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CONCURRENT RATIO SCHEDULES: FIXED vs. VARIABLE RESPONSE REQUIREMENTS[1]

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Rats were trained on concurrent fixed-ratio variable-ratio or concurrent fixed-ratio mixed-ratio schedules of food reinforcement. The variable-ratio schedule was composed of an arithmetic sequence of 11 ratios that averaged 50; the mixed-ratio schedule consisted of equiprobable ratios of 1 and 99. Fixed-ratio values, varied over experimental conditions, included 25, 35, 50, 60, and 99. The proportion of responses and time allocated to the variable- or mixed-ratio schedule increased as the size of the fixed ratio increased. For most subjects, higher proportions of responses and time were maintained on the fixed-ratio schedule at fixed-ratio values of 25 and 35; higher proportions of responses and time were maintained on the variable- or mixed-ratio schedule at fixed-ratio values of 50 or higher. On concurrent variable-ratio fixed-ratio schedules, the tendency for responding to be maintained exclusively by one schedule was related to the difference in local reinforcement rates obtained from those schedules. Exclusive responding was approximated when the difference in local reinforcement rates obtained from those schedules was large; responding was more evenly distributed between the schedules as the difference in the rates at which reinforcement was obtained from each decreased.

Key words: concurrent schedules, fixed ratio, variable ratio, mixed ratio, preference, local reinforcement rate, lever press, rats

Concurrent schedules are two or more schedules in effect simultaneously, each arranging reinforcement independently of the other(s) for separate responses (Ferster & Skinner, 1957, p. 724). Considerable research has been conducted with concurrent interval schedules (cf. Catania, 1966; de Villiers, 1977), but little work has been done with concurrent ratio schedules.

Herrnstein (1958) found that pigeons' distributions of key-peck responses between equal concurrent fixed-ratio fixed-ratio (*conc* FR FR) schedules often were unstable even after several hundred hours of exposure to the schedules. Near-exclusive preferences for a response key developed, but these were interrupted by occasional shifts in responding from one key to the other. Herrnstein and Loveland (1975) found that pigeons distributed key pecks fairly evenly between equal variable-ratio schedules (*conc* VR VR). When unequal VR schedules were arranged concurrently, preference for the schedules with the smaller average response requirement developed; exclusive preference was obtained for the smaller VR only when its average response requirement was approximately half, or less, of the larger VR.

The distribution of both responses and time between concurrent interval schedules is affected largely by the relative rates of reinforcement obtained from those schedules. On concurrent variable interval variable interval (*conc* VI VI), the relative distribution of both responses and time between schedules equals, or matches, the relative reinforcement rates obtained from the schedules (Herrnstein, 1961, 1970). However, matching occurs trivially on concurrent ratio schedules, because the relative rate of reinforcement depends exclusively on the relative rate of responding. Thus, matching occurs regardless of the distribution of responses on equal concurrent ratio schedules, but only when exclusive responding is maintained by one of two unequal ratio schedules.

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Herrnstein and Loveland (1975) suggested that responding on *conc* VR VR may be influenced by differing local rates of reinforcement obtained from each schedule. The time to earn a fixed number of reinforcements from a ratio schedule depends both on the ratio requirement and the subject's rate of responding on that schedule. Thus, according to Herrnstein and Loveland, a subject's distribution of responses between VR schedules should depend on the difference in the rates at which reinforcement is obtained from the two schedules: the greater the difference in local reinforcement rates, the greater should be the tendency for exclusive responding to be maintained by that schedule. Conversely, indifference between ratio schedules would be predicted when the difference in local reinforcement rates obtained from them is small.

The present experiment provides data from additional concurrent ratio schedules. An FR, whose value was varied across experimental conditions, was paired with a VR composed of an arithmetic sequence of 11 ratios, or a mixed ratio (MR) composed of two different ratios. The present study analyzes the tendency toward exclusive responding on *conc* VR FR as a function of the difference in local reinforcement rates obtained from those schedules.

METHOD

Subjects

Eight male albino rats, 6 to 12 months old at the start of the experiment, were maintained at 80% of their free-feeding weights. They were obtained from Midcontinent Research Animals, Shawnee, Kansas. All animals had brief histories of responding on various concurrent ratio schedules. Rats 25, 26, 32, and 33 also had prior experience with a concurrent-chain schedule (cf. Herrnstein, 1964; Autor, Note 1), consisting of VI initial links and FR terminal links; Rat 35 also had prior experience with *conc* VI VI.

Apparatus

A standard Lehigh Valley Electronics (LVE) two-lever rat chamber, measuring 30.6 cm long, 25.3 cm wide, and 26.0 cm high, was enclosed in an LVE sound-attenuating chest. The levers were 2.7 cm wide and 17.2 cm apart, center to center. Reinforcers in the form of 45-mg Noyes Precision Food Pellets were dispensed into a tray midway between the levers. Three small lamps (General Electric 313) were 5.6 cm above each lever. A feedback relay, mounted behind the front wall of the chamber, provided auditory feedback when either lever was depressed. A houselight provided general illumination during experimental sessions, and a fan attached to the chest ventilated the experimental space.

Contingencies were programmed and data were recorded by standard electromechanical equipment located in the same room as the experimental chamber. Equipment noise was masked by white noise generated inside the chamber and by noise from the ventilator fan and from extraneous equipment controlling other experiments.

