and the lines, or whether it increases only the rate during the lines. If there is an effect of relative rate of reinforcement independent of the following-schedule effect, contrast should occur in both unchanged components. But if the following-schedule effect accounts for all of steady-state contrast, the increase in response rate should be confined to the component preceding the locus of reinforcement variation.

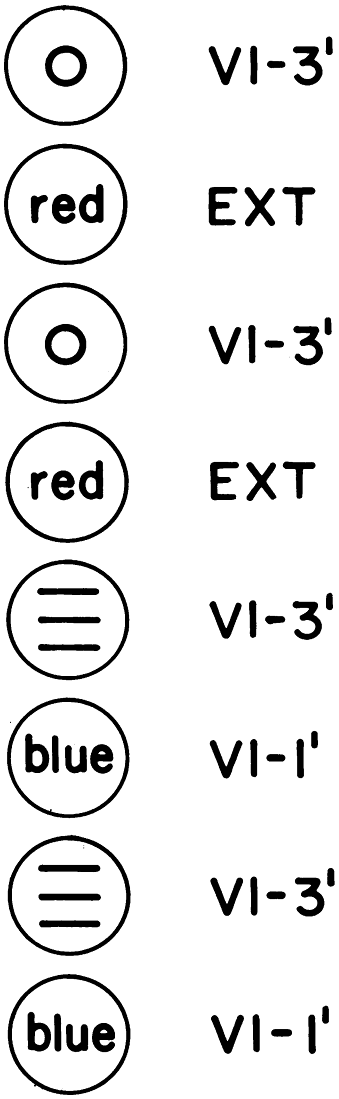

Fig. 1. Sequence of components for the multiple schedule used in Experiment 1. The sequence should be read from top to bottom. The sequence recycled continuously, so that the last blue component led immediately to the first circle component.

EXPERIMENT 1

METHOD

Subjects

Four White Carneaux pigeons were maintained at 80% of their free-feeding body weights by additional feeding after the end of the daily experimental sessions. All had extensive histories, including several previous studies of behavioral contrast (Williams, 1976a, 1979, in press).

Apparatus

A standard one-key operant chamber was enclosed within a larger wooden box. The subject area was 30.5 cm in all dimensions and was constructed of clear Plexiglas. Mounted on the front wall, which was painted gray, was a standard pigeon key 2.5 cm in diameter, requiring a minimum force of .1 N for operation. The stimuli—three horizontal white lines, a white circle, or diffuse red or blue colors—were projected on the key from behind by a 28-V IEE in-line projector. Directly below the response key was the window for the food hopper, which was illuminated by white light when food was available. The reinforcer was 3-sec access to Purina Pigeon Chow. The chamber was completely dark except for the illumination provided by the keylight and the occasional presentations of the hopper light.

Procedure

Figure 1 shows the four-component multiple schedule that was presented throughout training. Two components (the lines and the circle) were associated with identical but independent VI 3-min schedules, which remained unchanged throughout training. Reinforcers that were scheduled but not delivered were saved until the next presentation of that component. The sequence of components was such that the lines and circle were preceded equally often by a VI 1-min and by an EXT component, but followed exclusively by one or the other. The only change in any of the schedules shown in Figure 1 occurred in the component following the lines (the blue component of Figure 1), as that schedule was varied among VI 1-min, signaled VI 1-min, and EXT.

Table 1 shows the sequence of conditions received by all subjects. Except for the change in component duration, which was always the same for all four components, all of the experimental manipulations involved either the schedule, or the stimulus, associated with the component following the lines. If VI 1-min was in effect, the keylight was always blue, as shown in Figure 1. If EXT was in effect, the keylight was sometimes blue, and sometimes red. If the keylight was red, this meant that both the circle and lines were followed (and preceded) by EXT associated with red. If signaled VI 1-min was in effect, the keylight was red until the reinforcer was scheduled, and then changed to blue until the next peck produced the reinforcer. Throughout all conditions, sessions terminated after 72 min. The number of sessions for each condition was determined prior to the beginning of the condition on the basis of prior experience with the number of sessions required for behavior to stabilize.

RESULTS

15-sec Components

Figure 2 shows the results for individual subjects for the manipulation involving 15-sec components (Conditions 1 to 3 of Table 1). The first and third segments show the behavior when the blue component was associated with VI 1-min, and the middle segment shows the behavior when the schedule during blue was changed to EXT.

Since blue always followed the lines, the expectation was that the rate during the lines (unfilled circles) should increase when blue was changed to EXT (middle segment) and then decrease when blue was returned to VI 1-min.

Table 1

Sequence of Conditions in Experiment 1

Condition	*Schedule post lines*	*Stimulus post lines*	*Component duration*	*Number of sessions*
1.	VI 1-min	Blue (B)	15 sec	8
2.	EXT	B	15 sec	32
3.	VI 1-min	B	15 sec	24
4.	VI 1-min	B	60 sec	16
5.	EXT	B	60 sec	20
6.	VI 1-min	B	60 sec	16
7.	VI 1-min	B	10 sec	16
8.	EXT	B	10 sec	16
9.	EXT	Red (R)	10 sec	12
10.	VI 1-min	B	10 sec	16
11.	sig. VI 1-min	R→B	10 sec	12
12.	EXT	R	10 sec	12
13.	sig. VI 1-min	R→B	10 sec	12

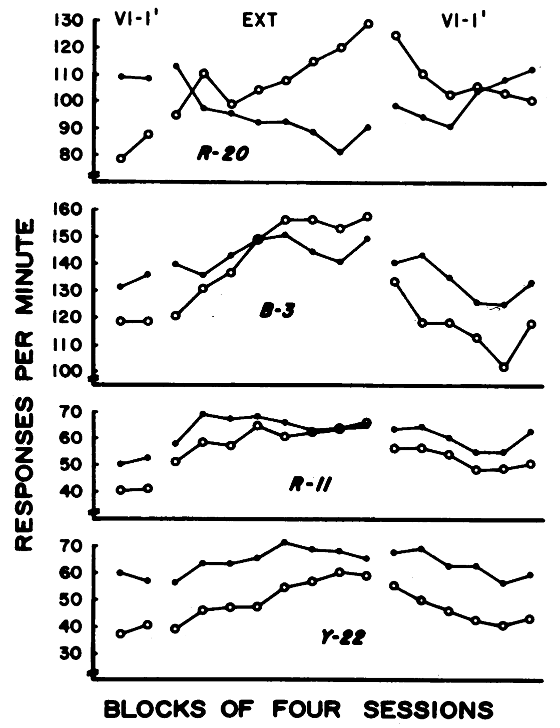

Fig. 2. Results of Conditions 1 to 3 from Table 1. The filled circles correspond to the circle components (see Fig. 1) and the unfilled circles correspond to the lines components. Component duration was always 15 seconds.

