**CHOICE FOR APERIODIC VERSUS PERIODIC RATIO
SCHEDULES: A COMPARISON OF CONCURRENT
AND CONCURRENT-CHAINS PROCEDURES**

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Choice between mixed-ratio schedules, consisting of equiprobable ratios of 1 and 99 responses per reinforcement, and fixed-ratio schedules of food reinforcement was assessed by two commonly used procedures: concurrent schedules and concurrent-chains schedules. Rats were trained under concurrent fixed-ratio mixed-ratio schedules, in which both ratio schedules were simultaneously available, and under a concurrent-chains schedule, in which access to one of the mutually exclusive ratio schedules comprising the terminal links was contingent on a single "choice" response. The distribution of responses between the two ratio schedules was taken as the choice proportion under the concurrent procedure, and the distribution of "choice" responses was taken as the choice proportion under the concurrent-chains procedure. Seven of eight rats displayed systematic choice; of those, each displayed nearly exclusive choice for fixed-ratio 35 to the mixed-ratio schedule under the concurrent procedure, but each displayed nearly exclusive choice for the mixed-ratio schedule to fixed-ratio 35 under the concurrent-chains procedure. Thus, preference for a fixed or a mixed schedule of reinforcement depended on the procedure used to assess preference.

Key words: choice behavior, schedule preference, concurrent schedules, concurrent chains, fixed-ratio schedules, mixed-ratio schedules, local reinforcement rate, lever press, rats

Two procedures have been used widely to study continuous choice in animals: concurrent schedules and concurrent-chains schedules (see deVilliers, 1977, and Fantino, 1977, for reviews). Concurrent schedules are two or more schedules of reinforcement in effect simultaneously (Ferster & Skinner, 1957, p. 724). The two schedules can be arranged on separate operanda and the subject can switch between the schedules simply by moving from one operandum to the other; or the two schedules can be arranged on the same operandum and the subject can switch between the schedules by responding to a second, "changeover," operandum (cf. Findley, 1958). A distinct exteroceptive stimulus is associated with each schedule with the changeover-response method.

The distribution of responses or time between concurrent schedules is taken as a measure of choice between the schedules.

In a concurrent-chains schedule (cf. Autor, Note 1, 1969; Herrnstein, 1964a), two chained schedules are arranged so that the initial links of the chains are in effect simultaneously, one on each of two operanda, and the subject can switch between the two initial links by moving from one operandum to the other. When the schedule requirement of one of the initial links is met, an exteroceptive stimulus change signals the terminal link of that chain and responses to the operandum associated with the opposite chain are no longer effective. Thus, the initial links are concurrent and simultaneously available, and the terminal links are mutually exclusive. Primary reinforcement is provided for the completion of a terminal-link schedule requirement, and the initial links are reinstated on both operanda after primary reinforcement is delivered. The distribution of responses in the initial links is taken as a measure of preference for the terminal-link schedules.

The distribution of responses between concurrent schedules has been described by the equation:

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$$\frac{R_1}{R_2} = b \frac{r_1^a}{r_2^a}, \quad (1)$$

where R_1 and R_2 represent response rates to each of two concurrent schedules and r_1 and r_2 represent obtained rates of reinforcement from those schedules (Baum, 1974). When both concurrent schedules are variable-interval schedules (VI), the coefficient (b) and exponent (a) of Equation 1 approach 1; that is, the distribution of responses to a schedule approximately "matches" the distribution of reinforcers obtained from the schedule (de Villiers, 1977; Herrnstein, 1961, 1970; but also see Baum, 1974, 1979; Davison & Hunter, 1976; Hunter & Davison, 1978; Lobb & Davison, 1975; Myers & Myers, 1977). However, when one concurrent schedule is periodic, providing reinforcement after fixed ratios or intervals, and the other is aperiodic, providing reinforcement after variable ratios or intervals, a greater number of responses typically is distributed to the aperiodic schedule than would be predicted by strict matching of response proportions to reinforcement proportions. The greater proportion of responses maintained by the aperiodic schedule can be construed as a preference for aperiodic to periodic reinforcement schedules. Nevin (1971) reported inconsistent response distributions across pigeon subjects under concurrent fixed-interval variable-interval (concurrent FI VI) schedules, but Lobb and Davison (1975) and Trevett, Davison, and Williams (1972) found that higher proportions of responses were maintained by the aperiodic schedule than by the periodic schedule when overall arithmetic mean rates of reinforcement were equal. Similarly, preference for the aperiodic schedule has been observed under concurrent fixed-ratio variable-interval (concurrent FR VI) schedules (Bacotti, 1977), concurrent fixed-ratio variable-ratio (concurrent FR VR) schedules (Rider, 1979), and concurrent FI VR schedules (Rider, 1981).

