

SIGNALLED REINFORCEMENT IN MULTIPLE AND CONCURRENT SCHEDULES¹

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Five pigeons were exposed to multiple and concurrent variable-interval, variable-interval reinforcement schedules in which reinforcement availability in one component was never signalled. During certain phases of the experiment, reinforcement availability in the other component was signalled. Behavioral contrast was observed in seven of eight instances when reinforcement availability in the multiple schedules was signalled. Under the concurrent schedules in which reinforcement availability was signalled, the subjects did not always allocate more time to (prefer) the component containing non-signalled reinforcement, as would be predicted by an account of behavioral contrast holding that contrast results from the introduction of a less-preferred condition in one component of a multiple schedule.

Despite several problems associated with defining behavioral contrast (see, for example, Bloomfield, 1969; Wilkie, 1971; Hemmes and Eckerman, 1972), the effect is often an increase in response rate in a constant or unchanged component of a multiple schedule that occurs when some change is made in the conditions prevailing in another component. Several investigators (*e.g.*, Terrace, 1972) have pointed out similarities between behavioral contrast and phenomena such as "positive induction" (Pavlov, 1927), "frustration effects" (Amsel and Roussel, 1952), the "Crespi effect" (Crespi, 1944), and "transient contrast" (Nevin and Shettleworth, 1966).

Much of the recent research on behavioral contrast has been concerned with determining what conditions in the altered component of a multiple schedule are necessary to produce contrast. Several hypotheses concerning the causes of behavioral contrast have emerged from this research. One hypothesis (Reynolds, 1961) is that a reduction in reinforcement frequency in the altered component is necessary to produce contrast; another (Terrace, 1966) is that a reduction in response rate in the altered component is necessary. Findings

inconsistent with both these hypotheses have been reported (*e.g.*, Wilkie, 1971; Richards, 1972).

Another hypothesis (Bloomfield, 1969) is that contrast occurs when a condition is introduced in a component that is less-preferred to the condition prevailing in the other, unaltered component. A similar notion has been advanced by Premack (1969). This account of contrast has received considerable empirical support. Many of the conditions that produce contrast are ones that are less-preferred when preference is measured by time allocation in concurrent schedules or response allocation in concurrent chain schedules (*cf.*, Bloomfield, 1969; Wilkie, 1972).

The purpose of the present research was to test further this preference account of contrast. In several recent experiments (Reynolds and Limpo, 1968; Brownstein and Hughes, 1970; Brownstein and Newsom, 1970) behavioral contrast has been found to occur in one component of a multiple schedule when reinforcement availability in another component is signalled. According to the preference hypothesis, subjects should prefer (*i.e.*, allocate more time to) non-signalled over signalled reinforcement in a concurrent choice situation. The major purpose of the present experiment was to test this prediction.

The present experiment consisted of two main parts. First, after exposure to a multiple variable-interval, variable-interval schedule, subjects were shifted to similar multiple sched-

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ules in which reinforcement availability in one component was signalled. For some subjects, reinforcement frequency in the component containing signalled reinforcement was increased. This part of the experiment was an attempt to replicate previous findings that (a) signalling reinforcement availability produces contrast, and (b) this effect occurs even if the frequency of reinforcement in the altered component is increased. In the second part of the experiment, the subjects were exposed to concurrent variable-interval, variable-interval schedules in which reinforcement availability in one of the components was signalled. This part of the experiment was to determine if the subjects preferred the component containing non-signalled reinforcement.

METHOD

Subjects and Apparatus

Five experimentally naive, adult, White King pigeons were maintained at 80% of their free-feeding weights.

A three-key operant chamber for pigeons (BRS-Foringer, Model PS-004) served as the experimental space. In the present experiment, the left-hand key was inoperative. The center key was operative during multiple schedule sessions. During concurrent schedule sessions, both the center and right-hand keys were operative. Operation of both keys required a force of approximately 0.2 N.

Mounted directly behind the transparent plastic keys were Industrial Electronics Engineers' stimulus display cells. Directly below the center key was a solenoid-operated grain feeder. During reinforcement periods, which consisted of 5.0-sec access to mixed grain, a #313 lamp illuminated grain in the feeder tray. All other sources of illumination in the chamber were extinguished during the reinforcement period. Two #313 lamps mounted above the keys served as houselight. Extraneous sounds were attenuated by white noise and the chamber air blower. Solid state logic circuits automatically scheduled experimental events and recorded data.