Such a pattern occurred for all four subjects. Of greater interest was whether a similar effect would occur during the circle component (unfilled circles). Rate during the circle did increase for three subjects, but the effect generally was not large. However, the remaining subject (R-20) did not show a rate increase during the circle, but instead showed a rate decrease, and this effect reversed when the VI 1-min schedule was reinstated.

60-sec Components

Figure 3 shows the results for individual subjects when 60-sec components were used (Conditions 4 to 6 of Table 1) with the order of conditions the same as those shown in Figure 2. Once again all subjects increased their response rates during the lines when the schedule during blue was changed to EXT, and this effect reversed with the return to VI 1-min. Unlike Figure 2, however, evidence for a corresponding effect on the rate during the circle component was much weaker. Only one subject (B-3) showed any rate increase during the circle, and that effect is of questionable validity because it is smaller than the session-to-session variability, particularly in the second baseline. Subject R-11 showed no change in rate to the circle, R-20 again showed a substantial decrease, and Y-22 exhibited a smaller decrease.

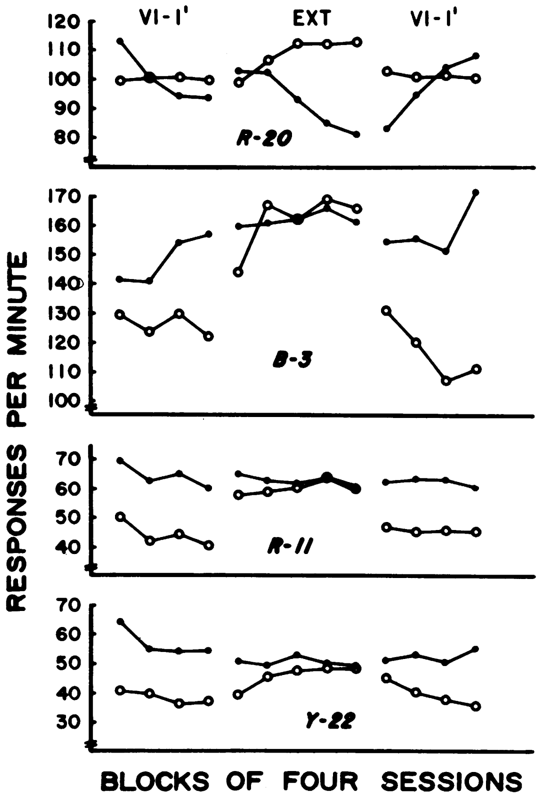

Fig. 3. Results of Conditions 4 to 6 of Table 1, where component duration was always 60 seconds. Filled circles represent behavior during the circle component, unfilled circles represent behavior during the lines component.

10-sec Components

Comparison of Figures 2 and 3 suggests that variation in reinforcement during blue affected behavior in the component (the circle) not immediately antecedent to blue, but only for some subjects and only if component duration was relatively short. Consequently, component duration was decreased to 10 sec to determine if the effect could be recovered. The second segment of Figure 4 shows the effects of changing the schedule during blue to EXT, and the subjects in the bottom three panels again showed a small rate increase during the circle component. And again the remaining

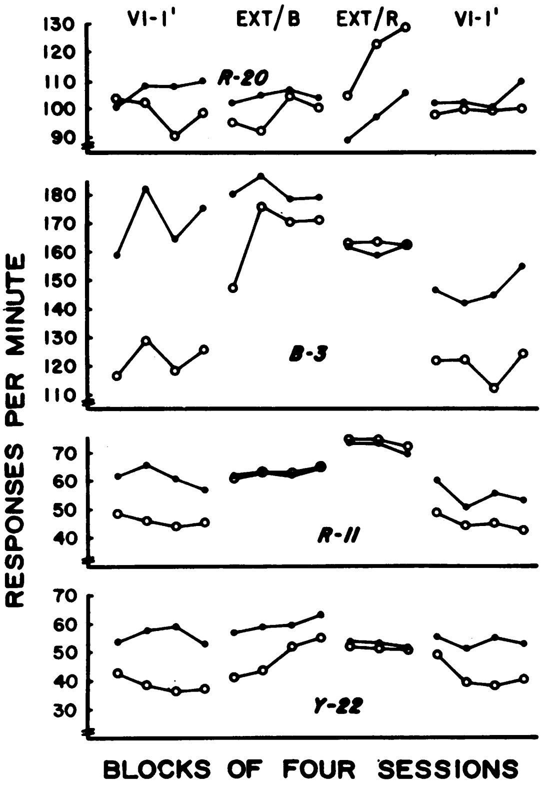

Fig. 4. Results of Conditions 7 to 10 from Table 1, where component duration was always 10 seconds. Filled circles represent behavior during the circle component, unfilled circles represent behavior during the lines component.

subject (R-20) showed a rate decrease during the circle, although this effect was smaller than that seen in Figure 2.

In all of the above comparisons, changing the schedule during blue to EXT exerted its effects despite the fact that responding during blue never completely extinguished. Shown in Table 2 are the response rates during the last four sessions of each condition in which EXT was in effect. The first three rows show that substantial responding remained for all subjects, even in Condition 2 after 32 sessions of training. Moreover, the response rates during blue showed little trend toward a further decline by the end of Conditions 5 and 8, and for one subject (R-20 in Condition 8), the rate of responding approached that when the schedule during blue was VI 1-min. The failure of extinction was probably due to the fact that the subjects had been trained on variations of the present procedure for over two years, and during all of this time the schedule associated with blue was always VI 1-min.

Because complete extinction to blue had not occurred, blue was replaced by red, with the results shown in the third segment of Figure 4. For the three subjects in the bottom three panels, the effect of this manipulation was to cause the rates during the lines and the circle to converge, since both unchanged VI 3-min components were both preceded and followed by identical conditions. Such convergence indicates that stimulus bias was not an important factor in causing the differences between the circle and lines components that were seen previously. For Subject R-20, on the other hand, rate during the lines was substantially higher than during the circle, suggesting that stimulus bias was involved for that subject. Changing the stimulus to red also had effects on the absolute rates themselves, but such effects were variable across subjects (e.g., B-3 vs. R-11), making their interpretation difficult.

Because of the effects of changing the stimulus associated with EXT, seen in the third panel of Figure 4, the conditions for the baseline of the last comparison were changed from VI 1-min to signaled VI 1-min. This meant that a minimal change in stimulus occurred when the signaled VI 1-min was changed to EXT, as both the circle and lines were followed by red on most occasions even during the baseline, except for the brief presentations of blue when the VI 1 reinforcer had been scheduled. Thus, the change to EXT following the lines affected the stimulus presentation only by removing the occasional presentations of blue. Figure 5 shows the results of this com-

Table 2

Rates of responding (response/min) to the blue stimulus for the last four sessions of training in each condition in which blue was associated with EXT. The number in parentheses corresponds to the condition designation shown in Table 1. The bottom two rows show the corresponding rates when red was substituted for blue.