Pretraining

All animals had prior experimental histories, making lever-press training unnecessary. All animals were exposed to 12 to 14 sessions of alternation training in which reinforcement was available for responding to one lever and responses to the other lever had no scheduled consequences. Which of the two levers was to provide reinforcement was determined on an irregular basis from reinforcement to reinforcement, with the provision that no more than three consecutive reinforcements could be obtained from the same lever. The number of responses required to produce reinforcement initially was set at one, and this was increased gradually to 33 over several sessions. The lamps above the lever from which reinforcement was available were illuminated, and responses to this lever operated the feedback relay. The lamps above the alternate lever were dark, and responses to this lever did not operate the feedback relay.

Experimental Procedure

Following pretraining, animals were placed on a concurrent schedule consisting of an FR on one lever and either an MR (Rats 25, 26, 32, and 33) or a VR (Rats 35, 40, 41, and 46) on the other lever. The FR value was varied over experimental conditions, and included 25, 35, 50, and 60; FR 99 also was used in one condition for Rat 46 only. The MR consisted of two ratios (1 and 99); the VR consisted of 11 ratios (1, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 99). The individual ratios comprising the MR and VR schedules were arranged equiprobably

in irregular sequences. Neither ratio comprising the MR schedule could occur more than four consecutive times, and none of the individual VR ratios could occur more than twice consecutively.

The lamps above the lever on which the FR was arranged were lit continuously; the lamps above the lever on which the MR or VR was arranged flashed on and off every half second.

Normally, both ratio schedules were in effect simultaneously and subjects could respond on either of them by moving from one lever to the other. No changeover delay was used. However, whenever nine consecutive reinforcements were obtained from either schedule, a forced-choice procedure required that the next reinforcement be obtained from the alternate schedule. During the forced choice, the lamps above the lever from which the nine consecutive reinforcements had been obtained were extinguished, and responses to this lever no longer produced auditory feedback. The collection of one reinforcement from the alternate schedule ended the forced-choice period, and both ratio schedules again were in effect concurrently (free choice). The forced-choice procedure ensured that subjects remained in contact with the contingencies of reinforcement specified by both ratio schedules.

The primary dependent variable was the distribution of responses between ratio schedules during free-choice periods. Relative response rate, computed by dividing the number of responses emitted on the MR or VR schedule during free choice only by the total number of free-choice responses, was computed daily and averaged over blocks of three consecutive sessions. Conditions were changed only when the mean relative response rates in two successive blocks were within one centile (.01) of each other, and when no consistent trend in relative responding on either schedule was evident. The sequence of conditions and number of sessions in each condition are given for each rat in Table 1.

A running-time meter was associated with each of the two schedules; the first response in a session on either schedule started its respective timer, which continued to operate until a changeover (CO) to the alternate schedule occurred (at which time the alternate schedule's timer began to operate) or until the onset of a forced-choice period, during which neither timer operated. The first response on either schedule following a forced choice again started its respective timer.

Sessions lasted until 100 reinforcements had been obtained, and were conducted at about the same time each day, six or seven days per week.

RESULTS

All rats learned to respond on the illuminated lever during pretraining; subjects switched from one lever to the other with the lights, emitting few responses to the unlit lever.

Rat 32 responded on one lever until a forced choice; he then responded on the alternate lever until another forced choice was imposed. This pattern of alternation persisted for several weeks and with several pairs of schedules, despite a variety of ploys to break it. Consequently, this subject was removed from the experiment.

All data reported are from the final six sessions of each condition. Table 1 lists the range of responses per session, total number of responses, time spent, COs, and reinforcements obtained on each schedule for each rat.

Figure 1 shows the relative response rate on the MR for Rats 25, 26, and 33, and on the VR for Rats 35, 40, 41, and 46, as a function of the value of the concurrently arranged FR. Rats with *conc* VR FR were exposed to each pair of schedules at least twice, so that the individual schedules were arranged on different levers in different conditions, thereby controlling for possible position or lever biases. Relative responding with FR on the right lever is plotted separately from that with FR on the left lever. Although some bias is evident in Figure 1 (especially in Rat 46), the distributions of responses between schedules were largely independent of the lever on which each schedule was arranged.

With few exceptions, a higher proportion of responses was maintained on whichever of the two concurrent ratio schedules had the smaller average response requirement. When the response requirements were equivalent, most animals distributed the majority of responses on the MR or VR. Exclusive responding on a schedule was approached in several instances but was never obtained. Generally, exclusive responding on the schedule with the smaller average response requirement was more closely approximated with the highest and lowest FR

Table 1

Range of responses emitted per session, total responses, time, reinforcements, and change-overs during free choice on each schedule during the final six sessions and number of sessions in each condition.