Results from studies employing concurrent-chains procedures have been comparable to those employing concurrent schedules, in that preference for aperiodic to periodic schedules has been demonstrated for both time-based schedules (Cicerone, 1976; Davison, 1969, 1972; Herrnstein, 1964b; Hursh & Fantino, 1973; Killeen, 1968; Navarick & Fantino, 1972,

1975; Rider, 1983) and response-based schedules (Fantino, 1967; Hendry, 1969; Navarick & Fantino, 1972; Sherman & Thomas, 1968). However, the preference for aperiodic schedules generally has been much stronger under concurrent-chains procedures than under concurrent procedures. For example, Rider (1979) found that both VR 50 and a mixed-ratio (MR) schedule, which consisted of equiprobable ratios of 1 and 99, were preferred to FR 50 but not to FR 35 under a concurrent procedure. By contrast, Fantino (1967) found that an MR schedule consisting of equiprobable ratios of 1 and 99 was preferred to FR values as low as 25 under a concurrent-chains procedure. Hendry (1969) found that the point of indifference to VR 50 was about FR 25, and Sherman and Thomas (1968) found that VR 120 was preferred to FR values as low as 60. Thus, aperiodic ratio schedules were preferred to FR values of approximately half the average aperiodic ratio under concurrent-chains procedures but preferred only to a fixed ratio equal to the average aperiodic ratio under a concurrent procedure.

Comparisons across studies of choice between periodic and aperiodic schedules are complicated because of the use of different subjects, species, and somewhat different procedures. In addition, the magnitude of preference for the aperiodic schedule, at least in concurrent-chains procedures, varies widely from experiment to experiment, depending at least in part on the individual ratios or intervals comprising the aperiodic schedule (see Fantino, 1967; Hursh & Fantino, 1973; Killeen, 1968; and Sherman & Thomas, 1968). Fantino (1969) also found that the magnitude of preference displayed for a terminal-link schedule was directly related to the accessibility of the terminal links, without affecting which of the alternatives was preferred; that is, as the initial-link schedule requirements became shorter, exclusive preference for one of the terminal-link alternatives was approached.

The present experiment directly compared concurrent and concurrent-chains procedures for assessing choice between periodic and aperiodic ratio schedules. Under concurrent ratio schedules, exclusive preference for the smaller ratio is approached as the values of the two ratios diverge (Herrnstein & Loveland, 1975; Rider, 1979). To maximize the choice prefer-

tion in the concurrent-chains procedure comparably, the terminal-link ratio schedules were made maximally accessible, via FR 1 initial links. In this way, choice proportions for the preferred ratio schedule should be extreme under both concurrent and concurrent-chains procedures.

METHOD

Subjects

Eight male albino rats, 5 to 11 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. Rat 33 had served in a prior experiment (Rider, 1979) and had a history of responding under concurrent ratio schedules. Rats 62, 63, 64, and 65 also had brief histories of responding under concurrent ratio schedules; Rats 94, 99, and 107 had previous experience with various concurrent and concurrent-chains schedules.

Apparatus

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

Contingencies of reinforcement were arranged and data recorded by electromechanical equipment located in the same room as the experimental chamber. Noise from this equipment was masked by white noise inside the chamber, the ventilating fan, and noise from equipment controlling other experiments.

Procedures

All animals had previous experience with two-lever schedules so pretraining was unnec-

essary. Subjects responded initially under a concurrent schedule in which an FR was in effect on one lever and an MR was in effect on the other lever (Concurrent Procedure). For all but Rat 33, FR 35 was paired with the MR; the MR consisted of ratios of 1 and 99 (MR 1/99) arranged equiprobably in irregular sequences, so that neither ratio occurred more than four consecutive times. Rat 33 was exposed to several different FR values, each paired with the same MR.

The lamps above the lever on which FR was scheduled were lit continuously and the lamps above the lever on which MR was scheduled flashed on and off every .5 sec. During "free choice," both schedules were in effect simultaneously and subjects could respond to either schedule by switching between the two levers. No changeover delay was used. Whenever nine consecutive reinforcers were obtained from one schedule, a "forced-choice" contingency required that the next reinforcer be obtained from the alternate schedule. This forced-choice procedure ensured that subjects remained in contact with the contingencies of reinforcement specified by both ratio schedules. During forced choice, the lamps above the lever from which the nine consecutive reinforcers had been obtained were extinguished and responses to that lever no longer operated the feedback relay or had other scheduled consequences. The completion of the ratio requirement arranged for the other schedule and the collection of reinforcement from that schedule ended the forced-choice period and both schedules again were in effect concurrently.