	SUBJECT			
CONDITION	*R-20*	*B-3*	*R-11*	*Y-22*
15 sec (2)	46.5	7.0	28.9	17.7
60 sec (5)	77.0	22.0	25.5	25.5
10 sec (8)	103.6	11.9	32.3	36.7
10 sec (9)	11.6	5.2	1.5	1.7
10 sec (12)	8.0	4.8	2.2	1.4

parison (Conditions 10 to 13 of Table 1). The first segment represents the behavior prior to the change to the signaled VI, and the second segment shows the effect of the change to the signaled VI. There were some effects of this change for some subjects (Y-22, R-11), but in general such effects were minimal in keeping with previous results (Figure 10 of Williams, 1979). The subsequent change to EXT, shown in the third segment of Figure 5, had a strong effect, however, as the rate during the lines increased for all subjects. But as with the previous manipulations, the effect on the rate during the circle was smaller and inconsistent across subjects.

The results from all comparisons are summarized in Table 3, which presents the increases in rate of responding that occurred in each condition in which the schedule following the lines was changed to EXT. Since an ABA design was used for each comparison, the rates during the last four sessions of the baseline on each side of each contrast manipulation were averaged, and a difference score was taken between that baseline measure and the response rates during the last four sessions of the contrast manipulation. The left side of Table 3 shows the rate increase to the lines, which is the component that was followed by the variable schedule. As is evident, a substantial contrast effect occurred in every case, with the exception of Condition 8 for Subject R-20. It should be noted that the absence of contrast in that one case was correlated with a very high rate of responding to the blue stimulus, despite EXT as the schedule (see the corresponding condition in Table 2).

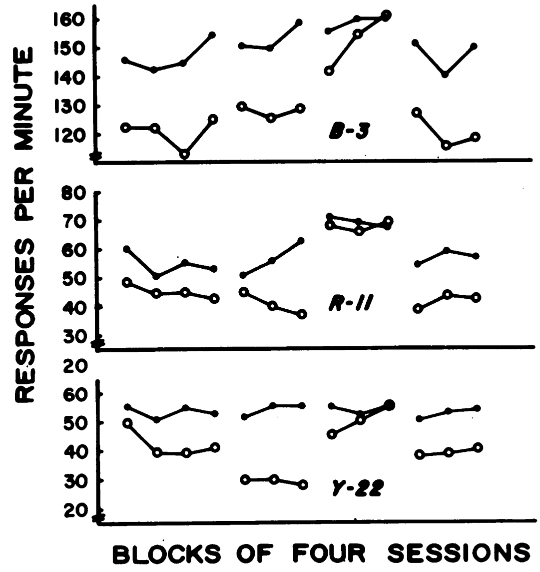

Fig. 5. Results of Conditions 10 to 13 from Table 1, where component duration was always 10 seconds, and where the baseline schedule following the lines was a signaled VI 1-min. Filled circles represent behavior during the circle component, unfilled circles represent behavior during the lines.

The results on the right side of Table 3 show the rate changes in the circle component, where presumably contrast can not be ascribed to the following-schedule effect. As in Figures 2 to 5, there was considerable variability among subjects, with one subject showing a rate decrease (R-20), two generally showing a rate increase (B-3, R-11), and one showing little effect (Y-22). It also should be noted from Table 3 that none of the subjects exhibited a significant rate increase to the circle when 60-sec components were used, suggesting that the effect depends upon the use of short components.

Table 3 shows clearly that the following-schedule effect is the most important determinant of contrast effects in the present situation, but the variability seen on the right side of Table 3 must be accounted for before the other determinants of contrast can be understood. One reason for the variability was individual differences in sensitivity to the schedule in the preceding component. This is seen from Table 4, which shows the response rates during the baseline conditions as a function of whether the preceding component was EXT or VI 1-min. The data from the 60-sec component conditions are not presented because the effect of the preceding component was recorded only for the first 15-sec of the component, rather than for the entire component. Considerable variability in the effect of the preceding schedule is evident from Table 4, as one subject (R-20) had a higher rate following the VI 1, two others (B-3, R-1) had higher rates following EXT, and the fourth (Y-22) had generally smaller effects that were inconsistent. Moreover, the pattern of differences seen in Table 4 appear similar to the differences shown in

Table 3

Summary of results of Experiment 1. Shown is the difference in response rates (responses/min) between the rate during the last four sessions of each contrast manipulation and the rate during the last four sessions of the two baseline periods on either side of the contrast manipulation. The numbers in parentheses refer to the condition designations shown in Table 1. Shown on the left side are the changes in rate during the lines component, which always preceded the schedules that was varied. Shown on the right side are the changes in rate during the circle component, which never preceded the variable schedule. Note that the two conditions with an asterisk involve the same baseline periods in the calculation of their difference scores.

	INCREASE DURING LINES (Following-Schedule Effect)				*INCREASE DURING CIRCLE*			
CONDITION	*R-20*	*B-3*	*R-11*	*Y-22*	*R-20*	*B-3*	*R-11*	*Y-22*
15 sec (2)	35.1	37.3	19.4	15.0	—18.9	13.9	6.1	7.3
60 sec (5)	12.3	48.5	17.0	11.3	—19.8	—2.9	.1	—6.1
10 sec (8)*	.9	48.4	20.2	15.4	—5.9	15.5	9.4	8.6
10 sec (9)*	31.4	39.1	31.0	11.7	—3.7	—2.5	16.5	—2.2
10 sec (12)	29.1	35.8	25.1	21.7	5.1	6.5	5.3	.5
Mean	21.8	41.1	22.5	15.0	—8.6	6.1	7.5	1.6

Table 3 with respect to whether a contrast effect occurred during the circle component. That is, only those subjects with higher rates following EXT exhibited contrast. To test for the relation between these two measures, a Pearson product-moment correlation was run, relating the absolute size of the contrast effects in the circle component, seen on the right side of Table 3, and the difference between the effects of EXT vs. VI 1-min as the preceding schedule, seen in Table 4 (e.g., for Subject R-20 in the 15-sec condition, the difference in rates as a function of the preceding schedule was —11.5). Each of the three separate entries for each subject was treated as an independent event, giving a total of 12 pairs of scores. The correlation between the two measures was .736, which with 10 df. is significant at the .01 level of confidence. Clearly, therefore, there was a strong relation between the effect of the preceding schedule during the baseline and whether contrast occurred during the circle component.

Discussion

The central question asked by Experiment 1 was whether there is any effect of relative rate of reinforcement on steady-state interactions in multiple schedules that is independent of the following-schedule effect. The answer to this

Table 4

Effects of the preceding schedule in Experiment 1. The data are averaged over the circle and lines component as a function of whether the preceding schedule was VI 1-min or EXT. Each entry represents the average of all conditions that were run with those schedules, and the conditions (designated in Table 1) included in an average are shown in parentheses. Response rates were calculated for the last four sessions of each condition and are in terms of response/min. The numbers in parentheses next to each pair of response rates are the standard deviations of the differences as a function of the preceding schedule for daily sessions (N=8).