Rat	Lever	Schedule	Range of responses per session	Total responses	Minutes	Reinforcements	Change-overs	Sessions
25	Right	FR 25	1,822-2,026	11,613	112.75	458	62	18
	Left	MR 1/99	229- 631	2,678	24.70	96	61	
	Right	FR 60	127- 540	1,822	14.35	30	75	22
	Left	MR 1/99	4,266-4,391	26,012	104.29	528	78	
	Right	FR 35	2,247-2,781	14,932	169.18	438	79	83
	Left	MR 1/99	264-1,046	4,312	74.35	122	74	
	Right	FR 50	1,721-2,407	12,945	123.50	257	58	16*
	Left	MR 1/99	2,114-2,874	14,682	129.76	313	58	
26	Right	FR 25	2,006-2,078	12,285	124.19	486	57	25
	Left	MR 1/99	58- 259	985	21.72	61	53	
	Right	FR 60	198- 724	2,859	66.97	48	85	20
	Left	MR 1/99	3,651-4,465	24,624	350.53	503	87	
	Right	FR 35	2,373-2,473	14,539	167.40	423	54	25
	Left	MR 1/99	624-1,008	4,571	116.77	135	53	
	Right	FR 50	1,331-1,931	9,622	138.10	189	75	95
	Left	MR 1/99	2,876-3,374	18,671	364.76	383	79	
33	Right	FR 25	1,987-2,058	12,107	138.09	476	114	12
	Left	MR 1/99	249- 455	2,086	54.13	79	112	
	Right	FR 60	1,261-1,958	9,539	114.15	160	225	19
	Left	MR 1/99	3,318-3,624	21,280	351.90	436	231	
	Right	FR 35	2,519-2,818	16,364	199.60	474	107	13
	Left	MR 1/99	223- 625	2,199	61.84	81	105	
	Right	MR 1/99	76- 522	1,540	55.50	68	152	7
	Left	FR 35	2,677-2,812	16,618	287.13	484	151	
	Right	FR 50	1,157-1,774	8,574	179.72	170	186	29
	Left	MR 1/99	3,090-4,086	21,312	406.24	425	190	
35	Right	FR 25	2,012-2,217	12,832	61.19	504	83	23
	Left	VR 50	221- 940	3,236	17.60	66	82	
	Right	FR 60	71- 385	1,146	5.69	18	63	45
	Left	VR 50	4,269-4,438	26,185	108.88	528	63	
	Right	FR 35	2,549-2,987	16,793	73.48	486	88	32
	Left	VR 50	97- 927	2,995	16.86	67	85	
	Right	FR 50	2,214-2,822	15,216	62.86	302	105	46
	Left	VR 50	2,057-2,767	14,188	63.32	288	106	
	Right	VR 50	3,393-3,838	21,923	105.75	446	94	34
	Left	FR 50	827-1,415	6,226	33.86	123	94	
	Right	VR 50	186- 402	1,736	11.26	30	57	54
	Left	FR 25	2,162-2,261	13,193	66.99	519	58	
	Right	VR 50	4,166-4,341	25,598	120.12	514	113	32
	Left	FR 60	302- 542	2,483	14.06	40	113	
	Right	VR 50	309-1,058	4,293	31.37	80	91	33
	Left	FR 35	2,707-2,953	16,908	88.33	487	91	
40	Right	FR 25	1,466-1,850	9,873	59.80	390	81	32
	Left	VR 50	1,340-1,800	9,549	52.58	198	79	
	Right	FR 60	116- 603	2,191	12.44	37	64	14
	Left	VR 50	3,978-4,276	24,670	119.25	516	69	

Table 1 continued

Rat	Lever	Schedule	Range of responses per session	Total responses	Minutes	Reinforcements	Changeovers	Sessions
	Right	FR 35	2,553-2,884	16,091	86.55	468	83	38
	Left	VR 50	800-1,241	6,019	33.31	107	78	
	Right	FR 50	2,652-3,348	17,999	95.70	360	93	15
	Left	VR 50	1,636-2,063	11,366	62.92	237	95	
	Right	VR 50	2,934-3,164	18,389	120.75	374	112	22
	Left	FR 50	1,690-1,967	11,025	57.03	223	110	
	Right	FR 50	1,614-1,961	10,864	57.53	217	70	10
	Left	VR 50	2,721-3,147	17,615	88.69	367	71	
	Right	FR 25	2,032-2,324	12,951	77.71	513	78	20
	Left	VR 50	185- 744	2,384	17.33	41	74	
	Right	VR 50	439- 999	3,945	33.97	84	77	15
	Left	FR 25	1,970-2,155	12,409	106.75	493	78	
	Right	VR 50	4,271-4,486	26,243	149.98	531	64	48
	Left	FR 60	126- 317	1,135	7.74	19	62	
	Right	VR 50	1,155-1,798	8,371	61.44	163	66	97
	Left	FR 35	2,194-2,516	14,352	96.13	419	69	
41	Right	FR 25	2,071-2,254	12,902	79.34	510	118	17
	Left	VR 50	393- 726	3,138	16.47	56	114	
	Right	FR 60	222- 732	2,684	21.63	41	111	16
	Left	VR 50	3,881-4,256	24,504	124.93	512	113	
	Right	FR 35	677-1,071	5,077	33.10	145	74	18
	Left	VR 50	2,984-3,513	20,086	83.18	414	72	
	Right	VR 50	87- 191	736	5.56	11	60	15
	Left	FR 35	2,933-3,032	18,016	68.74	535	63	
	Right	FR 35	2,928-3,049	17,970	62.14	523	60	36
	Left	VR 50	146- 278	1,388	7.79	23	58	
	Right	FR 50	21- 188	453	8.61	6	74	23
	Left	VR 50	4,314-4,543	26,500	193.45	538	75	
	Right	VR 50	3,867-4,030	23,834	217.31	485	125	23
	Left	FR 50	578- 975	4,490	49.53	87	123	
	Right	VR 50	47- 254	1,041	16.49	16	134	20
	Left	FR 25	2,183-2,286	13,512	129.50	532	139	
	Right	VR 50	4,124-4,329	25,433	225.24	522	140	77
	Left	FR 60	263- 562	2,223	23.43	34	137	
46	Right	FR 25	1,820-2,026	11,472	99.65	453	135	33
	Left	VR 50	915-1,337	6,902	53.17	141	131	
	Right	FR 60	3- 132	279	5.36	4	67	24
	Left	VR 50	4,342-4,448	26,357	156.95	541	72	
	Right	FR 35	35- 152	555	4.91	17	69	13
	Left	VR 50	4,216-4,449	25,854	147.06	533	68	
	Right	VR 50	7- 209	525	6.01	8	65	6
	Left	FR 35	3,045-3,113	18,486	122.83	538	69	
	Right	VR 50	3,705-4,577	24,946	190.48	491	141	15
	Left	FR 99	695-2,375	9,194	62.18	89	136	
	Right	VR 50	1,944-2,403	13,209	109.80	373	149	60
	Left	FR 50	2,524-3,015	16,367	149.17	327	150	
	Right	FR 50	857-1,102	5,669	41.39	112	102	16
	Left	VR 50	3,729-4,122	23,572	194.55	475	103	
	Right	VR 50	2,109-2,526	13,667	106.78	276	119	24
	Left	FR 60	2,947-3,362	19,139	151.14	324	119	
	Right	VR 50	15- 236	587	24.53	12	98	31
	Left	FR 25	2,189-2,284	13,450	134.97	532	98	