Procedure

The subjects were exposed to a series of two-component multiple and concurrent reinforcement schedules. Table 1 shows, in summary form, the procedure for each subject.

Multiple schedules. A separate arithmetic variable-interval (VI) schedule was associated with each component. Reinforcement availability in one component (C1) was never signalled. At different times in the experiment, reinforcement availability in the other component (C2) was either signalled, by the turning on the houselight, or non-signalled.

Both components were 3.0 min in duration and were presented in strict alternation. The components were temporally separated by 5.0-sec blackouts. Scheduled reinforcements were

Table 1

Order in which the subjects were exposed to the various schedules. *Mult* designates a multiple schedule. *Conc* designates a concurrent schedule. The schedule associated with component C1 was either VI 1.0-min (multiple schedules) or VI 2.0-min (concurrent schedules). The number following the schedule designation indicates the *relative* frequency of reinforcement in the C2 component. S and NS indicate that C2 reinforcement was, respectively, signalled and non-signalled. The final number indicates the number of sessions a subject was exposed to a schedule.

Sequence	Subject				
	P-1	P-2	P-3	P-4	P-5
1	<i>mult</i> 0.50 NS-10	<i>conc</i> 0.50 NS-10	<i>mult</i> 0.50 NS-15	<i>mult</i> 0.50 NS-10	<i>mult</i> 0.50 NS-15
2	<i>mult</i> 0.50 S-7	<i>conc</i> 0.50 S-12	<i>mult</i> 0.50 S-6	<i>mult</i> 0.50 S-9	<i>mult</i> 0.50 S-11
3	<i>mult</i> 0.50 NS-9	<i>conc</i> 0.67 S-19	<i>conc</i> 0.50 NS-14	<i>conc</i> 0.50 NS-15	<i>conc</i> 0.50 NS-14
4	<i>mult</i> 0.67 S-9	<i>conc</i> 0.67 NS-15	<i>conc</i> 0.50 S-11	<i>conc</i> 0.50 S-15	<i>conc</i> 0.50 S-14
5	<i>mult</i> 0.50 NS-10	<i>mult</i> 0.50 NS-14	-	-	-
6	<i>mult</i> 0.75 S-9	<i>mult</i> 0.50 S-10	-	-	-
7	<i>conc</i> 0.50 NS-13	<i>mult</i> 0.50 NS-14	-	-	-
8	<i>conc</i> 0.50 S-12	<i>mult</i> 0.67 S-9	-	-	-
9	<i>conc</i> 0.67 S-11	-	-	-	-
10	<i>conc</i> 0.67 NS-13	-	-	-	-
11	<i>conc</i> 0.75 NS-13	-	-	-	-
12	<i>conc</i> 0.75 S-12	-	-	-	-

cancelled at the completion of a component. For Subjects P-2 and P-5, the components were associated with red and green keylights. For the remaining subjects, the stimuli were vertical and horizontal orientations of a 2.54 by 0.32 cm white line on a green background.

The VI schedule associated with each component consisted of a rectangular distribution of interreinforcement intervals. The average interreinforcement interval in C1 was always 1.0 min. The average interreinforcement interval in C2 was, at different times and for different subjects, either 1.0, 0.5, or 0.33 min. The relative reinforcement frequency in C2 was thus either 0.50, 0.67, or 0.75.

Concurrent schedules. The stimuli associated with the components of the current schedules were identical to those of the multiple schedules. Separate, arithmetic VI schedules were associated with the components. The concurrent schedules were arranged by a changeover key technique (*cf.*, Findley, 1958). Two keys were used. The right-hand key was illuminated by white light. The stimuli associated with the components were projected on the center key. Pecks on the right-hand (changeover) key changed the prevailing stimulus on the center (main) key. Pecks on the main key were reinforced according to the VI schedule associated with the prevailing stimulus. Responding on the main key was never reinforced immediately after a response on the changeover key. Instead, responses on the changeover key initiated a changeover delay period of 2.0 sec, during which time reinforcement was not available for responding on the main key.

Reinforcement availability in C1 of the concurrent schedules was never signalled. During sessions in which C2 reinforcement was signalled, the houselight was turned on provided (a) reinforcement was available in C2, (b) the stimulus on the main key was that associated with C2, and (c) the 2.0-sec changeover delay period had terminated.