Under the concurrent-chains procedure, FR 1 schedules were in effect in the initial links of both chains. The terminal link of one chain was an FR schedule and the terminal link of the other chain was the MR 1/99 schedule. During the initial links, the lamps above both levers were unlit and a single response to either lever turned on the lamps associated with the ratio schedule arranged in that chain's terminal link (solid lights for the FR and flashing lights for the MR). Further responses to this lever were reinforced according to the ratio schedule in effect in that terminal link, while responses to the alternative lever had no scheduled consequences and did not operate the feedback relay. The collection of one reinforcer from a terminal-link ratio schedule

turned off the lamps above that lever and instated a 5-sec intertrial interval, during which responses to neither lever had scheduled consequences and did not operate the feedback relay. This 5-sec period prevented responses at the end of a terminal-link ratio schedule from being counted as subsequent choice responses for the same schedule. Five seconds after reinforcement was delivered, the initial links were reinstated and the next response again determined which terminal link was entered.

As in the concurrent procedure, a forced-choice period was used to prevent subjects from obtaining reinforcers exclusively from one schedule. Whenever nine consecutive reinforcers were obtained from one terminal-link ratio schedule, the subject was required to obtain the next reinforcer from the alternate schedule. The ninth consecutive reinforcer from either terminal link produced entry into the opposite terminal link: The lamps above its lever were lit, the terminal-link ratio schedule associated with that lever was in effect, and responses to the other lever, from which nine consecutive reinforcers had been obtained, had no scheduled consequences. The initial links were reinstated after reinforcement was delivered in this forced-choice period, following the usual 5-sec intertrial interval.

Choice between ratio schedules was measured as the distribution of responses between the ratio schedules under the concurrent procedure and as the proportion of initial-link responses under the concurrent-chains procedure. In each case, the choice proportion could vary between 0 and 1; this proportion was calculated daily and averaged over blocks of three consecutive sessions. Conditions were changed only when the mean choice proportions in two successive blocks were within one centile (.01) of each other and when no consistent trend in choice for either schedule was evident. Table 1 lists the sequence of experimental conditions and the number of sessions each condition was in effect for each rat.

A running-time meter was associated with each schedule in the concurrent procedure and with each terminal link under the concurrent-chains procedure. Under concurrent schedules, the first response in a session to either schedule started its respective timer, which continued to operate until a response to the alternate schedule occurred, thereby starting the alternate timer, or until the onset of a forced-choice

period, during which neither timer operated. The first response to either schedule following the end of a forced-choice period again started its respective timer. Under the concurrent-chains procedure, the running-time meters recorded time spent in each of the terminal links during free choice only. Separate timers re-

Table 1

Sequence of experimental conditions and the number of sessions each was in effect for each rat.

<i>Lever</i>	<i>Schedule</i>	<i>Procedure</i>	<i>Sessions</i>
<i>Rat 33</i>			
Right Left	MR 1/99 FR 50	Concurrent	13
Right Left	MR 1/99 FR 50	Concurrent Chains	12
Right Left	MR 1/99 FR 35	Concurrent Chains	7
Right Left	FR 35 MR 1/99	Concurrent Chains	21
Right Left	FR 25 MR 1/99	Concurrent Chains	15
Right Left	MR 1/99 FR 25	Concurrent Chains	26
Right Left	MR 1/99 FR 25	Concurrent	6
Right Left	FR 25 MR 1/99	Concurrent	13
Right Left	FR 25 MR 1/99	Concurrent Chains	49
Right Left	FR 35 MR 1/99	Concurrent Chains	21
Right Left	FR 35 MR 1/99	Concurrent	8
Right Left	FR 35 MR 1/99	Concurrent Chains	21
Right Left	FR 50 MR 1/99	Concurrent Chains	32
Right Left	FR 50 MR 1/99	Concurrent	24
Right Left	FR 80 MR 1/99	Concurrent	24
Right Left	FR 35 MR 1/99	Concurrent	33
<i>Rat 62</i>			
Right Left	FR 35 MR 1/99	Concurrent	15
Right Left	FR 35 MR 1/99	Concurrent Chains	14
Right Left	FR 35 MR 1/99	Concurrent	20
Right Left	FR 35 MR 1/99	Concurrent Chains	6