*Removed from experiment due to ill health before stability was reached.

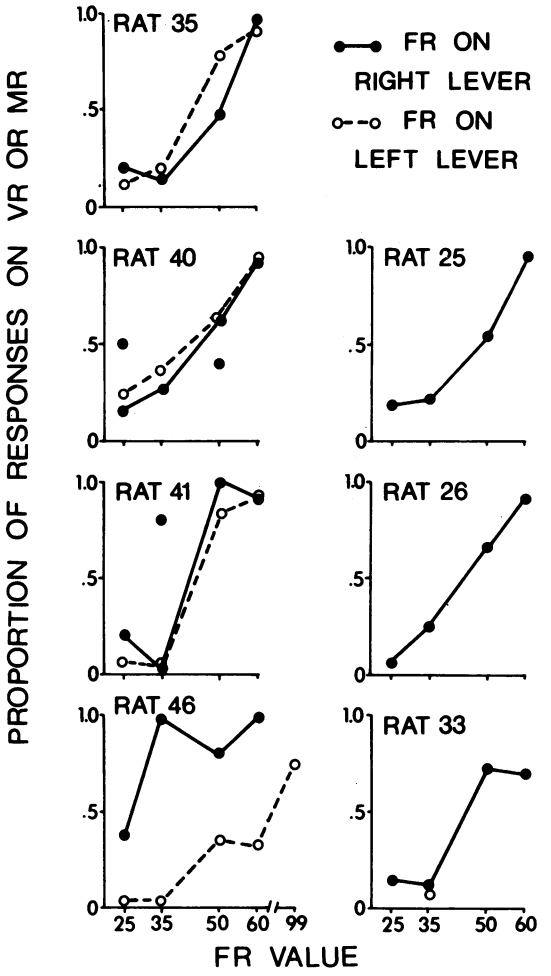

Fig. 1. Relative response rates on VR 50 and MR 1/99 as a function of the value of the concurrently scheduled FR. Rats 35, 40, 41, and 46 responded on *conc* VR FR; Rats 25, 26, and 33 responded on *conc* MR FR. Unconnected data points (Rats 40 and 41) represent the first of two exposures to the same pair of schedules on the same levers.

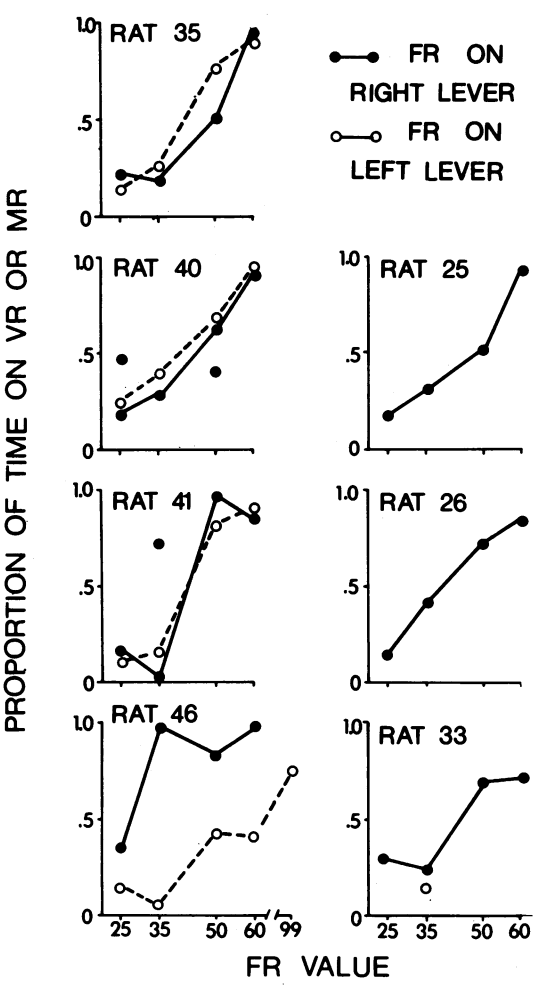

Fig. 2. Allocation of time on VR 50 and MR 1/99 as a function of the value of the concurrently scheduled FR. Rats 35, 40, 41, and 46 responded on *conc* VR FR; Rats 25, 26, and 33 responded on *conc* MR FR. Unconnected data points (Rats 40 and 41) represent the first of two exposures to the same pair of schedules on the same levers.

values employed than with the intermediate FR values.

