EFFECTS OF REINFORCEMENT RATE AND REINFORCER MAGNITUDE ON CHOICE BEHAVIOR OF HUMANS¹

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Two experiments with human subjects investigated the effects of rate of reinforcement and reinforcer magnitude upon choice. In Experiment 1, each of five subjects responded on four concurrent variable-interval schedules. In contrast to previous studies using non-human organisms, relative response rate did not closely match relative rate of reinforcement. Discrepancies ranged from 0.03 to 0.43 (mean equal to 0.19). Similar discrepancies were found between relative amount of time spent responding on each schedule and the corresponding relative rates of reinforcement. In Experiment 2, in which reinforcer magnitude was varied for each of five subjects, similar discrepancies ranging from 0.05 to 0.50 (mean equal to 0.21), were found between relative response rate and relative proportion of reinforcers received. In both experiments, changeover rates were lower on the long-interval concurrent schedules than on the short-interval ones. The results suggest that simple application of previous generalizations regarding the effects of reinforcement rate and reinforcer magnitude on choice for variable-interval schedules does not accurately describe human behavior in a simple laboratory situation.

Of the variables included in the matching relation describing relative response rate (the rate of responding on one schedule divided by the sum of the rates of responding in both), on each of two concurrent variable-interval schedules, two—relative rate of reinforcement and relative magnitude of the reinforcers delivered for responding on each of the schedules—have received the greatest attention. The matching relation has been found consistently between relative response rate and relative rate of reinforcement, with some generality evidenced over a range of reinforcers and schedules (Herrnstein, 1961; Shull and Pliskoff, 1967; Schroeder and Holland, 1969; Silberberg and Fantino, 1970; Fantino, Squires, Delbrück, and Peterson, 1972; Todorov, 1973). Studies of reinforcer magnitude have been less numerous and their results less consistently support a matching relation (Fantino *et al.*, 1972). Only two studies of reinforcer magnitude have em-

ployed simple concurrent schedules of the type used to investigate the effects of reinforcement rate. Catania (1963) found evidence to support matching for two of three subjects using equal variable-interval concurrent schedules of 2 min. Fantino *et al.* (1972) failed to find matching with six subjects on any of three equal variable-interval concurrent schedules of 10 sec, 60 sec, and 600 sec.

While studies of the matching relation have included a range of schedules and reinforcement contingencies, one aspect has tended to remain invariant—the choice of subject. With one exception (Schroeder and Holland, 1969), all relevant research has been conducted with non-human subjects. Yet it is with regard to determinants of response choice that interspecies generality is of particular interest. The concurrent operant setting provides a closer analog to non-laboratory situations faced by humans than one with a single operant. The experiments reported below addressed this question of generality. Two experiments focused on the effects of rate of reinforcement (Experiment 1) and reinforcer magnitude (Experiment 2) on choice proportions of humans on variable-interval concurrent schedules.

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EXPERIMENT I: EFFECTS OF RATE OF REINFORCEMENT ON CHOICE

METHOD

Subjects

Three female and two male college students, who volunteered via a recruitment notice, served.

Apparatus

The subject room contained a desk and chair, wall-mounted poster, and clock. A 5 by 17 by 14 in. (12.5 by 43 by 35 cm) aluminum box with two lights, counter, toggle switch, and button on the face was mounted on the desk. A poster with the words "Amounts Earned" printed on top was attached to the wall in front of the desk. Cards with different values could be hung beneath the label. The wall clock was mounted to the right of the desk. Scheduling and recording apparatus was located in an adjacent room.

Fig. 1. Diagram of subject's panel.

Procedure

The effects of four concurrent schedules were investigated. On two of these—concurrent variable-interval 15-sec variable-interval 30-sec (*conc* VI 15-sec VI 30-sec) and concurrent variable-interval 150-sec variable-interval 300-sec (*conc* VI 150-sec VI 300-sec)—the ratio between reinforcement rates on the component schedules was 2:1. On the other two—*conc* VI 15-sec VI 75-sec and *conc* VI 150-sec VI 750-sec—the ratio was 5:1. All component VI schedules were designed using the procedure described by Segal (1964). The interval ranges and cycle lengths for the six schedules are shown in Table I. Different schedule starting points were used each session.