Table 1 continued

Lever	Schedule	Procedure	Sessions
<i>Rat 63</i>			
Right	MR 1/99	Concurrent	19
Left	FR 35		
Right	MR 1/99	Concurrent Chains	56
Left	FR 35		
Right	MR 1/99	Concurrent	12
Left	FR 35		
Right	MR 1/99	Concurrent Chains	16
Left	FR 35		
<i>Rat 65</i>			
Right	MR 1/99	Concurrent	12
Left	FR 35		
Right	MR 1/99	Concurrent Chains	20
Left	FR 35		
Right	MR 1/99	Concurrent	10
Left	FR 35		
Right	MR 1/99	Concurrent Chains	8
Left	FR 35		
<i>Rat 94</i>			
Right	FR 35	Concurrent	25
Left	MR 1/99		
Right	FR 35	Concurrent Chains	25
Left	MR 1/99		
Right	FR 35	Concurrent	10
Left	MR 1/99		
Right	FR 35	Concurrent Chains	29
Left	MR 1/99		
<i>Rat 99</i>			
Right	FR 35	Concurrent	22
Left	MR 1/99		
Right	FR 35	Concurrent Chains	25
Left	MR 1/99		
Right	FR 35	Concurrent	12
Left	MR 1/99		
Right	FR 35	Concurrent Chains	24
Left	MR 1/99		
<i>Rat 107</i>			
Right	FR 35	Concurrent	24
Left	MR 1/99		
Right	FR 35	Concurrent Chains	33
Left	MR 1/99		
Right	FR 35	Concurrent	34
Left	MR 1/99		
Right	FR 35	Concurrent Chains	9
Left	MR 1/99		

corded the duration of forced-choice periods for each schedule.

Sessions lasted until 100 reinforcers were obtained and were conducted at the same time each day, 6 or 7 days per week.

RESULTS

Figure 1 shows the choice proportions during free choice only for Rat 33 in each session of each experimental condition. Under the concurrent procedure, more free-choice responses were distributed to the FR schedule than to the MR schedule at FR values of 25, 35, and 50; a greater proportion of responses to the MR schedule occurred only when FR 80 was arranged concurrently with the MR. By contrast, under the concurrent-chains procedure, a greater proportion of initial-link responses was maintained by the MR schedule when paired with FR values of 25, 35, or 50. Preference for the MR during the final six sessions of each condition was strong over both FR 35 and FR 50 under the concurrent-chains procedure. These preferences persisted regardless of the lever on which the ratios were arranged and through several reversals of the concurrent and concurrent-chains procedures.

Choice proportions for Rats 62 and 63 are shown in Figure 2; choice proportions for Rats 65 and 94 are shown in Figure 3; and choice proportions for Rats 99 and 107 are shown in Figure 4. The figures are based on free-choice responses only and represent each session from each experimental condition. Each rat responded under concurrent FR 35 MR 1/99 initially; nearly exclusive responding to the FR 35 eventually developed under the concurrent procedure, with choice proportions stabilizing after 12 to 25 sessions. The choice proportions were reversed under the concurrent-chains procedure for each rat. This reversal of choice proportions was fairly abrupt: More than half of initial-link responses were to the MR lever by the second session under the concurrent-chains procedure for each rat. Nearly exclusive preference for the MR schedule eventually was maintained. Choice proportions for all six rats returned in favor of FR 35 when the concurrent procedure was reinstated. With the exception of Rat 62, this reversal of the choice proportions, again, was abrupt. The return to the concurrent-chains procedure resulted in another abrupt reversal of choice proportions for all six rats.

When responding under the concurrent procedure was maintained primarily by the FR schedule, the MR still controlled responding to some extent. The first response in a session invariably was to the MR lever; responses to

Fig. 1. Choice proportions for the fixed-ratio schedule for Rat 33 across all experimental conditions. The procedure (concurrent or concurrent-chains), response requirement of the fixed-ratio schedule, and lever on which the fixed ratio was arranged (left or right) are indicated for each condition.

the MR generally occurred until a response did not produce reinforcement, at which time responding to the FR lever began. This pattern of responding also prevailed following forced-choice periods.

Rat 64 responded on a lever until a forced choice; he then responded on the alternate lever until another forced choice was imposed. This pattern persisted through several pairs of schedules under both concurrent and concurrent-chains procedures. Consequently, data from this rat are omitted from analysis.

Figure 5 displays choice proportions for all rats under both concurrent and concurrent-chains procedures plotted with respect to the

difference in local reinforcement rates obtained from the FR and MR schedules over the last six sessions in each condition. Local reinforcement rates were computed for each rat by dividing the number of reinforcers obtained from a schedule during both free- and forced-choice periods by the total time allocated to that schedule during both free- and forced-choice periods. Time allocation for the concurrent-chains procedure includes terminal-link time only. Little or no free-choice responding on the FR schedule occurred under the concurrent-chains procedure; very little free-choice responding on the MR schedule occurred under the concurrent procedure, and

Fig. 2. Choice proportions for the fixed-ratio schedule for Rats 62 and 63 across all experimental conditions. The procedure (concurrent or concurrent-chains) is indicated for each condition. Fixed-ratio 35 was arranged for the right lever for Rat 62 and for the left lever for Rat 63, through all conditions.

the frequent reinforcement afforded by the one-response ratio produced a deceptively high local MR reinforcement rate. Consequently, free- and forced-choice data were pooled together to obtain an estimate of reinforcement rates garnered from each schedule during the time allocated to each.