Figure 2 shows the allocation of time between schedules for each rat. Time allocation was computed by dividing the time spent responding on the MR or VR schedule during free choice by the total time spent on both schedules during free choice. Time allocation between MR and FR was less extreme (closer to .5) than the distribution of responses between these schedules in nine conditions and more extreme in only two conditions; these measures were within .01 of each other in two conditions. Time allocation was less extreme than relative responding in 23 *conc* VR FR conditions, more extreme in eight conditions, and within .01 of relative responding in five conditions.

Herrnstein and Loveland (1975) proposed that the tendency for exclusive responding on *conc* VR VR should increase as the difference in time required to earn a fixed number of reinforcements increases. This proposal, extended to *conc* VR FR, was evaluated by plotting relative response rates on the VR as a function of the difference in local reinforcement rates obtained from the VR and FR. Local reinforcement rates were computed by dividing a subject's reinforcements obtained from a

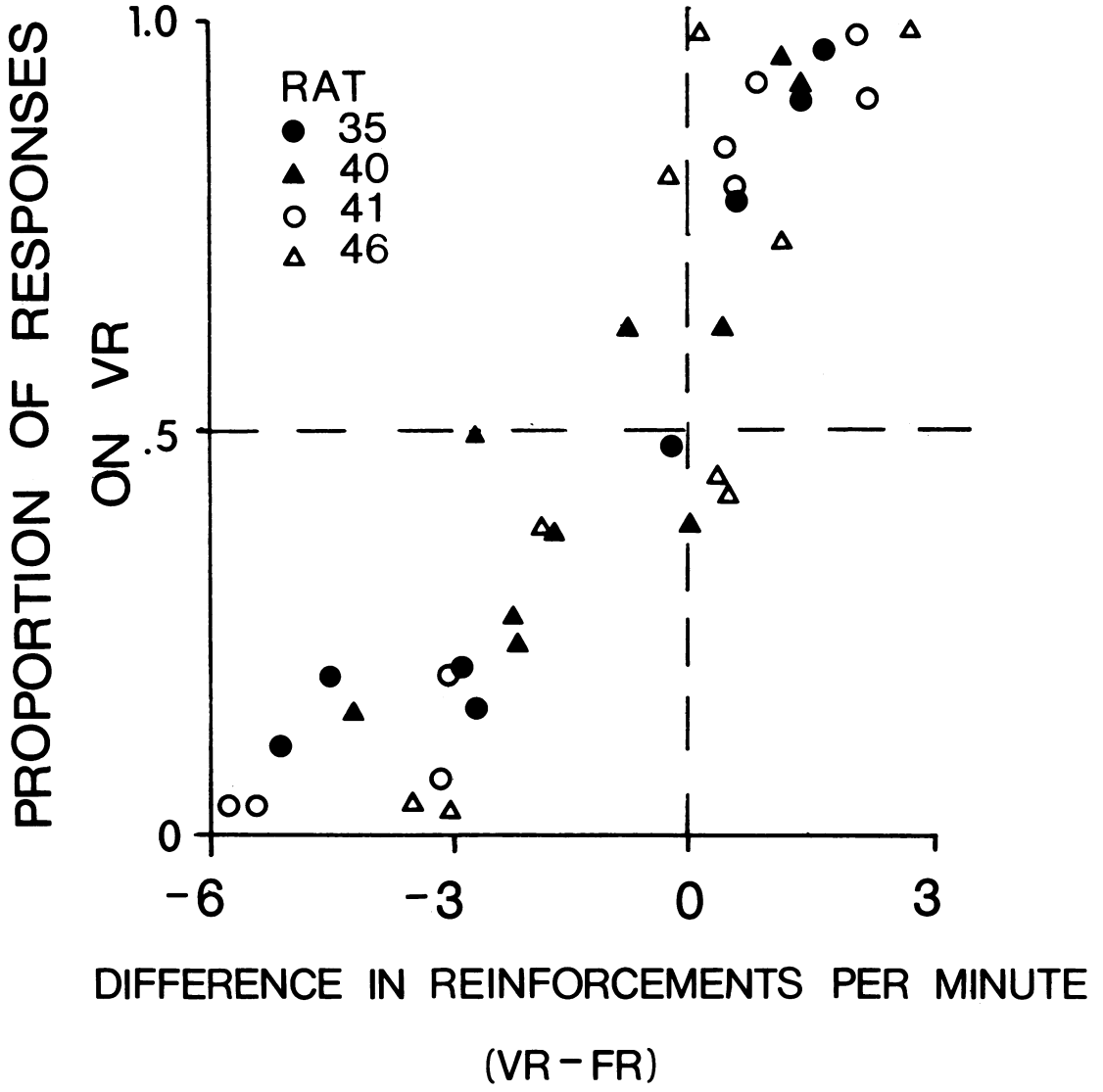

Fig. 3. Relative response rates on VR 50 as a function of the difference in local reinforcement rates obtained on *conc* VR FR. Reinforcement rate differences represent VR reinforcements per min minus FR reinforcements per min.

schedule by the total time allocated to that schedule during free-choice periods. Figure 3 displays VR reinforcements per min minus FR reinforcements per min on the x-axis; relative responding with respect to the VR is plotted on the y-axis. Each data point represents the final six sessions of each condition for Rats 35, 40, 41, and 46. Data from *conc* MR FR are not included in this figure. For these subjects, when responding was maintained predominantly by the MR, very long pauses preceding the long mixed ratio resulted in a local reinforcement rate only slightly greater, or no greater, than that obtained from the FR. Local MR reinforcement rate was never more than .75 reinforcements per min greater than local FR reinforcement rate. When responding was maintained predominantly by the FR, the subjects' practice of completing only the short mixed ratio during free choice resulted in a deceptively high local MR reinforcement rate. These response characteristics confound an

analysis of relative responding as a function of local reinforcement rate differences on *conc* MR FR.