		SUBJECT			
Condition	*Schedule*	*R-20*	*B-3*	*R-11*	*Y-22*
15 sec (1,3)	EXT	96.4	133.1	58.2	49.9
		(2.6)	(7.1)	(2.8)	(3.6)
	VI 1	107.9	122.2	47.2	52.6
10 sec (7,10)	EXT	102.3	149.6	55.2	42.5
		(2.1)	(8.1)	(2.4)	(3.6)
	VI 1	109.4	143.2	44.9	50.6
10 sec (11,13)	EXT	104.0	141.5	55.3	46.2
		(3.3)	(4.6)	(3.6)	(4.8)
	VI 1	104.1	137.9	43.2	44.1

question is that no such effect occurred generally, but that there were small effects that did occur for some subjects under some conditions. Given that the following-schedule effect occurred in all conditions, for all subjects, the implication is that contrast effects in multiple schedule are due primarily to the following-schedule effect, and that the general effect of relative rate of reinforcement must be understood in those terms.

But it is also clear from the present results that some degree of contrast did occur that was separate from the following-schedule effect. In particular, two subjects did exhibit a contrast effect during the circle component (which was not followed by the variable schedule), which, while small, was generally consistent across conditions. As shown by the relation between Tables 3 and 4, one cause of these effects was the preceding schedule of reinforcement. That is, those subjects that emitted higher rates following an EXT component during the baseline were also the subjects which showed a contrast effect in the circle component, which was independent of the following schedule effect. A moment's reflection reveals the relation between these two observations. The effect of changing the schedule during blue from VI 1-min to EXT was not just to affect the reinforcement schedule following the lines component, but also to affect the schedule that preceded both the lines and the circle. In the baseline condition both were preceded half the time by VI 1-min and half the time by EXT, but during the contrast manipulation, both were preceded on all occasions by EXT. Thus, if a preceding period of EXT produced a higher rate in the baseline condition than did a preceding period of VI 1-min, this meant that a rate increase should occur during the contrast manipulation because EXT now preceded the constant components on all occasions. Conversely, in the case of Subject R-20, where the preceding period of EXT produced a lower rate of responding than did a preceding period of VI 1-min, changing the VI 1-min to EXT in the contrast manipulation should reduce the response rate in the constant components. Thus, the interactions that were seen, which were independent of the following-schedule effect, appear to be due entirely to the additional effect of the preceding schedule.

But the issue remains as to why some subjects show an effect of the preceding schedule and some do not. The issue is emphasized by the frequent demonstration of effects of the preceding schedule reported in other studies (Green & Rachlin, 1975; Hinson, Malone, McNally, & Rowe, 1978; Malone, 1976). There appears to be no simple answer to this question, although the effect is known to depend upon the similarity of the discriminative stimuli and the amount of prior training (Malone, 1976). But even these variables do not provide a complete account, because in the present case the subjects showing the effect had over five years of prior training in multiple schedules, and the effects occurred with stimuli that were made as discriminable as possible. Despite the persistence of such effects, their inconsistency across subjects show them not to be truly steady-state, in the sense they are the inevitable end results of a given set of schedules.

That the following-schedule effect is the fundamental basis of steady-state contrast effects is also supported by the effect of component duration, as shown in Figure 3 and Table 3. Large effects of the following schedule occurred with the 60-sec components, but there was no contrast, for any subject, that was independent of the following-schedule effect (shown by the rate during the circle component). There are two possible explanations of the effects of component duration that are seen in Table 3. The first is that the effect of the preceding schedule persists for only a short period of time, so that its contribution to the average rate is not sufficient with the longer components to produce a significant contrast effect. An alternative interpretation is that the following-schedule effect extends backward beyond the just-preceding component. The latter possibility should be considered because the blue component was separated from the circle component by only 20 to 60 seconds when 10 to 15-sec components were employed, so it is possible that variations in reinforcement during blue could exert effects on the circle component even with the two components not temporally contiguous.

EXPERIMENT 2

The results of Experiment 1 suggest that steady-state interactions in multiple schedules are due primarily, and perhaps exclusively, to the effect of the following schedule. But the generality of those results can be questioned on the grounds that the procedure was far more complex than most multiple schedule studies, and because the subjects were atypical in experience (over five years of continuous training on several varieties of multiple schedules). Accordingly, Experiment 2 tested for the generality of the effects seen in Experiment 1 in a somewhat simplified procedure. A three-component multiple schedule was used with a fixed sequence of ABC, ABC, etc. Components A and C were always associated with the same reinforcement schedule while Component B was sometimes associated with a higher-density schedule and sometimes with a lower-density schedule. The expectation from Experiment 1 is that the effect of manipulating reinforcement rate in Component B should be primarily on the response rate in Component A. But also of interest is whether there is any effect of reinforcement rate during Component B on response rate during Component C, and if so, which conditions are most likely to produce such an effect. Of particular interest is the effect of prior training.

A second aspect of Experiment 2 concerns the relation between the following-schedule effect and the phenomenon of matching in multiple schedules (cf. Shimp & Wheatley, 1971). If, as suggested by Experiment 1, the effect of relative rate of reinforcement is due primarily to the effect of the following schedule, the implication is that matching also should be determined by the following-schedule effect. By using a three-component schedule, it should be possible to determine how, if at all, the matching relation is upheld. That is, will matching hold for the relation among all three components, or will it hold only for the relation between the variable component and that component that always precedes the variable component?

METHOD

Subjects

Four White Carneaux pigeons were maintained at 80% of their free-feeding weights by additional feeding, when necessary, at the end of the experimental sessions. All subjects had received prior training on a conditional discrimination in an autoshaping procedure, involving the stimuli: red, green, white circle, and a white horizontal line.

Apparatus

A standard conditioning chamber was constructed from a plastic picnic chest. The bird's chamber was approximately 30.5 cm in all dimensions. On the front panel were mounted two pigeons keys, 1.7 cm in diameter, which required a minimum force of .10 N for operation. Only the left key was used, so the right key remained dark throughout the study. The stimuli were projected onto the key from a standard 28-V 12-stimulus IEE in-line projector. Ten cm below the keys was a 5- by 5-cm aperture through which the birds were fed when the food hopper was activated. Reinforcement consisted of 2.5-sec access to Purina Pigeon Chow. No houselight was used, so the chamber was completely dark except for the illumination provided by the keylight, and the occasional presentations of the hopper light.

Procedure

A three-component multiple schedule was used throughout training, with the fixed sequence, ABC, ABC, etc. Components A and C were always associated with identical VI 3-min schedules, whereas the schedule during Component B was either VI 1-min or VI 6-min. Component B was always associated with a diffuse green keylight. The stimuli associated with Components A and C initially were three horizontal white lines and a white backward S, both projected onto an otherwise dark key. Two subjects had the lines associated with Component A and the backward S associated with Component C; the remaining two subjects had the stimulus assignments reversed. Later in training, (beginning with Condition 3 in Table 3), the backward S stimulus was changed to a white circle on a yellow background for all subjects.