Data points in the upper-right and lower-left quadrants of Figure 5 represent preference for the schedule that provided the higher local rate of reinforcement. Data points in the lower-right quadrant represent preference for the MR schedule but a higher local rate of reinforcement from the FR schedule. Without exception, the schedule that produced the higher local rate of reinforcement maintained the higher proportion of responses under the concurrent procedure (filled circles). But the MR schedule often was preferred to the FR under the concurrent-chains procedure (unfilled circles) even though a higher local rate of reinforcement was obtained from the FR schedule.

Table 2 presents the mean number of re-

Fig. 3. Choice proportions for the fixed-ratio schedule for Rats 65 and 94 across all experimental conditions. The procedure (concurrent or concurrent-chains) is indicated for each condition. Fixed-ratio 35 was arranged on the left lever for Rat 65 and for the right lever for Rat 94, through all conditions.

sponses, reinforcers, and time allocated to each schedule for each rat during the last six sessions in each condition. Ranges for these measures are given in parentheses. Only terminal-link responses and time are given for the concurrent-chains procedure; the number of initial-link responses to each schedule under the concurrent-chains procedure is the same as free-choice reinforcers obtained from those schedules.

DISCUSSION

The rats in the present study exhibited orderly choice behavior in a concurrent procedure and a concurrent-chains procedure. The concurrent-chains procedure included a one-response choice phase, the FR 1 initial links, in which rats selected MR or FR terminal-link schedules. This explicit choice phase was ab-

Fig. 4. Choice proportions for the fixed-ratio schedule for Rats 99 and 107 across all experimental conditions. The procedure (concurrent or concurrent-chains) is indicated for each condition. Fixed-ratio 35 was arranged on the right lever through all conditions for both rats.

sent in the concurrent procedure, the MR and FR schedules being available simultaneously. These two procedures for assessing choice produced opposite results: Preference for the FR schedule was displayed consistently under the concurrent procedure, but preference for the MR schedule was displayed consistently under the concurrent-chains procedure. These results raise the possibility that different variables control choice under concurrent and concurrent-chains procedures.

Preference for MR 1/99 to FR 35 in rats under the concurrent-chains procedure is consistent with preference for aperiodic to periodic schedules in pigeons under similar procedures (Cicerone, 1976; Davison, 1969, 1972; Fantino, 1967; Hendry, 1969; Herrnstein, 1964b; Hursh & Fantino, 1973; Killeen, 1968; Navarick & Fantino, 1972, 1975; Sherman & Thomas, 1968). Choice in concurrent chains is influenced considerably by a terminal link's smallest requirement for reinforcement. Duncan and Fantino (1970) found that the value

Fig. 5. Choice proportions for the fixed-ratio schedule during the last six sessions of each condition plotted with respect to the difference in local reinforcement rates obtained from fixed-ratio and mixed-ratio schedules. Local reinforcement rate differences represent fixed-ratio reinforcers per minute minus mixed-ratio reinforcers per minute during both free-choice and forced-choice periods.

of the shortest possible time to reinforcement provided by a terminal link was a surprisingly accurate predictor of choice in studies by Herrnstein (1964b), Fantino (1967), Killeen (1968), and Davison (1969). Accordingly, the magnitude of preference for two-valued mixed schedules to fixed schedules is inversely related to the mixed schedule's smaller requirement for reinforcement (Cicerone, 1976; Fantino, 1967; Hursh & Fantino, 1973). That is, immediacy of reinforcement appears to be a more potent contributor to choice than overall reinforcement rate in concurrent-chains procedures. Choice behavior in the concurrent-chains procedure of the present experiment supports this interpretation: Preference for the MR suggests that the occasional relatively immediate reinforcement provided by the MR schedule's one-response ratio was a more potent contributor to initial-link choice behavior than the overall terminal-link response requirement.

Responding under the concurrent procedure also can be described in terms of the

Table 2

Mean number of responses emitted, time allocated, and reinforcers obtained from each schedule over the last six sessions of experimental conditions. The range of each of these measures is given in parentheses.