The VI schedules associated with both components consisted of a rectangular distribution of interreinforcement intervals. The average interreinforcement interval in C1 always was 2.0 min. The average interreinforcement interval in C2 was such that the relative frequency of reinforcement in C2 was either 0.50, 0.67, or 0.75. To ensure that the subjects obtained the appropriate number of reinforcers in each

component, a procedure similar to the one described by Stubbs and Pliskoff (1969) was used. One channel of a two-channel tape reader assigned reinforcement in C1; the other channel assigned reinforcement in C2. Once reinforcement was assigned in either component, the tape drive stopped until reinforcement occurred.

Experimental sessions generally lasted 1 hr. Sessions were scheduled seven days per week and occurred at approximately the same time each day.

RESULTS

Multiple Schedules

Figure 1 shows normalized response rate for both components of the multiple schedules during the sessions in which reinforcement availability in the C2 component was signalled. These rates were found by dividing the response rate in a component for a given session by the average response rate (shown in Table 2) of the seven baseline sessions immediately before the signalling procedure was introduced. Thus, if response rate in a component during the sessions in which reinforcement availability in the C2 component was signalled increased over the average baseline rate, the normalized response rate would be greater than 1.00. The vertical bar at B shows the range of response rates in the C1 component for the seven baseline sessions. The number below the subject designation indicates the relative frequency of reinforcement in the C2 component.

Table 2

Average response rate (responses per minute) in each component of the *mult* 0.50 NS schedule for the last seven baseline sessions preceding the introduction of the *mult* 0.50 S, *mult* 0.67 S, and *mult* 0.75 S schedules. (NS = non-signalled; S = signalled)

Subject	Component	Baseline Preceding		
		<i>Mult</i> 0.50 S	<i>Mult</i> 0.67 S	<i>Mult</i> 0.75 S
P-1	C1	32.9	24.2	25.7
	C2	32.0	22.7	22.8
P-2	C1	34.2	26.9	—
	C2	34.8	19.9	—
P-3	C1	46.2	—	—
	C2	47.5	—	—
P-4	C1	29.0	—	—
	C2	28.3	—	—
P-5	C1	19.7	—	—
	C2	20.2	—	—