Figure 3 shows, as Herrnstein and Loveland (1975) predicted, that responding approached exclusivity as the difference in local rates of reinforcement increased. Conversely, responding was distributed between the schedules more evenly when their local rates of reinforcement were nearly equal. Figure 3 indicates some overall preference for the VR. Relative responding on the VR was about .8 or higher in several instances where local VR reinforcement rate was only slightly higher, or no higher, than local FR reinforcement rate. By contrast, an .8 or stronger preference for the FR occurred only when local FR reinforcement rate was at least 2.5 reinforcements per min more than local VR reinforcement rate.

Local Response Characteristics

Local response rates were computed by dividing responses on a schedule by the time allocated to that schedule during free choice. That time allocation was generally less extreme than relative responding (Figures 1 and 2) is reflected by the tendency for local response rates to be higher on the preferred schedule than on the unpreferred schedule. Figure 4 shows local response rates on each schedule at each FR value. Where subjects were exposed to the same pair of schedules twice or more, the mean is plotted. For most subjects, MR or VR responding increased as FR value increased: with the exception of Rat 41, who displayed considerable variability, local MR or VR response rate was highest at FR 60 and lowest at FR 25 or FR 35. No consistent pattern in local FR response rate was evident.

Responding on the FR schedules was characterized by a break-run pattern: a pause after each reinforcement was followed by a very high rate of responding until the next reinforcement. When responding was maintained predominantly by the MR schedule, each reinforcement was followed quickly by another response; a very long pause usually followed the first or second unreinforced response (which indicated the long mixed ratio was in effect) following reinforcement. This pattern of

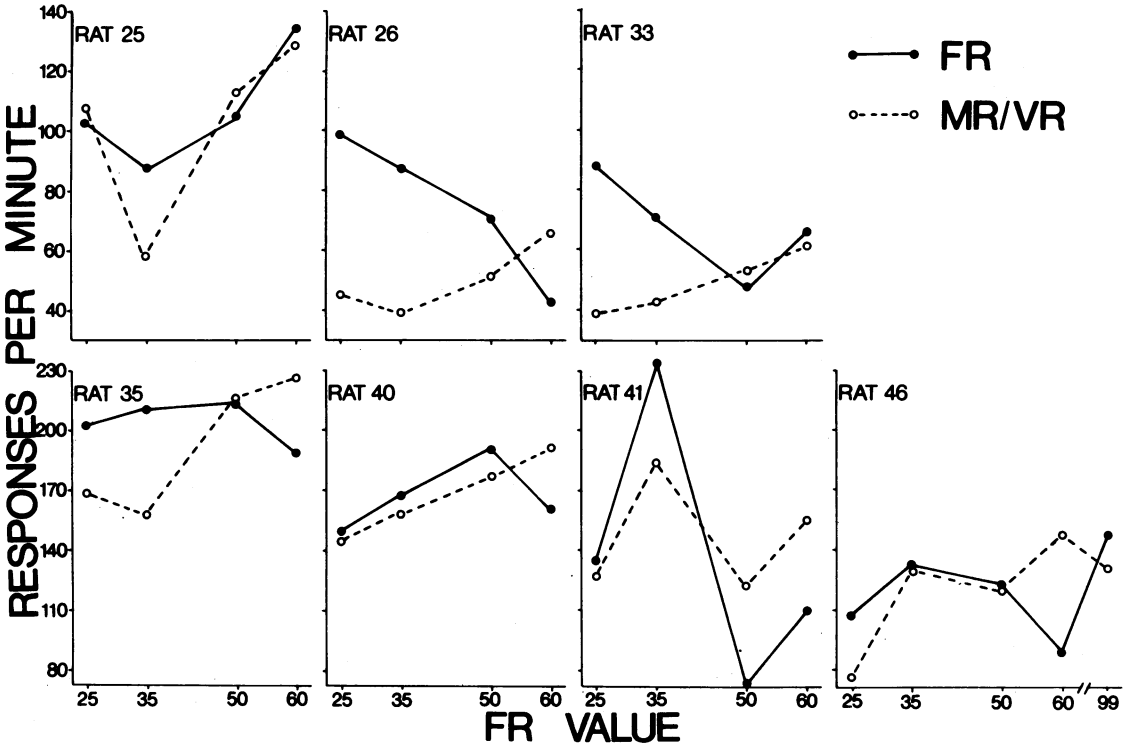

Fig. 4. Local rate of responding on FR and VR or MR at each FR value. Where subjects received the same pair of schedules twice or more, the mean response rate is plotted.

responding is characteristic of mixed schedules comprised of unequal FR components (e.g., Alferink & Crossman, 1975; Crossman & Silverman, 1973; Fantino, 1967). Pausing did not usually occur on the VR.

COs from one schedule to the other were infrequent. The number of COs in each condition listed in Table 1 is somewhat inflated, since each forced choice required a CO; subsequent return to the preferred schedule following forced choice entailed another CO.