Table 3 shows the sequence of conditions received by all subjects. For Conditions 1 and 2, component duration was always 30 sec, and the manipulation was to change the rate of reinforcement during Component B from VI 1-min to VI 6-min. Separating Conditions 2 and 3 were 2 to 3 months of additional training that will not be reported which was designed to reduce the considerable variability found in Conditions 1 and 2. As a result of these manipulations, the backward S stimulus was replaced by a white circle on a yellow back-

Table 5

Sequence of Conditions in Experiment 2

Condition	*Schedule during Component B*	*Component duration*	*Additional manipulations*	*Number of sessions*
1.	VI 1-min	30 sec	–	40
2.	VI 6-min	30 sec	–	30
3.	VI 1-min	10 sec	–	25
4.	VI 1-min	10 sec	reversal of stimuli in components A & C	25
5.	VI 6-min	10 sec	–	25
6.	VI 6-min	10 sec	30-sec TO after component C	20
7.	VI 1-min	10 sec	30-sec TO after component C	20

ground. Also during this time, one subject, B-23, died and was replaced by R-75.

Beginning with Condition 3, component duration was 10 sec for the remainder of training. The experimental manipulation was again the rate of reinforcement during Component B. Condition 4 differed from Condition 3 only in that the stimuli associated with Components A and C were reversed.

Beginning with Condition 6, the procedure was changed to where each completion of an ABC sequence was followed by a 30-sec TO in which the chamber was completely darkened. Since component duration was 10 sec, this meant that each sequence required a total of 30 sec, so that the result was that TO now occupied half of the entire experimental session. Condition 7 was similar to Condition 6 except that the schedule during Component B was changed to VI 1-min.

Throughout training, experimental sessions terminated after 75 minutes. This meant that a total of 25 minutes per session was given for each component during Conditions 1 to 5, but that only 12.5 minutes per session were given during Conditions 6 and 7.

RESULTS

Figure 6 shows the mean response rates in each component over sessions. Of major interest is the relation between Components A and C, each associated with a VI 3-min schedule. Early in training with a VI 1 schedule in Component B, response rates were higher in Component A, but this effect then reversed with continued training. When the schedule during Component B was then changed to VI 6, the effect reversed again. Thus, by the end of both conditions, response rates in Components A and C were predicted by the following-schedule effect. That is, the reinforcement rate in Component B more strongly affected response rate in the component that preceded it, than it affected response rate in the component that followed.

The results shown in Figure 6 are presented in terms of means across subjects because there was considerable variability among subjects, much of which was associated with stimulus preferences. This can be seen from Table 6, which shows the results for individual subjects for the last ten sessions of each condition. It should be noted that Subjects B-23 and R-56 received one set of stimulus conditions for Components A and C and that Subjects R-38 and R-63 received the opposite assignment of stimuli to conditions. For the former pair of subjects the effects can be described entirely in terms of the following-schedule effect. That is, rate during Component A was increased during Condition 2, but rate in Component C was unaffected. For the latter pair of subjects, however, the following-schedule effect does not describe the results well, as both R-38 and R-63 exhibited a rate increase in both components.

A second source of variability was the effect of the preceding component, i.e., the effect of reinforcement rate in Component B on re-

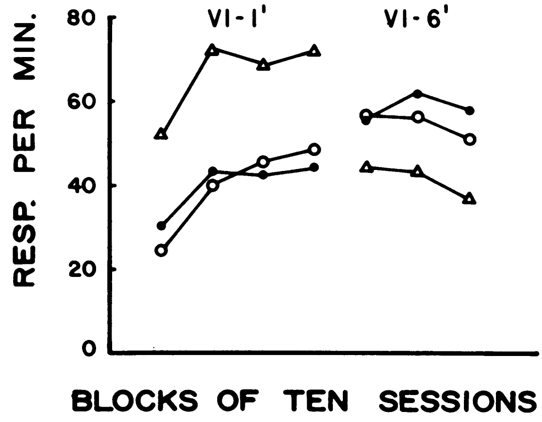

Fig. 6. Results of Conditions 1 and 2 of Experiment 2 (see Table 3), where component duration was 30 seconds. The results are averages of the response rates of all subjects. The filled circles represent behavior during the A component, unfilled circles represent behavior during the C component, and the triangles represent behavior during the B component, where rate of reinforcement was varied.

Table 6

Individual subject data for Sessions 31 to 40 of Condition 1 and Sessions 21 to 30 of Condition 2 (See Table 5). Data are in terms of responses per minute.

	Condition 1 *(VI 1)*		*Condition 2* *(VI 6)*	
Subject	*Component* *A*	*Component* *C*	*Component* *A*	*Component* *C*
B-23	64.1	70.9	79.6	66.7
R-56	47.8	55.4	68.8	57.3
R-38	41.5	37.1	54.8	50.1
R-63	26.7	32.0	34.2	36.5

sponse rate in Component C. Such an effect occurred for all subjects early in training but became more variable as training was continued. Examples of such effects can be seen in Figure 7, which shows the local response rates within Components A and C at various points in training. Two individual subjects are shown, one of which was the worst with respect to the following-schedule effect (R-38, see Table 6), and one which was the best (B-23). Also shown is the mean local rate across subjects. The two subjects not shown were similar to the mean pattern during Sessions 1 to 10 of Condition 1, but were not thereafter, as their local rates became less sensitive to the transitions between components.

Several observations related to Figure 7 are noteworthy. First, during the first ten sessions of Condition 1, all subjects had a lower rate in Component C than in Component A, and this was due to the strong local negative contrast effect at the beginning of Component C. With continued training on Condition 1, response rates in both components increased, and the relation between them reversed. Thus, the average rate in Component C became higher than in Component A, although Subject R-38 was an exception. This reversal in the average rate occurred in some cases despite the continuation of the negative local contrast effect at the beginning of Component C (Subject B-23), thus demonstrating that local rate patterns and effects on average rate need have no necessary relation. With the change to Condition 2, the average rates in Components A and C again reversed, and again the reversal occurred in some cases despite the occurrence of local positive contrast at the beginning of Component C (Subject R-38).