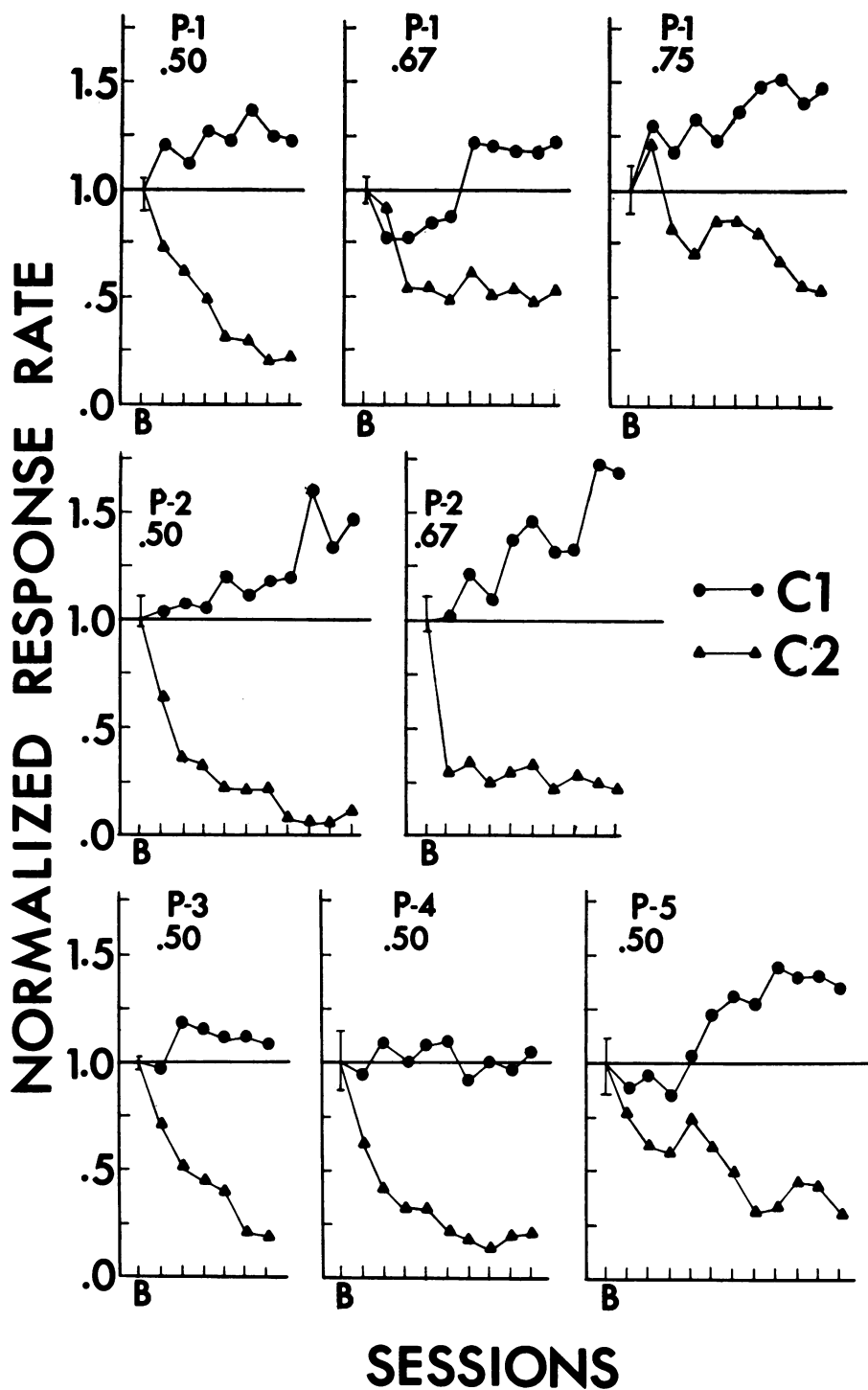


Fig. 1. Normalized response rates in the two components of the multiple schedules in which C2 reinforcement was signalled. Rates were normalized with respect to the average rate of the last seven sessions in which C2 reinforcement was not signalled. The number below the subject designation indicates the relative frequency of reinforcement in C2. The vertical bar at B shows the range of response rates during C1 for the baseline sessions.

The rate of responding in C2 decreased for all subjects when reinforcement availability in this component was signalled. This decrease occurred in all of the multiple schedules but was especially evident when reinforcement frequency in the two components was equal. The rate of responding in the unaltered component (C1) increased for all subjects except P-4. There was considerable variability in the magnitude of this behavioral contrast effect.

the number of responses emitted in C2 by the total number of responses emitted in both C1 and C2. When reinforcement availability in neither component of the concurrent schedules was signalled (unfilled bars), the subjects emitted a number of pecks in the C2 component that was approximately proportional to the relative frequency of reinforcement in that component. When reinforcement availability in C2 was signalled (filled bars), the proportion of pecks emitted in C2 was generally small.

Concurrent Schedules

Performance on the concurrent schedules is shown in Figures 2 and 3. Table 3 shows the original data from which the relative measure of Figures 2 and 3 were derived.

Figure 2 shows the relative number of responses emitted in the C2 component of the concurrent schedules when reinforcement availability in C2 was non-signalled and signalled. This measure was found by dividing

Figure 3 shows the relative amount of time spent in C2 of the concurrent schedules when reinforcement availability in C2 was non-signalled and signalled. This measure was found by dividing the amount of time spent in C2 by the total amount of time spent in both C1 and C2. When reinforcement availability in neither C1 nor C2 was signalled (unfilled bars), the subjects spent an amount of time in C2