COs from FR to MR or VR invariably occurred following a reinforcement. COs from VR usually occurred following a reinforcement, although some COs prior to the completion of a ratio were observed. COs from MR generally occurred after the first or second response after reinforcement on that schedule. Quickly after each reinforcement from the MR, another response to the MR lever was emitted. When that response produced reinforcement another response followed. This pattern continued until a response did not produce reinforcement. In that case, a pause preceded the completion of the long ratio and the sequence was repeated, or a CO to the FR was made.

For Rats 25, 26, and 33, the first response in a session invariably was to the MR lever, even when responding was maintained predominantly by the FR. Similarly, the first response following a forced-choice period was to the MR lever, regardless of which schedule maintained the majority of responses.

Forced-Choice Responding

Table 2 lists the range of responses per session, total responses, time spent, and reinforcements obtained on each schedule during forced choice in the final six sessions of each condition for each rat. Response rate during forced choice remained roughly constant across conditions for Rat 40 but varied considerably for Rats 35, 41, and 46. (Forced-choice response rate was available in no more than two conditions for Rats 25, 26, and 33.) Forced-choice response rate coincided with the strength of preference for a schedule during free choice for Rats 35, 41, and 46: forced-choice response rates were low when relative free-choice responding was extreme, and comparatively high when indifference between the schedules was approached. Forced-choice response rates were somewhat lower than local response rates on the same lever during free choice in most conditions for which these data are available. Two factors contributed to this: (a) onset of a forced-choice period often precipitated prolonged pauses in responding, and (b) occasional bursts of responding on the unlit lever competed with responding on the forced-choice lever.

DISCUSSION

Responding was maintained on *conc* MR FR and *conc* VR FR; as expected, the proportion of both responses and time on the aperiodic schedules increased as the value of the FR increased (Figures 1 and 2). In general, time allocation was less extreme than relative responding. This was due, at least in part, to the fact that local response rates were usually higher on the preferred schedule than on the unpreferred schedule.

Relative responding on *conc* VR FR was related closely to the difference in local reinforcement rates obtained from those schedules (Figure 3). Herrnstein and Loveland (1975) suggested that responding on *conc* VR VR may be influenced by differing local rates of reinforcement obtained from those schedules. Although their analysis was with respect to VR schedules, the present study supports a more general rule that also includes responding on *conc* VR FR.

The finding that, in most cases, higher proportions of responses were maintained by the aperiodic ratio schedules, when the FR value equaled their average, can be interpreted as preference for the aperiodic schedules over the FR. This result is consistent with results from concurrent-chain procedures, in which initial-link choice responses occasionally produce access to one of two mutually exclusive terminal-link ratio schedules. However, preferences for aperiodic ratio schedules displayed in concurrent chains have been considerably stronger than those obtained in the present study. Fantino (1967) found that pigeons were approximately indifferent between an MR schedule (consisting of ratios of 1 and 99) and FR 20; the MR was slightly preferred to FR 25. Similarly, Hendry (1969) reported that the point of equivalence to VR 50 was about FR 25, as far as preference was concerned. Sherman and Thomas (1968) found that a VR 120 schedule was preferred to FR values as low as 60 or 90. In the present study, the point of equivalence

Table 2

Range of responses emitted per session, total responses, time, and reinforcements during forced choice on each schedule during the final six sessions of each condition.

Rat	Lever	Schedule	Range of responses per session	Total responses	Minutes	Reinforcements
25	Right	FR 25	—	0	0	0
	Left	MR 1/99	664-773	4,313	*	46
	Right	FR 60	285-464	2,428	*	42
	Left	MR 1/99	—	0	0	0
	Right	FR 35	—	0	0	0
	Left	MR 1/99	261-721	3,190	50.63	38
	Right	FR 50	50-224	706	8.95	15
	Left	MR 1/99	1-293	1,149	28.39	15
26	Right	FR 25	—	0	0	0
	Left	MR 1/99	724-819	4,620	*	53
	Right	FR 60	227-447	2,109	*	37
	Left	MR 1/99	—	0	0	0
	Right	FR 35	—	0	0	0
	Left	MR 1/99	481-753	3,938	117.98	42
	Right	FR 50	136-223	1,097	45.77	24
	Left	MR 1/99	0- 81	82	1.75	2
33	Right	FR 25	—	0	0	0
	Left	MR 1/99	551-760	4,246	*	45
	Right	FR 60	0-105	194	*	4
	Left	MR 1/99	—	0	0	0
	Right	FR 35	—	0	0	0
	Left	MR 1/99	663-780	4,332	*	45
	Right	MR 1/99	394-846	4,025	*	48
	Left	FR 35	—	0	0	0
	Right	FR 50	0- 51	197	4.13	4
	Left	MR 1/99	0- 94	94	1.02	1
35	Right	FR 25	—	0	0	0
	Left	VR 50	116-444	1,742	*	30
	Right	FR 60	456-580	3,129	20.10	54
	Left	VR 50	—	0	0	0
	Right	FR 35	0- 34	68	0.32	2
	Left	VR 50	287-626	2,535	14.62	45
	Right	FR 50	0- 98	249	1.10	5
	Left	VR 50	0- 96	169	0.68	3
	Right	VR 50	—	0	0	0
	Left	FR 50	177-296	1,424	7.88	31
	Right	VR 50	354-413	2,327	15.93	52
	Left	FR 25	—	0	0	0
	Right	VR 50	—	0	0	0
	Left	FR 60	288-521	2,601	12.18	46
	Right	VR 50	71-383	1,315	11.25	33
	Left	FR 35	—	0	0	0
40	Right	FR 25	0- 22	22	*	1
	Left	VR 50	1-163	543	*	10
	Right	FR 60	344-522	2,708	*	47
	Left	VR 50	—	0	0	0
	Right	FR 35	—	0	0	0
	Left	VR 50	5-435	1,096	*	25