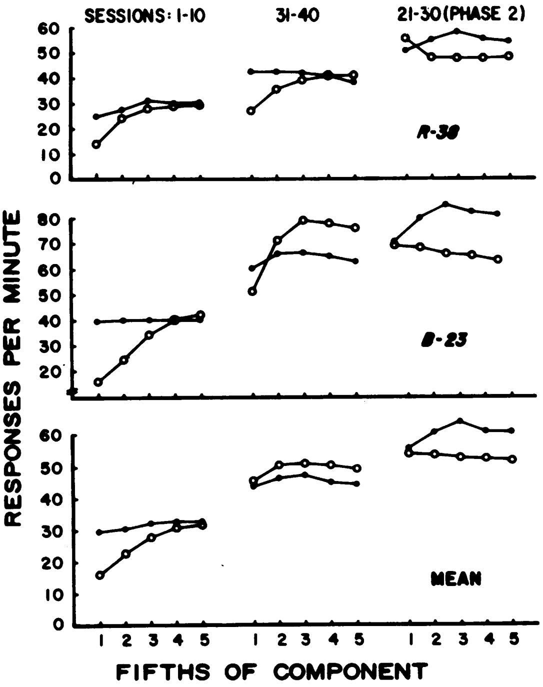

Fig. 7. Local rates of responding obtained in Conditions 1 and 2 of Experiment 2. The first segment corresponds to Sessions 1 to 10 of Condition 1, the second segment to Sessions 31 to 40 of Condition 1, and the third segment corresponds to Sessions 21 to 30 of Condition 2. The filled circles represent behavior in the A component of the ABC sequence, the unfilled circles represent the behavior in the C component. The data in the bottom panel are the means of all four subjects.

The major conclusions from Conditions 1 and 2 can be summarized as follows. Early in training the local contrast effects at the beginning of Component C played a major role in determining the average response rate, but with continued training its role diminished, and an effect on average rate emerged that was in the opposite direction of the local contrast effects. Nevertheless, local contrast persisted for some subjects, serving to diminish the difference between the mean rates in Components A and C below the level that might have occurred otherwise.

In order to test the validity of the above descriptions, two separate statistical analyses were conducted, using a 3-way analysis of variance with the three factors being stimulus assignment (Subjects B-23 & R-56 vs. R-38 & R-63), component (A vs. C), and segment within the component (fifths of the component, as shown in Figure 7). The first test compared the difference between the response rates during Sessions 31 to 40 of Condition 1 with the corresponding rates during Sessions 1 to 10. Difference scores were used because they provide the most direct method of assessing how response rate changed with continued training. The only significant effect was the component variable, $F_{(1,2)} = 19.97$, $p < .05$, thus demonstrating that the response rates increased more in Component C than in Component A (i.e., the crossover effect for Condition 1 in Figure 6 was statistically reliable). The second test involved difference scores for Sessions 21 to 30 of Condition 2 vs. Sessions 31 to 40 of Condition 1, again with the same three factors. Here the component variable was also significant, $F_{(1,2)} = 256.8$, $p < .01$, thus demonstrating that there was a greater change in rate during Condition 2 for Component A. Surprisingly, the interaction between the stimulus variable and the component variable was also significant, $F_{(1,2)} = 180.3$, $p < .01$, whereas neither the VI segment, or any of the other interactions were significant (all with F's $<$ 1.0). Thus, the major conclusion from both analyses is that change in reinforcement rate in Component B exerted a stronger effect on Component A than on Component C, with the effect of the following schedule being essentially similar to that found in Experiment 1.

Because of the significant interaction between the stimulus variable and the component variable in the above analysis, which has no obvious interpretation, several stimulus changes were made in order to reduce the role of the stimulus variable. The results of those changes will not be presented, but as a result the remaining conditions of the experiment were run with one of the stimuli (the backward S) being changed to a white circle on a yellow background. Also during this time, one subject (B-23) died and was replaced by a new subject (R-75).

All of the remaining conditions were run with 10-sec components, in order to maximize the contrast effects, and to provide a basis for relating the following-schedule effect to previous studies showing matching in short-component schedules. Figure 8 shows the mean results for all of the remaining conditions.

Condition 3, with a VI 1-min schedule in Component B, produced a pattern similar to Condition 1, as response rate was lower in Component A than in Component C. Condition 4 assessed whether the stimulus variable was important, as the stimuli associated with Components A and C were interchanged (note that these assignments were counterbalanced across subjects throughout the study). The effect of this change was initially to cause behavior in the two components to converge, demonstrating that the difference between Components A and C depended upon learning which stimulus was associated with which location in the sequence of components. The rates in the two components then diverged with continued training, demonstrating that the following-schedule effect did not depend upon some idiosyncratic assignment of stimuli to components.

The major manipulation of interest was the change in reinforcement rate during Component B from VI 1-min to VI 6-min during Condition 5, shown in the third segment of Figure 8. Once again the mean results were in accordance with the following-schedule effect, as the relation between response rates in Components A and C was again reversed. Of greater interest, however, was the change in absolute rates, particularly for Component C. As shown in Figure 8, the mean rate of responding during Component C did not increase, but slightly decreased. Thus, in terms of the average rate, there was no effect of changing relative rate of reinforcement that was independent of the following-schedule effect.

But the effects seen with the mean rates did not occur for all subjects. Table 7 shows the results for individual subjects during the last five sessions of Conditions 4 and 5 (along with the rates during the last five sessions of all of the remaining conditions). Two subjects (R-75, R-38) did respond in accordance with the mean rates shown in Figure 8, as there was a rate increase during Condition 5 in Component A but no change in rate during Component C. However, the rates in both components increased for Subject R-56, whereas for Subject R-63 the rate during Component A increased but that during Component C decreased.

Because of the variability, the differences between Components A and C were tested statistically using a t test on the difference score: Component A (Condition 5 $-$ Condition 4) minus Component C (Condition 5 $-$ Condition 4). The results of the test were statistically reliable, $t_{(3)} = 3.34$, $p < .05$, indicating that the change in rate during Component A was reliably greater than the change in rate during Component C.