		Free Choice						Forced Choice					
Lever	Schedule	Responses		Minutes		Reinforcers		Responses		Minutes		Reinforcers	
Rat 33													
Right	Concurrent												
Left	MR 1/99	136	(261)	8.19	(9.36)	10.5	(8)	754	(334)	15.28	(13.10)	8.3 (2)	
	FR 50	4,037	(334)	60.88	(13.53)	81.2	(7)	0		0		0	
Right	Concurrent												
Left	Chains												
	MR 1/99	4,472	(179)	100.19	(25.89)	89.2	(3)	0		0		0	
	FR 50	81	(148)	1.21	(2.53)	1.7	(3)	456	(52)	6.28	(1.12)	9.2 (1)	
Right	Concurrent												
Left	Chains												
	MR 1/99	4,543	(196)	90.64	(8.62)	90.0	(0)	0		0		0	
	FR 35	0		0		0		341	(11)	7.35	(2.90)	10.0 (0)	
Right	Concurrent												
Left	Chains												
	FR 35	303	(163)	4.35	(1.32)	8.8	(5)	303	(36)	5.02	(1.35)	8.8 (1)	
	MR 1/99	4,197	(603)	53.66	(13.10)	82.3	(4)	0		0		0	
Right	Concurrent												
Left	Chains												
	FR 25	394	(230)	5.56	(6.08)	15.5	(9)	202	(5)	3.94	(0.90)	8.0 (0)	
	MR 1/99	3,736	(599)	49.33	(18.61)	76.5	(9)	0		0		0	
Right	Concurrent												
Left	Chains												
	MR 1/99	2,290	(578)	36.15	(10.06)	46.7	(10)	241	(298)	5.74	(7.35)	4.3 (3)	
	FR 25	1,107	(286)	9.18	(4.48)	44.5	(11)	127	(75)	3.48	(2.25)	4.5 (4)	
Right	Concurrent												
Left	Chains												
	MR 1/99	34	(25)	3.98	(1.91)	7.8	(9)	796	(194)	11.33	(2.73)	8.8 (1)	
	FR 25	2,113	(209)	38.71	(17.81)	83.3	(8)	0		0		0	
Right	Concurrent												
Left	Chains												
	FR 25	2,074	(101)	30.82	(9.18)	81.5	(4)	0		0		0	
	MR 1/99	19	(8)	4.58	(2.24)	9.8	(5)	814	(214)	11.79	(7.18)	8.7 (1)	
Right	Concurrent												
Left	Chains												
	FR 25	1,017	(90)	10.87	(1.97)	40.2	(3)	153	(52)	3.65	(1.52)	6.0 (2)	
	MR 1/99	2,414	(191)	32.35	(8.05)	50.5	(2)	269	(298)	4.80	(5.77)	3.3 (2)	
Right	Concurrent												
Left	Chains												
	FR 35	659	(483)	7.00	(5.52)	19.0	(14)	271	(60)	5.60	(1.37)	7.8 (2)	
	MR 1/99	3,589	(510)	44.78	(5.09)	73.0	(12)	17	(99)	0.20	(1.18)	0.2 (1)	
Right	Concurrent												
Left	Chains												
	FR 35	2,842	(177)	34.21	(6.32)	81.8	(5)	0		0		0	
	MR 1/99	65	(109)	4.07	(3.07)	9.3	(4)	816	(200)	11.48	(2.05)	8.8 (1)	
Right	Concurrent												
Left	Chains												
	FR 35	922	(207)	11.29	(8.18)	26.5	(6)	244	(12)	5.28	(1.17)	7.0 (0)	
	MR 1/99	3,359	(502)	51.21	(12.35)	66.0	(7)	17	(99)	0.44	(1.27)	0.5 (1)	
Right	Concurrent												
Left	Chains												
	FR 50	24	(99)	0.35	(1.26)	0.5	(2)	487	(50)	9.74	(2.48)	9.7 (1)	
	MR 1/99	4,491	(283)	88.99	(33.76)	89.8	(1)	0		0		0	

