TIME ALLOCATION ON CONCURRENT SCHEDULES WITH ASYMMETRICAL RESPONSE REQUIREMENTS¹

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Pigeons were trained on concurrent schedules in which key pecking was required by both schedules (concurrent variable-interval variable-interval schedules) and on concurrent schedules in which key pecking was required by only one of the schedules (concurrent variable-interval variable-time schedules). The distribution of reinforcements was systematically varied with both types of concurrent schedules. The distribution of time between the schedules depended on the reinforcement distribution and was independent of the symmetry of the response requirement. The relation between time and reinforcement distributions appears to be invariant over a wide range of manipulations of responding maintained by concurrent schedules.

On concurrent variable-interval variable-interval (*conc VI VI*) schedules, both relative responses and relative time allocated to one of the schedules covary with the relative reinforcements provided by that schedule (Catania, 1966; Rachlin, 1973; Shull and Pliskoff, 1967). Several studies have examined the possibility that the distribution of time is independent of the distribution of a discrete response.

In one study (Brownstein and Pliskoff, 1968), pigeons switched between two stimulus colors by pecking a changeover key. In the presence of each color, reinforcers were delivered independently of what the pigeon was doing in that color. Despite the absence of a specified discrete response, relative time in a color matched the relative reinforcements in that color. Similarly, Baum and Rachlin (1969) found that the relative time in an end of a shuttle box matched the relative reinforcements delivered in that end. The distribution of time did not depend on the distribution of some specified discrete response maintained by food, because no discrete response was specified.

In previous studies, either the same discrete response was required by both concurrent schedules or a discrete response was required

by neither. One exception was a study (Wilkie, 1972) that manipulated the symmetry of the response requirements: either a discrete response was required by both concurrent schedules or by only one. With the relative number of reinforcements held constant at 0.5, changing the symmetry of the response requirements had no effect on the time distribution. The present study examined the time distributions with symmetrical and asymmetrical response requirements at several reinforcement distributions.

METHOD

Subjects

Three White Carneaux pigeons and one Silver King pigeon were maintained at 80% (± 10 g) of their free-feeding weights. Water was continuously available in the home cage. All birds had key-pecking experience with variable-interval schedules of reinforcement.

Apparatus

The experimental chamber was a Lehigh Valley Electronics (Model 1519) two-key pigeon chamber. A houselight, centered between and above the left and right keys could be illuminated red. By projection from the rear, the left key (main key) could be illuminated red or amber and the right key (changeover key) could be illuminated with a white bar. A minimum force of 0.2 N was required to operate the keys. Effective key pecks pro-

¹This research was supported by Grant #MH 21368-01 from NIMH. Reprints may be obtained from any one of the authors, Department of Psychology, University of North Carolina at Greensboro, Greensboro, North Carolina 27412.

duced an audible feedback click. White noise in the chamber and a ventilation fan helped mask extraneous sounds.

Procedure

In all conditions, a changeover-key concurrent schedule was used (Findley, 1958); each reinforcement schedule was associated with a different main-key color (red and amber). A peck on the changeover key switched the main-key color and its correlated schedule. In all phases, a 2-sec changeover delay ensured that a reinforcer, 4-sec access to mixed grain, could not be delivered within 2 sec of a changeover.

In one condition, a peck on the main key was required for reinforcement in both main-key colors (*conc VI VI* schedules). In a second condition, a main-key peck still was required in one color but not in the other (concurrent variable-interval variable-time or *conc VI VT* schedules). In the VT schedule (red), reinforcers occurred at variable times independently of any specific response.

Simply eliminating the response requirement from red was not sufficient to eliminate main-key pecking in that color. Responding was made completely asymmetrical by turning off the red keylight, discontinuing feedback for pecks on this key, and turning on a red houselight. (One bird, R-4, continued pecking the main key while the red houselight was on, so the chamber was darkened entirely, except for the changeover key.) In all procedures, the keys were darkened and pecks ineffective before and after each session and during reinforcement.

Both the symmetrical and asymmetrical response requirement procedures were examined under several different relative reinforcement distributions. The procedure of Stubbs and Pliskoff (1969) ensured that the obtained and scheduled relative reinforcement distributions were equivalent: a single VI schedule operated regardless of the current main-key color until a reinforcer was assigned. (The next interval began after the assigned reinforcer was collected.) A prespecified proportion of the reinforcers was assigned to each color according to a pseudo-random sequence. The intervals between reinforcers were determined from Catania and Reynolds' (1968) formula with $t = 45$ sec, $N = 15$, providing about 80 reinforcement opportunities per hour.

The experiment examined several different relative reinforcement frequencies with and without a key-peck requirement in red (a key peck was always required in amber). Table 1 shows for each bird the sequence and the number of sessions for each condition. "Responding" and "no responding" refer to the presence or absence of main-key pecking in red. Conditions were changed when visual inspection of the proportion of time spent in amber appeared stable for five consecutive days. Sessions were conducted daily and terminated after 60 reinforcements.