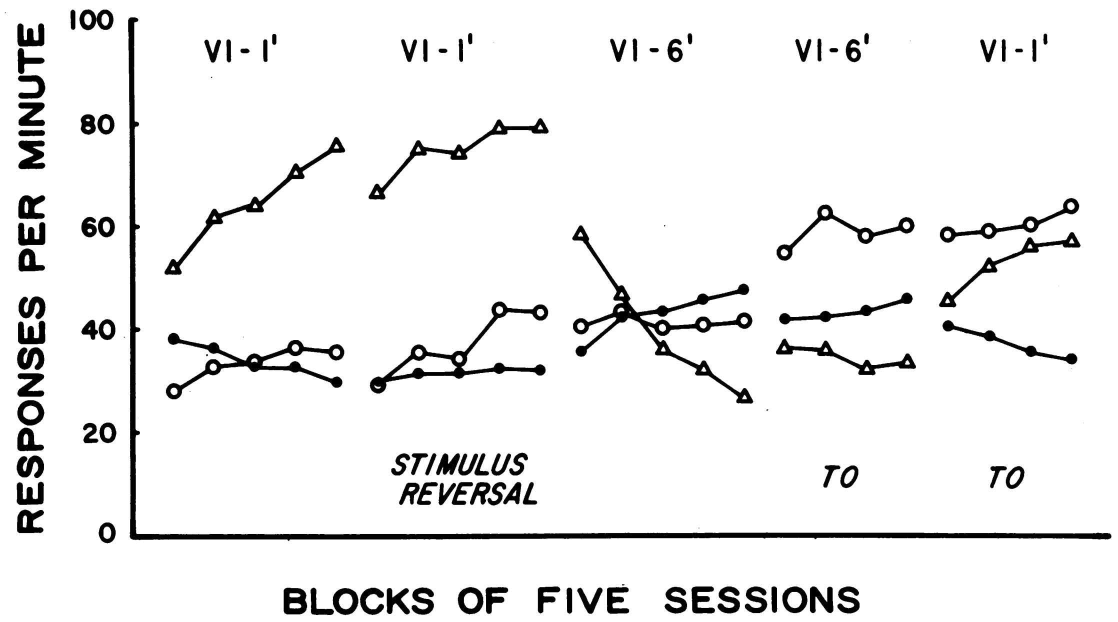

Fig. 8. Results of Conditions 3 to 7 of Experiment 2, where component duration was always 10 seconds. The results are the averages of all four subjects. The filled circles correspond to the A component of the ABC sequence, the unfilled circles correspond to the C component, and the triangles corresponding to the B component. The schedule designation at the top of each segment corresponds to Component B. The TO designation signifies that the TO followed each complete cycle of the ABC sequence.

Comparison of Conditions 4 and 5 also allows an assessment of the degree to which the relative rates of responding in the various components matched their relative rates of reinforcement. Given the asymmetric effects of reinforcement in Component B on responding in Components A and C, it is clear that matching could not occur for all three components. Thus, it is more appropriate to assess the relation between relative response rate and relative reinforcement rate for individual pairs of components. Two such pairs, the relation between Components A and B, and that between C and B, were examined. The analysis suggested by Baum (1974) was used, based on Equation 1, where R_1 and R_2 refer to response rates in the two components, and r_1 and r_2 refer to reinforcement rates.

$$\frac{R_1}{R_2} = b\left(\frac{r_1}{r_2}\right)^a \tag{1}$$

Table 7

Data for individual subjects for Conditions 4 to 7 (see Table 5). The schedule during Component B is presented in parentheses next to the designation of condition. Response rates were calculated from the last five sessions of each condition and are in terms of responses/min. For each subject separate rates are presented for Components A and C.

	SUBJECT							
	R-75		*R-56*		*R-38*		*R-63*	
CONDITION	*A*	*C*	*A*	*C*	*A*	*C*	*A*	*C*
4 (VI 1)	24.3	29.7	29.1	52.8	37.0	34.2	38.2	55.5
5 (VI 6)	45.2	30.1	57.2	71.4	45.8	35.4	43.8	32.7
6 (VI 6) TO added	35.3	47.2	38.5	77.9	55.4	59.6	56.3	55.8
7 (VI 1) TO added	21.6	62.3	24.8	73.5	54.8	58.4	37.1	60.8

The b constant reflects the bias toward one component independent of the reinforcement rates, and the a constant reflects sensitivity of responding to the reinforcement schedules themselves (matching occurs with $a = 1.0$).

Because there were only two values of relative rate of reinforcement for each subject, the results for all four subjects were pooled and a single solution was found for the aggregate, using a least square analysis to find the best fit of the logarithmic form of Equation 1. For the relation between Components A and B, the solution yielded a value of $a = .85$ and a value of $b = .92$, and the linear-regression equation accounted for 97% of the total variance. For the relation between Component C and Component B, the solution yielded a value of $a =$

.68 and a value of $b = .94$, and the linear-regression equation accounted for 87% of the variance. The A/B comparison yielded a greater slope than the C/B comparison not only for the pooled data, but also for all four individual subjects. It also should be noted that the value of $a = .85$ for the A/B comparison is comparable to that found in studies of matching in concurrent schedules, where the modal value of a has been .80 (Baum, 1979; Myers & Myers, 1977).

The last two segments of Figure 8 show the effect of adding a 30-sec TO after the completion of each ABC cycle. Because TO has many of the functional properties of extinction, the expectation was that Component C would have its response rate increased. At issue was whether a similar increase would occur for the remaining two components as well. The results were that a large increase in response rate did occur in Component C, a considerably smaller increase occurred in Component B, whereas a slight decrease in rate occurred in Component A. Once again, therefore, the average response rates were predicted by the following-schedule effect playing the major role.

But again the effects on individual subjects were not as consistent. Comparison of Conditions 5 and 6 in Table 7 shows that all subjects showed a rate increase during Component C, but two subjects showed a rate decrease during Component A (R-75, R-56) whereas the two others showed a rate increase (R-38, R-63). The results were again tested for reliability using a t test on the difference score: Component C (Condition 6 − Condition 5) minus Component A (Condition 6 − Condition 5). The results were again significant, $t_{(3)} = 4.84$, $p < .05$, showing that the addition of the TO produced a greater increase in rate during Component C.

The TO variable was continued in Condition 7, shown in the last segment of Figure 8, where the reinforcement rate in Component B was increased to VI 1-min. This change in reinforcement rate in Component B again had its effects primarily in Component A, as the mean response rate decreased in Component A but was unaffected in Component C. Table 7 shows the data for individual subjects, and once again some variability across subjects is evident. Three of the four subjects showed a substantial rate decrease during Component A, whereas the remaining subject (R-38) showed little effect in either component. The changes in rate during Component C were smaller and inconsistent across subjects. Again the difference in rates for Conditions 6 vs. 7 was assessed by a t test on the difference score: Component A (Condition 6 − Condition 7) minus Component C (Condition 6 − Condition 7), and again the difference was statistically reliable, $t_{(3)} = 3.34$, $p < .05$.

The above comparisons leave little doubt that variation in reinforcement rate in Component B had stronger effects on Component A than on Component C, thus demonstrating the reliability of the following-schedule effect in a new situation. But the issue of primary interest is whether there were schedule interactions independent of the following-schedule effect. This issue is best addressed by the summary of all of the conditions of Experiment 2, shown in Table 8. On the left side are the changes in response rate in the component preceding the locus of the variable schedule (always Component A except for Condition 6, where TO was added following Component C). All 16 entries are positive, showing that the following schedule exerted strong effects in all conditions. On the right side of Table 8 are the rate changes in the component preceded by the locus of the variable schedule (always Component C except for Condition 6). Here 10 of the 16 entries are positive, and the rate changes are much smaller. Moreover, the mean change in rate across conditions for each subject is generally very small, and does not differ significantly from zero by any conventional statistical test. Several of the individual entries are substantial, however, and one subject (R-38) exhibited a rate increase in every condition. Thus, there appears to be some amount of contrast independent of the following-schedule effect, but the variables controlling such effects are unclear and were unsystematic across conditions and subjects.