Table 2 continued

		Free Choice				Forced Choice						
Lever	Schedule	Responses		Minutes		Reinforcers		Responses		Minutes		Reinforcers
Rat 33 continued												
Right	Concurrent											
Left	FR 50	4,074	(298)	48.88	(13.12)	81.0	(6)	0	0	0	0	0
	MR 1/99	78	(203)	5.99	(3.53)	10.8	(7)	768	(204)	11.50	(6.52)	8.2 (2)
Right	Concurrent											
Left	FR 80	202	(490)	2.61	(5.83)	2.5	(6)	694	(172)	15.40	(9.33)	8.7 (2)
	MR 1/99	4,414	(611)	58.09	(15.16)	88.8	(4)	0	0	0	0	0
Right	Concurrent											
Left	FR 35	2,754	(199)	40.11	(7.98)	80.0	(5)	0	0	0	0	0
	MR 1/99	267	(487)	8.03	(5.08)	12.7	(8)	695	(388)	9.83	(6.78)	7.3 (4)
Rat 62												
Right	Concurrent											
Left	FR 35	2,799	(210)	58.89	(6.32)	80.8	(7)	0	0	0	0	0
	MR 1/99	134	(112)	9.77	(4.84)	10.8	(7)	782	(106)	18.36	(6.37)	8.3 (1)
Right	Concurrent											
Left	Chains											
	FR 35	18	(68)	0.11	(0.33)	0.5	(2)	333	(38)	10.90	(6.08)	9.7 (1)
	MR 1/99	4,456	(293)	27.28	(17.06)	89.8	(1)	0	0	0	0	0
Right	Concurrent											
Left	FR 35	2,775	(200)	58.88	(13.73)	80.3	(5)	0	0	0	0	0
	MR 1/99	160	(228)	8.57	(4.86)	11.2	(6)	762	(140)	14.63	(6.25)	8.5 (1)
Right	Concurrent											
Left	Chains											
	FR 35	6	(35)	0.04	(0.21)	0.2	(1)	345	(2)	8.40	(2.78)	10.0 (0)
	MR 1/99	4,491	(302)	64.49	(16.42)	89.8	(1)	0	0	0	0	0
Rat 63												
Right	Concurrent											
Left	MR 1/99	56	(108)	1.70	(1.55)	9.8	(8)	832	(104)	10.78	(4.17)	8.5 (1)
	FR 35	2,839	(241)	28.65	(3.99)	81.7	(7)	0	0	0	0	0
Right	Concurrent											
Left	Chains											
	MR 1/99	4,336	(1,013)	51.71	(35.18)	86.5	(8)	0.2	(1)	0.05	(0.28)	0.2 (1)
	FR 35	151	(314)	1.30	(2.41)	4.3	(9)	310	(65)	3.69	(0.77)	9.0 (2)
Right	Concurrent											
Left	MR 1/99	74	(123)	1.65	(1.21)	8.8	(7)	817	(123)	13.70	(5.72)	8.5 (1)
	FR 35	2,854	(179)	26.88	(1.51)	82.7	(6)	0	0	0	0	0
Right	Concurrent											
Left	Chains											
	MR 1/99	3,903	(1,102)	42.33	(14.92)	79.5	(19)	50	(99)	1.00	(2.78)	0.8 (1)
	FR 35	387	(728)	2.57	(5.05)	11.2	(21)	291	(105)	2.94	(0.97)	8.5 (3)
Rat 65												
Right	Concurrent											
Left	MR 1/99	107	(108)	4.06	(3.58)	11.0	(4)	802	(96)	8.47	(6.87)	8.3 (1)
	FR 35	2,770	(121)	27.47	(2.55)	80.7	(4)	0	0	0	0	0
Right	Concurrent											
Left	Chains											
	MR 1/99	4,561	(169)	44.69	(34.61)	89.7	(1)	0	0	0	0	0
	FR 35	41	(72)	0.28	(0.47)	1.2	(2)	315	(39)	3.41	(0.73)	9.2 (1)
Right	Concurrent											
Left	MR 1/99	83	(75)	2.82	(0.83)	10.2	(2)	793	(103)	7.66	(2.88)	8.7 (1)
	FR 35	2,794	(96)	23.60	(7.33)	81.2	(2)	0	0	0	0	0
Right	Concurrent											
Left	Chains											
	MR 1/99	4,495	(194)	50.31	(29.23)	90.0	(0)	0	0	0	0	0
	FR 35	6	(35)	0.04	(0.24)	0.2	(1)	339	(33)	3.66	(1.03)	9.8 (1)