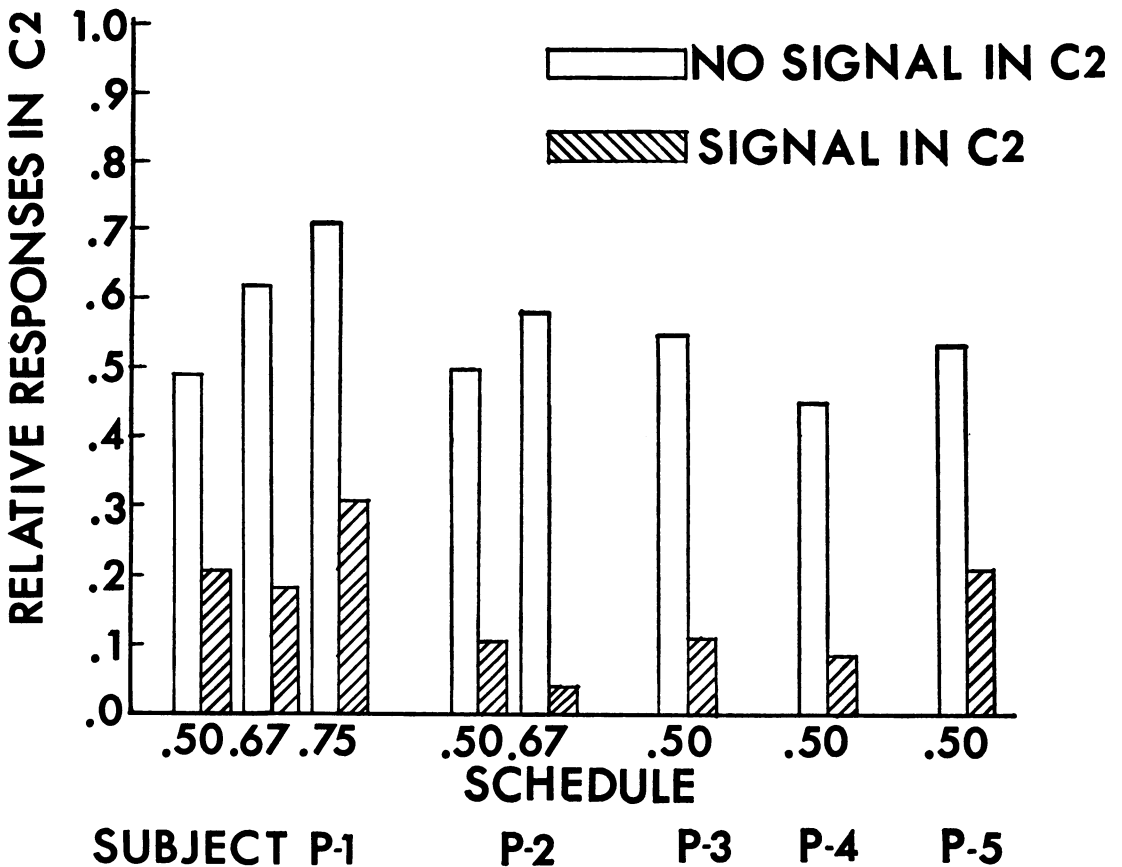


Fig. 2. The relative number of responses emitted in C2 of the concurrent schedules. Data are averages of last six sessions under a particular schedule.