RESULTS

The top row of Figure 1 shows time distributions for each bird and condition. The logarithm of the ratio of time in amber to time in red is plotted over the logarithm of the ratio of the reinforcers obtained in amber to the reinforcers obtained in red. Different symbols indicate the schedule (VI or VT) in red as well as the presence or absence of responding in red (responding or no responding). If time and reinforcement ratios matched perfectly, then all points would fall on the diagonal line. While there are some systematic deviations from matching (undermatching in the case of Birds R-3 and R-4; see Baum, 1974), they are well within the range previously reported for *conc VI VI* schedules. In general, the time distribution was independent of responding in red. For three birds (R-1, B-3, and R-3) the corresponding VI and VT points were virtually identical. For Bird R-4, the one VI point and the corresponding VT point were discrepant. However, there was little difference between the VT (no responding) and VT (responding) time ratios despite the near equivalence of response rates in red for the VI and VT (responding) conditions.

The time ratios in Figure 1 provide a molar description of the distribution of time between the two schedules. At a more molecular level, the time distribution resulted from how quickly the bird changed from amber to red in relation to how quickly the bird changed from red to amber. The rate (or speed) of changing from amber to red was calculated by dividing half the total changeovers by the time in amber. The middle row of Figure 1 shows these changeover rates from amber to red. Changeover rate from amber varied in-

Table 1

Sequence of conditions, number of sessions, and measures of concurrent responding (means of the last five sessions).

Bird	Condition	Sessions	Amber Resp. per Min of Session Time	Relative Resp. in Amber	Relative Time in Amber	Changeovers per Min of Session Time
	Schedule in Red and Relative Reinf. in Amber					
R-1	VI 0.7-min	17	41	0.64	0.63	7.8
	VI 0.5-min	20	31	0.45	0.52	8.0
	VT 0.5 (responding)	30	41	0.58	0.54	10.3
	VT 0.5 (no responding)	20	39	1.00	0.50	9.5
	VI 0.5-min	58	34	0.50	0.52	8.3
	VI 0.3-min	27	29	0.40	0.35	7.8
	VT 0.3 (no responding)	25	27	1.00	0.39	8.7
	VT 0.7 (no responding)	43	40	1.00	0.68	7.3
B-3	VI 0.7-min	22	46	0.68	0.72	6.4
	VI 0.5-min	17	34	0.52	0.52	7.0
	VT 0.5 (responding)	30	37	0.72	0.53	9.2
	VT 0.5 (no responding)	15	34	1.00	0.54	8.8
	VI 0.3-min	30	26	0.42	0.30	5.8
	VT 0.3 (no responding)	26	32	1.00	0.34	7.3
	VT 0.7 (no responding)	49	43	1.00	0.66	6.8
R-3	VI 0.3-min	33	31	0.29	0.34	8.2
	VT 0.3 (responding)	40	23	0.41	0.35	8.7
	VT 0.3 (no responding)	15	32	1.00	0.39	9.3
	VT 0.7 (no responding)	21	40	1.00	0.70	8.6
	VT 0.1 (no responding)	40	23	1.00	0.23	6.1
	VT 0.9 (no responding)	25	55	1.00	0.85	3.2
R-4	VI 0.3-min	31	22	0.31	0.32	6.6
	VT 0.3 (responding)	42	16	0.46	0.41	11.3
	VT 0.3 (responding)	10	11	0.37	0.46	9.6
	VT 0.3 (no responding)	25	17	1.00	0.43	13.4
	VT 0.7 (no responding)	21	24	1.00	0.76	6.5
	VT 0.1 (no responding)	21	10	1.00	0.33	12.2
	VT 0.9 (no responding)	30	32	1.00	0.92	3.4

versely with the ratio of reinforcements in amber; the larger the proportion of reinforcements in amber, the slower the bird was to change out of amber. Furthermore, the relation between the changeover rate from amber and the reinforcement ratio was essentially the same regardless of responding in red. (The changeover rates from red to amber, not shown, likewise varied inversely with the proportion of reinforcements in red independently of responding in red.) Thus, the independence of the time distribution from key pecking in red held at the molecular level of changeover rates as well as at the molar level of time ratios.

The bottom row of Figure 1 shows the rate of amber-key responses calculated with respect to session time (responses to the amber key per minute of session time, excluding reinforcement). The amber-key rate increased with the ratio of amber reinforcements inde-

pendently of responding in red. Changes in amber-key rate resulted mainly from changes in the distribution of time between amber and red, because the local response rate in amber (responses to the amber key per minute of time in amber) remained essentially constant across procedures.

DISCUSSION

Together, the three rows of data show that the effects of manipulating the response dependencies in red were largely restricted to main-key responding in red.

Previous research showed that the relation between time and reinforcement distributions was the same regardless of whether a specific discrete response was required in both concurrent schedules or in neither schedule (Baum and Rachlin, 1969; Brownstein, 1971; Brownstein and Pliskoff, 1968). The present

Fig. 1. The logarithm of the ratio of time in amber to time in red (top row), changeover rates from amber to red (middle row), and amber-key responses per minute of session time (bottom row) plotted over the logarithm of reinforcers in amber to reinforcers in red (N_A/N_R). The different symbols indicate the response requirement in effect for food in red: VI or VT. The VT (responding) points indicate that high rates of red-key pecking prevailed despite the absence of a pecking requirement in red. Pecking did not occur on the main key in red during the other VT conditions (VT no responding). Each point represents the mean of the last five sessions of a condition.

data showed that the relation between the time and reinforcement distributions was the same whether or not the same response was occurring for both schedules. Thus, the relation between time and reinforcement distributions appears to be invariant over a wide range of transformations in responding in each of the components of the concurrent schedule (see also Baum, 1974; Hollard and Davison, 1971).

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Received 17 September 1974.

(Final Acceptance 24 February 1975.)