TABLE 1

Interval range and cycle length for the six variable-interval schedules. Cycle length refers to the number of minutes before the interval sequence was repeated, assuming no delay in reinforcement.

Schedule	Interval Range (sec)	Cycle Length (min)
VI 15-sec	4-45	25
VI 30-sec	5-75	50
VI 75-sec	8-231	62
VI 150-sec	9-419	50
VI 300-sec	37-538	50
VI 750-sec	49-1048	62

The reinforcer was counter points backed up with money. For all four concurrent schedules, the amount of money scheduled per hour was identical. On the short-interval schedules (*conc* VI 15-sec VI 30-sec and *conc* VI 15-sec VI 75-sec), each count was worth 0.1¢. Counts per reinforcement were 8 (0.8¢) on *conc* VI 15-sec VI 30-sec, and 10 (1.0¢) on *conc* VI 15-sec VI 75-sec. On the long-interval schedules (*conc* VI 150-sec VI 300-sec and *conc* VI 150-sec VI 750-sec), each count was worth 1¢. Counts per reinforcement were 8 (8¢) on *conc* VI 150-sec VI 300-sec and 10 (10¢) on *conc* VI 150-sec VI 750-sec. Thus, on each concurrent schedule a maximum of \$2.88 per hour could be earned.

Subjects used the toggle switch (*i.e.*, change-over key) on the panel to select either of the component schedules. Flicking the switch to the left or right illuminated the respective left or right panel light. A different colored light lens was used with each schedule. The component schedule with the higher rate of reinforcement was always located on the left. The response reinforced on either schedule was a button press. The specified number of counts registered immediately after the reinforced response. Throughout the experiment, a 1.5-sec changeover delay (COD) was used. The COD stipulated that when the subject flicked the switch to the other schedule, at least 1.5 sec had to elapse before a button press could be reinforced. The amount of each reinforcement on the two schedules (referred to by the lens color on the panel) was indicated on the wall poster.

Each subject responded in from six to eight 2-hr sessions scheduled over approximately two weeks. The sequence in which each of the concurrent schedules was presented is shown in Table 2. Each schedule was repeated once.

Table 2
Sequence of Conditions—Experiment 1

Schedule	Reinforcers (cents)	Duration (min)
(a) VI 15-sec	1.0	30
(b) VI 30-sec	1.0	30
(c) <i>conc</i> VI 15-sec VI 30-sec	0.8, 0.8	180*
(d) VI 75-sec	1.0	30
(e) <i>conc</i> VI 15-sec VI 75-sec	1.0, 1.0	180*
(f) <i>conc</i> VI 15-sec VI 30-sec	0.8, 0.8	90*
(g) <i>conc</i> VI 15-sec VI 75-sec	1.0, 1.0	90*
(h) VI 150-sec	10	30
(i) VI 300-sec	10	30
(j) <i>conc</i> VI 150-sec VI 300-sec	8, 8	180*
(k) VI 750-sec	10	30
(l) <i>conc</i> VI 150-sec VI 750-sec	10, 10	180*
(m) <i>conc</i> VI 150-sec VI 300-sec	8, 8	90*
(n) <i>conc</i> VI 150-sec VI 750-sec	10, 10	90*

*Minimum duration if stability criterion was met. Otherwise additional 30-min periods were studied until criterion was met.

The initial presentation lasted at least 3 hr or until choice proportions were judged stable. The stability criterion involved comparison of the relative response rates for the last three half-hour periods (a,b,c). The rates were considered stable when they showed no consistent trend, *i.e.*, neither $a > b > a$ nor $c > b > a$. If the criterion was not met, additional half-hour periods were scheduled until the criterion was met. The second presentation lasted at least 1.5 hr and until relative response rates for three consecutive half-hour periods met the stability criterion. Schedule changes were made at the end of any half-hour during a session when the stability criterion was reached.