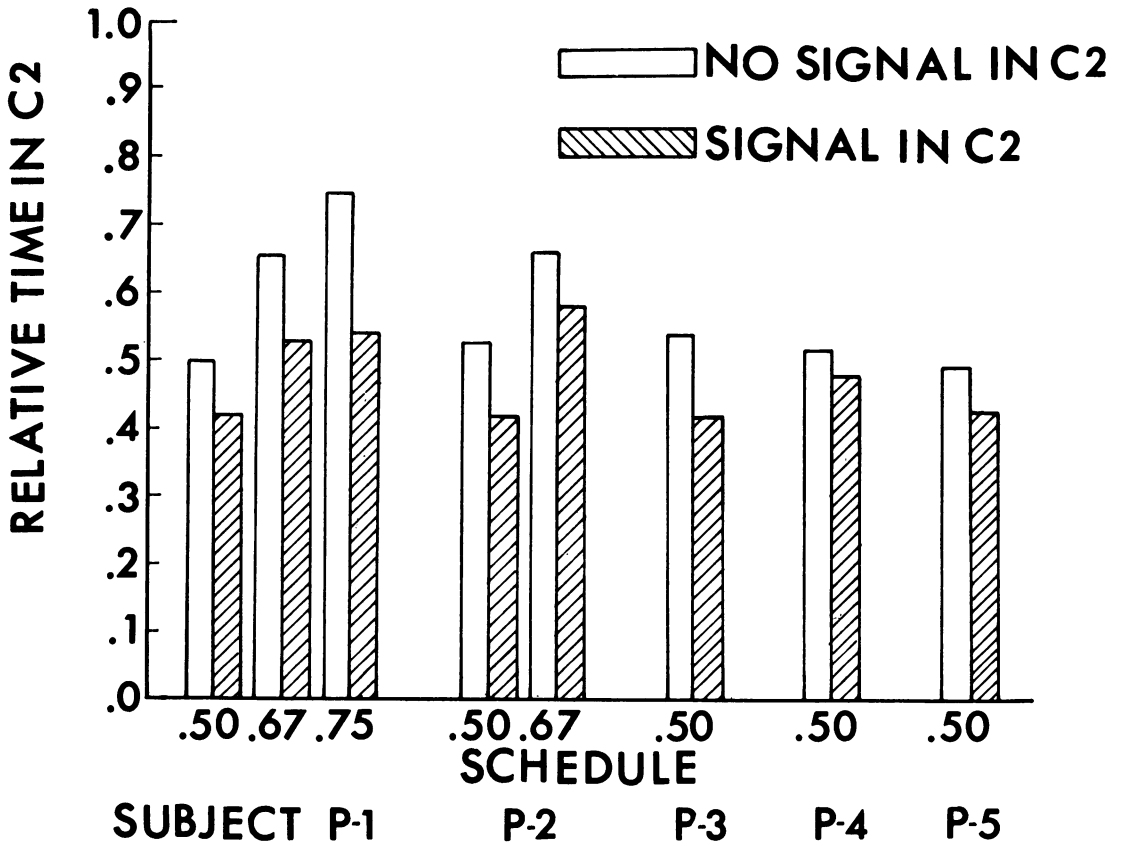


Fig. 3. The relative amount of time spent in C2 of the concurrent schedules. Data are averages of last six sessions under a particular schedule.

Table 3

Original data from which the relative measures of Figures 2 and 3 were derived. Data are sums of the last six sessions for a particular schedule. (NS = non-signalled; S= signalled)

Subject	Schedule	Responses in		Time (sec) in		Number of Changeovers
		C1	C2	C1	C2	
P-1	Conc 0.50 NS	6704	6661	10789	10811	1785
	Conc 0.50 S	7686	2004	12528	9072	3411
	Conc 0.67 NS	5047	8066	7350	14250	2389
	Conc 0.67 S	7069	1597	10154	11446	3320
	Conc 0.75 NS	4208	10419	5403	16197	2061
P-2	Conc 0.75 S	4666	2146	9943	11666	3217
	Conc 0.50 NS	6631	6541	10150	11450	1617
	Conc 0.50 S	6392	740	12530	9070	2201
P-3	Conc 0.67 NS	8604	11748	7342	14258	1879
	Conc 0.67 S	9176	402	9070	12530	3103
	Conc 0.50 NS	8936	11207	9935	11665	3806
P-4	Conc 0.50 S	9343	1217	12525	9075	2771
	Conc 0.50 NS	6824	5582	10367	11233	2312
P-5	Conc 0.50 S	8440	773	11233	10367	4172
	Conc 0.50 NS	6036	6842	11018	10582	1113
	Conc 0.50 S	9565	2596	12312	9288	3207

that was approximately proportional to the relative frequency of reinforcement in that component. When reinforcement availability in C2 was signalled (filled bars), the relative amount of time the subjects spent in this component decreased. However, the subjects spent less than one-half of the session in the C2 component (*i.e.*, preferred the component in which reinforcement availability was non-signalled) only when the relative frequency of reinforcement in the C2 component was 0.50. When more reinforcements occurred in C2 than in C1, the subjects preferred C2 over C1.

The number of times the subjects switched from one component to another under the concurrent schedules is shown in the far right column of Table 3. With one exception (Subject P-3), the subjects switched components more frequently when reinforcement availability in the C2 component was signalled than when it was not.

DISCUSSION

The multiple schedule results of the present experiment replicate Brownstein and Hughes' (1970) finding that the introduction of signalled or discriminated reinforcement availability in a component of a multiple variable-interval, variable-interval schedule produces in most, but not all, subjects an increased response rate (behavioral contrast) in the unchanged component. The results also replicate Reynolds and Limpo's (1968) findings that contrast occurs even when the frequency of reinforcement in the component containing signalled reinforcement availability is greater than that in the unaltered component.

The failure to observe a consistent preference for non-signalled reinforcement during exposure to the concurrent schedules is at variance with the preference account of contrast. While a small degree of preference for non-signalled reinforcement was observed when the frequency of signalled and non-signalled reinforcement was equal, preference of the opposite direction was observed when the frequency of signalled reinforcement was greater than the frequency of non-signalled reinforcement. This finding suggests that preference for the unaltered component, while perhaps being a sufficient condition for the

production of contrast, is not a necessary condition.

There are other difficulties with the preference hypothesis which, along with the present findings, suggest that this hypothesis must at least be modified. One of these problems is apparent in the present experiment. Even when contrast and preference jointly occur, there is no apparent relationship between the degree of preference and the amount of contrast. A second problem with this account of contrast is that preference for a condition is generally not transitory. Since contrast is generally believed to be only a transitory effect (*cf.*, Terrace, 1966), presumably the cause of contrast is also transitory. A third problem with this account is its apparent inability to explain the absence of contrast when a multiple variable-interval, extinction schedule discrimination is established without "errors" (*cf.*, Terrace, 1966). While preference for the components of such a schedule does not appear to have been experimentally ascertained, it is hard to believe that the subjects would be indifferent between the components of such a schedule, as would be predicted by the preference hypothesis.

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