DISCUSSION

The results generally replicated those of Experiment 1, and of previous work (Williams, 1976a, 1979), showing that the most important source of contrast in multiple schedules is the effect of the following schedule of reinforcement. Given that Experiments 1 and 2 differed in several important respects, the implication is that the following-schedule effect has wide

Table 8

Summary of contrast effects in Experiment 2. Positive numbers represent contrast effects, negative entries represent induction effects. The measure was computed by taking the response rates in the condition designated and subtracting rates in the condition that preceded. Rates were taken from the last 5 sessions of each condition and are in terms of responses/min. Entries on the left side of the table are for the component that was followed by the variable schedule (always Component A except for Condition 6, where TO was added following Component C). Entries on the right side are for the component that preceded the variable schedule (always Component C except for Condition 6 where Component A is used). Note that Conditions 2, 5, and 6 involve positive contrast, whereas Condition 7 involves negative contrast. Also note that the entry for Condition 2 under Subject R-75 was actually B-23.

	Following-Schedule Effect				*Contrast other than Following-Schedule Effect*			
CONDITION	*R-75*	*R-56*	*R-38*	*R-63*	*R-75*	*R-56*	*R-38*	*R-63*
2	15.5	21.0	13.3	7.5	—4.2	1.9	13.0	4.5
5	20.9	28.1	8.8	5.6	.4	18.6	1.2	—22.8
6	17.1	6.5	24.2	23.1	—9.9	—18.7	9.6	12.5
7	13.7	13.7	.6	19.2	—15.1	4.4	1.2	—5.0
Mean	16.8	17.3	11.7	13.9	—7.2	1.6	6.3	—2.7

generality and probably is the fundamental determinant of interactions found with multiple schedules, at least in steady-state situations.

But also at issue is whether there are sources of steady-state contrast other than the following-schedule effect, and if so, how they are to be interpreted. Several aspects of the present data speak to this issue, but do not provide a final resolution. First, for some subjects there was no evidence of any contrast effect that was independent of the following-schedule effect (e.g., R-20 in Experiment 1, R-75 in Experiment 2), as changing the relative rate of reinforcement affected responding only in the component that preceded the locus of reinforcement variation. Second, much, perhaps all, of the contrast effects independent of the following-schedule effect could be accounted for by the additional effects of the preceding schedule of reinforcement, as only those subjects that were sensitive to the preceding schedule exhibited such contrast effects (Table 4 of Experiment 1). Third, some significant portion of the effect of the preceding schedule can be regarded as transient (local) and transitory in nature, as Condition 1 of Experiment 2 demonstrated a local contrast effect early in training, which then decreased with further training. As demonstrated in Experiment 1, however (also see Malone, 1975), such effects need not be transitory, because they may persist for indefinite periods of time. What determines the occurrence of local contrast, and why it persists for some subjects and not others is uncertain, but previous work has shown both the number and type of stimuli to be important variables (Malone, 1976). Particularly noteworthy is the finding that local contrast typically does not occur when TO is used in lieu of an explicit S—, whereas the overall contrast effect with the two procedures is quite similar (Vieth & Rilling, 1972). Also noteworthy are the recent findings of Farley (1980) that stimuli associated with contrast due to the preceding schedule do not have an enhanced conditioned reinforcement value, whereas stimuli associated with contrast due to the following schedule do have an enhanced conditioned reinforcement value. All of these findings are consistent with the view that local contrast is a form of Pavlovian induction (cf. Malone, 1976).

Of all the above conclusions, the second deserves the greatest scrutiny, since it implies that the molar effects of relative rate of reinforcement should be understood at a more fundamental level. The conclusion that there is *no* independent, molar, effect of relative rate of reinforcement can be challenged, however, given the nature of the evidence. Experiment 2 provides only weak evidence, as the use of the three-component schedule meant that any molar effect of relative rate of reinforcement was confounded with the effect of the preceding schedule. That is, any contrast effect in the component preceded by the variable schedule (usually Component C) could be due either to the local effect of the preceding schedule, or to the molar effect of relative rate of reinforcement. Thus, the only evidence in Experiment 2 against an independent role for relative rate of reinforcement is that *no* contrast occurred in the component preceded by the variable schedule. Some contrast did occur, however, although those effects were generally small and highly variable.

Experiment 1 provided stronger evidence against an effect of relative rate of reinforcement independent of the schedule transitions. There it was possible to isolate an effect of the preceding schedule, and a strong correlation was found between the occurrence of the preceding-schedule effect and the residual amount of contrast not due to the following schedule. But of course correlational evidence does not prove that the effect of the preceding schedule was the sole cause of the residual contrast effects, so that any conclusions must remain tentative.

It is probably unreasonable to expect that contrast can be reduced totally to the sum of the following-schedule effect and the local effects of the preceding schedule, since there are other factors that may often play a role. One such factor that deserves attention is changes in response topography. For example, Mackintosh (1974, p. 374) has suggested that the local positive contrast effect at the beginning of the component produces short-IRT responses that are then reinforced and then appear throughout the component. Similarly, Marcucella & MacDonald (1977) have argued that the interaction between the obtained IRT distribution and the local contingencies of a VI schedule is responsible for at least some forms of negative contrast. Moreover, there is at least suggestive evidence that changes in response topography occur that increase the percentage of total pecks that occur to the key surface. Lyons & Thomas (1967) have shown that the degree of stimulus control by the key stimulus varies regularly with transitions between differential and nondifferential reinforcement, and it is likely that such changes in stimulus control are associated with a more sharply defined location of pecking. Thus, changes in the measured rate of responding that are described as contrast may not be the direct result of changes in relative rate of reinforcement, but rather are mediated by molecular contingencies whose effects on measured rate of responding often are difficult to predict beforehand. Given such a possibility, it is unlikely that all of contrast can be explained by a single variable, because changes in response rates can be due to several variables not under direct experimenter control.

But the possibility that contrast may be an amalgam of several different effects should not discourage the isolation of its fundamental determinants. To the extent that quantitative descriptions of contrast are generally valid (Herrnstein, 1970; Lander & Irwin, 1968; Nevin, 1974), and to the extent matching in multiple schedules is a general phenomenon (Shimp & Wheatley, 1971), there must be steady-state contrast effects that depend upon the single variable of relative rate of reinforcement. The present data provide strong support for the existence of a single dominant variable, but go beyond previous accounts by showing that relative rate of reinforcement should not be conceptualized as a molar variable, because it is temporally asymmetric in its effects, depending solely on the effect of the following schedule of reinforcement. How a temporally asymmetric process generates the regular quantitative effects of relative rate of reinforcement (e.g., matching) is still a mystery, but a mystery whose unraveling may hold the key to the general understanding of schedule interactions.

A final comment on the present results concerns their relation to previous work that has used response-independent schedules of reinforcement. Williams (1976b) and Farley (1980), using multicomponent schedules similar to those used here, functionally separated the effect of the preceding schedule, the effect of the following schedule, and the effect of overall relative rate of reinforcement independent of the local transitions. Unlike the present findings, all three variables were found to play important roles, with some evidence that the molar effect of relative rate of reinforcement was the most important. This difference is important because it shows that response-dependent and response-independent schedules share only some of the same controlling variables, so that attempts to generalize from one schedule situation to the other must be viewed with caution.

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