Subjects responded on each of the component schedules separately before they were paired. In the first session, instructions describing the contingencies accompanied introduction of the first two VI schedules. Subjects worked under the VI 15-sec schedule (a) first. The following instructions were read by the experimenter.

You will be able to make money by pressing the button when the green light comes on. Every few seconds, a press of the button will give you 10 counts. Each count is worth one-tenth cent. The number of counts that will be added each time is shown on the wall. The amount you have earned will be paid to you at the end of each session.

Subjects then worked 30 min under the VI 15-sec schedule. Flicking the toggle switch had no effect. In this and in all subsequent single-schedule conditions, subjects received 10 counts for each reinforced response.

Subjects then worked 30 min under the VI 30-sec schedule (b) after receiving instructions similar to the above. The two schedules were then made available concurrently (c). Subjects received the following instructions:

You can now choose which of the two tasks you want to work on. You make the choice at any time with this switch (experimenter demonstrates). You can switch tasks as often as you like. By switching back and forth you can earn money on both tasks. You will be able to earn money on each task as often as you did before. As is shown on the wall, you get eight counts each time on the green task and eight each time on the white task.

The *conc* VI 15-sec VI 30-sec schedule remained in effect at least 3-hr. The VI 75-sec schedule (d) was then introduced for 30 min, followed by the *conc* VI 15-sec VI 75-sec schedule (e). Finally, the two concurrent schedules were repeated (f,g). Each schedule change was signalled by the change in the color of the lights and also by the amount of each reinforcement.

Subjects were then introduced to the long-interval schedules. The procedure and instructions were similar to those given above, except that each count was now worth one cent.

RESULTS

In all conditions, subjects typically met the stability criterion in close to the minimum durations specified. Subjects worked an average of 195 min in the first presentation and an average of 120 min in the second.

Table 3 shows the separate (1,2) and averaged (avg) data from the final three 30-min periods of the two presentations of each schedule. With one exception, no systematic changes in behavior were apparent in the replications, although variability in some cases was substantial.

The exception occurred in the data of Subject S (male) whose behavior changed markedly during the replication of the *conc* VI 150-sec VI 300-sec and *conc* VI 150-sec VI 750-sec

Table 3

Absolute and relative response rates per minute, relative time, relative reinforcement rate, difference between relative response rate and relative reinforcement rate, changeovers per minute, and proportion of scheduled reinforcers received by each subject working on four unequal variable-interval concurrent schedules. Data shown for the first (1) and second (2) presentation of each schedule are the averages from the final three 30-min periods of each presentation. The average of (1) and (2) is also given (avg). Relative rates refer to the component schedule with the shorter mean interreinforcement interval (IS²I). The COD was 1.5 sec for all concurrent schedules.