Table 2 continued

Lever	Schedule	Free Choice			Forced Choice			Reinforcers
		Responses	Minutes	Reinforcers	Responses	Minutes		
Rat 94								
Right Left	Concurrent FR 35	2,826 (208)	25.53 (10.25)	81.5 (6)	0	0	0	
	MR 1/99	215 (223)	3.56 (3.37)	10.8 (6)	710 (116)	8.62 (7.32)	7.7 (1)	
Right Left	Concurrent Chains FR 35	6 (35)	0.33 (2.00)	0.2 (1)	348 (2)	5.09 (1.27)	10.0 (0)	
	MR 1/99	4,511 (313)	64.98 (67.47)	89.8 (1)	0	0	0	
Right Left	Concurrent FR 35	2,889 (415)	22.36 (7.90)	83.2 (12)	0	0	0	
	MR 1/99	164 (349)	2.74 (2.41)	8.0 (14)	796 (104)	8.19 (3.77)	8.8 (2)	
Right Left	Concurrent Chains FR 35	321 (522)	1.82 (2.96)	9.2 (15)	313 (69)	3.58 (1.00)	9.0 (2)	
	MR 1/99	3,975 (767)	29.80 (20.59)	81.8 (13)	0	0	0	
Rat 99								
Right Left	Concurrent FR 35	2,779 (64)	26.37 (12.68)	80.3 (2)	0	0	0	
	MR 1/99	124 (136)	5.98 (8.02)	11.5 (3)	757 (212)	8.80 (6.98)	8.2 (2)	
Right Left	Concurrent Chains FR 35	0	0	0	347 (4)	4.15 (1.53)	10.0 (0)	
	MR 1/99	4,272 (302)	35.80 (14.95)	90.0 (0)	0	0	0	
Right Left	Concurrent FR 35	2,765 (174)	23.44 (1.58)	80.3 (5)	0	0	0	
	MR 1/99	195 (214)	3.17 (3.10)	11.3 (6)	663 (101)	6.38 (1.05)	8.3 (1)	
Right Left	Concurrent Chains FR 35	6 (35)	0.06 (0.38)	0.2 (1)	339 (35)	6.01 (4.70)	9.8 (1)	
	MR 1/99	4,193 (808)	46.04 (31.51)	90.0 (0)	0	0	0	
Rat 107								
Right Left	Concurrent FR 35	2,855 (260)	27.90 (3.58)	82.7 (7)	0	0	0	
	MR 1/99	107 (90)	2.59 (1.05)	8.5 (7)	759 (113)	7.95 (2.08)	8.8 (1)	
Right Left	Concurrent Chains FR 35	0	0	0	347 (4)	6.69 (3.80)	10.0 (0)	
	MR 1/99	4,267 (296)	39.07 (31.28)	90.0 (0)	0	0	0	
Right Left	Concurrent FR 35	2,767 (137)	29.54 (8.88)	79.7 (4)	0	0	0	
	MR 1/99	172 (104)	5.38 (4.56)	12.2 (5)	728 (108)	7.21 (2.08)	8.2 (1)	
Right Left	Concurrent Chains FR 35	0	0	0	347 (8)	7.07 (6.23)	10.0 (0)	
	MR 1/99	4,359 (523)	46.64 (16.05)	90.0 (0)	0	0	0	

smallest possible requirement for reinforcement. The practice of pressing the MR lever until a response was not reinforced under the concurrent procedure was common; this pattern also was observed by Rider (1979). When a response to the MR lever was not reinforced, responding to the FR lever commenced. This

pattern conceivably could reflect a tendency to complete the smallest possible ratio requirement for reinforcement. Initially, choice is between FR 35 and an MR schedule that provides a .5 chance of reinforcement for a single response; consequently, a response to the MR lever occurs. An unreinforced response to the

MR lever indicates that the 99-response ratio is in effect and hence another 98 responses are required for reinforcement. Thus, choice then is between FR 35 and FR 98; consequently, responding to the FR 35 lever begins. This line of reasoning would predict that a higher distribution of responses to the FR schedule would occur at FR values as high as 97. However, choice proportions favor the MR schedule at FR values as low as 50 and 60 under the concurrent procedure (Rider, 1979). Thus, choice behavior in this situation must be influenced by something other than the smallest possible response requirement for reinforcement at any given moment.

Herrnstein and Loveland (1975) suggested that responding under concurrent ratio schedules may be determined by different local rates of reinforcement obtainable from each schedule—reinforcements obtained from a schedule divided by the time spent responding under that schedule. Rider (1979) showed that the distribution of responses between concurrent FR VR schedules, in fact, was well correlated with differences in the local rates of reinforcement obtained from each schedule. Results from the present study (Figure 5) also support this analysis. Without exception, the schedule that maintained the higher proportion of responses under the concurrent procedure was the schedule that provided the higher local rate of reinforcement.

The correlation between choice behavior and terminal-link reinforcement rate did not hold with data from the concurrent-chains procedure. In fact, for Rats 33, 63, 65, and 94, higher local rates of reinforcement generally were obtained from the FR schedule, under both concurrent and concurrent-chains procedures. Choice for the MR schedule under the concurrent-chains procedure persisted despite a lower rate of reinforcement and a higher average response cost from the MR schedule.

The present study made use of some atypical experimental procedures whose potential effects on choice deserve further analysis. The forced-choice contingency was used to ensure that subjects remained in contact with the requirements for reinforcement imposed by both MR and FR schedules. Although the effects of this contingency are unknown, it would seem that forced choices would tend to minimize preferences. During forced choices, responses

to the unpreferred lever were reinforced and the rat was removed spatially from the preferred lever. Nonetheless, the seven rats that displayed preference consistently returned to the preferred lever after forced choices under both concurrent and concurrent-chains procedures. VI schedules usually comprise the initial links of concurrent chains; preference probably was enhanced by the use of FR 1 initial links (cf. Fantino, 1969). The concurrent procedure used in the present study did not include a changeover delay and the initial links of the concurrent chains were signaled only by the absence of lights above the levers, both nonconventional variations. Also, rats have been used infrequently in published studies of concurrent chains. Only Ito and Asaki (1982) and Rider (1983) have used rats previously; otherwise, pigeons have been the preferred subjects. Thus, although the specific concurrent and concurrent-chains procedures produced clearly and reliably different effects on choice, the generality of these results remains to be evaluated.

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