Table 2 continued

Rat	Lever	Schedule	Range of responses per session	Total responses	Minutes	Reinforcements
	Right	FR 50	—	0	0	0
	Left	VR 50	0-156	171	1.07	3
	Right	VR 50	—	0	0	0
	Left	FR 50	0- 46	85	0.62	2
	Right	FR 50	43-199	674	4.38	14
	Left	VR 50	0- 86	111	0.80	2
	Right	FR 25	—	0	0	0
	Left	VR 50	271-446	1,977	12.75	46
	Right	VR 50	85-373	1,311	10.65	24
	Left	FR 25	—	0	0	0
	Right	VR 50	—	0	0	0
	Left	FR 60	440-525	2,913	23.38	51
	Right	VR 50	70-218	901	7.38	19
	Left	FR 35	—	0	0	0
41	Right	FR 25	—	0	0	0
	Left	VR 50	138-317	1,331	*	34
	Right	FR 60	323-506	2,491	*	47
	Left	VR 50	—	0	0	0
	Right	FR 35	159-237	1,158	*	38
	Left	VR 50	0- 40	77	*	2
	Right	VR 50	367-495	2,638	73.71	54
	Left	FR 35	—	0	0	0
	Right	FR 35	—	0	0	0
	Left	VR 50	342-488	2,473	17.58	54
	Right	FR 50	373-480	2,670	72.97	57
	Left	VR 50	—	0	0	0
	Right	VR 50	—	0	0	0
	Left	FR 50	136-329	1,303	26.23	28
	Right	VR 50	335-468	2,323	24.58	52
	Left	FR 25	—	0	0	0
	Right	VR 50	—	0	0	0
	Left	FR 60	332-453	2,406	35.48	44
46	Right	FR 25	—	0	0	0
	Left	VR 50	0-152	316	*	6
	Right	FR 60	464-588	3,160	40.92	54
	Left	VR 50	—	0	0	0
	Right	FR 35	241-311	1,693	22.04	49
	Left	VR 50	—	0	0	0
	Right	VR 50	313-534	2,633	32.02	54
	Left	FR 35	—	0	0	0
	Right	VR 50	—	0	0	0
	Left	FR 99	92-491	1,638	12.02	20
	Right	VR 50	—	0	0	0
	Left	FR 50	—	0	0	0
	Right	FR 50	48-148	554	7.45	12
	Left	VR 50	—	0	0	0
	Right	VR 50	—	0	0	0
	Left	FR 60	—	0	0	0
	Right	VR 50	339-465	2,569	51.23	54
	Left	FR 25	—	0	0	0

*Data unavailable in this condition.

to both MR and VR schedules, with average response requirements of 50, was between FR 35 and FR 50: the aperiodic schedules were preferred to FR 50 but not to FR 35.

Comparisons across these three studies and the present study are complicated by important procedural differences among them. Primarily, the previous studies employed concurrent chains; the present study used a simple concurrent procedure. Also, rats were subjects in the present study whereas pigeons served in the others. Despite these differences, the present results extend the generality of animals' preference for aperiodic over periodic ratio schedules.

The VR schedule was composed of 11 different ratios, including a 1-response ratio. Thus, the first response following reinforcement on the VR had a 1-in-11 chance of producing reinforcement. If the first postreinforcement response was not reinforced, a 1-in-10 chance existed for reinforcement of the 10th response. Thereafter, reinforcement probability increased with each successive 10th response, until, by the 99th response, reinforcement was certain. On *conc* VR 50 FR 50, subjects had a slightly greater than .5 chance of receiving reinforcement from the VR in at least as few responses as required by the FR. But responding on the FR produced reinforcement regularly spaced among 50 responses; responding on the VR produced reinforcement irregularly, and unpredictably, spaced among an average of 50 responses. On the VR, a chance that reinforcement would occur within the next 10 responses always existed; the same was not true for responding on the FR. It is likely that these factors controlled relative responding on *conc* VR FR when the obtained local rates of reinforcement from these schedules were approximately equal.

The first postreinforcement response on the MR had a .5 chance of producing reinforcement. However, the first unreinforced response on the MR indicated with certainty that another 98 responses were required for reinforcement. When the MR was paired with FR 25 or FR 35, it could be argued that subjects responded to whichever lever had the smaller immediate response requirement. At the start of a session or following a forced-choice period, all animals responded first to the MR because of the occasional 1-response ratios. When a response to the MR lever did not produce reinforcement, subjects switched away from FR 98 (the longer mixed ratio) to FR 25 or FR 35. However, subjects persevered on the MR when FR 50 or FR 60 was scheduled concurrently, despite the fact that the immediate choice was for a ratio of 98 over the smaller ratio of 50 or 60. The critical difference in outcomes was that completion of FR 50 or FR 60 produced reinforcement and left the subject with another response requirement of 50 or 60; completion of the longer mixed ratio produced reinforcement and, occasionally, a variable number of additional reinforcements via the 1-response ratio. These occasional short response requirements were probably responsible for the maintenance of responding on the MR when the concurrently scheduled FR value was 50 or 60.

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