Schedule	Subject	i Response Rates/Min		iii	Relative				viii	ix
		VI with Shorter Mean IS ² I	VI with Longer Mean IS ² I	TOTAL	Response Rate	Time	Reinf. Rate	Absolute Devia- tion (iv-vi)	Changeovers/min	Prop. Scheduled Reinf. Received
(1) Conc VI 15-sec VI 30-sec	S 1	35	43	78	0.45	0.48	0.63	0.18	9.8	0.75
	2	80	81	162	0.50	0.49	0.65	0.15	13.5	0.86
	avg	58	62	120	0.48	0.49	0.65	0.16	11.7	0.81
	Gi 1	25	18	43	0.59	0.61	0.70	0.11	14.5	0.81
	2	36	33	69	0.52	0.56	0.67	0.15	15.1	0.90
	avg	31	36	56	0.56	0.58	0.69	0.13	14.8	0.86
	B 1	35	29	63	0.55	0.55	0.67	0.12	8.5	0.87
	2	31	31	62	0.50	0.51	0.66	0.16	10.5	0.89
	avg	33	30	63	0.53	0.53	0.67	0.14	9.5	0.88
	J 1	69	57	127	0.55	0.54	0.65	0.10	4	0.75
	2	94	28	122	0.77	0.78	0.75	0.02	2.5	0.77
	avg	82	43	124	0.66	0.66	0.70	0.06	3.2	0.76
	Go 1	18	15	33	0.55	0.49	0.67	0.12	10.5	0.88
	2	20	16	37	0.56	0.54	0.68	0.12	10.3	0.86
	avg	19	15	35	0.56	0.52	0.68	0.12	10.4	0.87
(2) Conc VI 15-sec VI 75-sec	S 1	71	79	150	0.47	0.50	0.82	0.35	9.9	0.80
	2	45	64	109	0.41	0.43	0.78	0.37	17.3	0.72
	avg	58	72	130	0.44	0.46	0.80	0.36	13.6	0.76
	Gi 1	28	27	55	0.50	0.57	0.84	0.34	13.8	0.88
	2	36	40	76	0.47	0.49	0.82	0.35	14.2	0.87
	avg	32	34	65	0.48	0.53	0.83	0.35	14	0.88
	B 1	38	31	69	0.55	0.56	0.83	0.28	7.8	0.91
	2	35	30	64	0.54	0.55	0.83	0.29	8.3	0.91
	avg	36	30	66	0.54	0.56	0.83	0.29	8.1	0.91
	J 1	90	13	103	0.87	0.89	0.90	0.03	1.2	0.83
	2	101	20	121	0.84	0.88	0.87	0.03	2.3	0.87
	avg	95	16	112	0.86	0.89	0.89	0.03	1.7	0.85
	Go 1	30	18	48	0.62	0.49	0.83	0.21	10.7	0.88
	2	33	20	52	0.63	0.56	0.83	0.20	8.3	0.90
	avg	31	19	50	0.62	0.52	0.83	0.21	9.5	0.89

schedules. On the former schedule, relative response rate decreased from 0.53 to 0.04 while hourly earnings decreased from \$2.55 to \$2.20. On the latter, relative response rate decreased from 0.64 to 0.05 while earnings decreased from \$2.20 to \$1.93. In reply to post-experimental questioning, the subject said he recognized that his earnings had decreased and attributed his behavior to boredom created by

the infrequent reinforcement on those schedules.

Data relevant to the question of whether relative response rates matched relative rates of reinforcement are shown in columns i-vii of Table 3. Columns i-iv show the absolute and relative response rates for each subject on the four schedules. Total absolute response rates showed little systematic change across sched-

Table 3 Continued

Schedule	Subject	i	ii	iii	iv	v	vi	vii	viii	ix
		Response Rates/Min		TOTAL	Relative			Absolute Deviation (iv-vi)	Changeovers/Min	Prop. Scheduled Reinf. Received
		VI with Shorter Mean IS ² I	VI with Longer Mean IS ² I		Response Rate	Time	Reinf. Rate			
(3) <i>Conc</i> VI 150-sec VI 300-sec	S 1	8	7	16	0.53	0.59	0.62	0.09	2.9	0.90
	2	3	68	70	0.04	0.05	0.65	0.61	2.0	0.74
	avg	6	38	43	0.28	0.32	0.63	0.35	2.5	0.82
	Gi 1	49	43	92	0.54	0.55	0.66	0.12	12.6	0.98
	2	50	17	66	0.75	0.85	0.73	0.02	6.9	0.89
	avg	49	30	79	0.64	0.70	0.70	0.07	9.7	0.94
	B 1	56	13	69	0.82	0.82	0.72	0.10	0.8	0.95
	2	58	4	62	0.94	0.93	0.68	0.26	0.8	0.99
	avg	57	8	65	0.88	0.88	0.70	0.18	0.8	0.97
	J 1	16	12	27	0.57	0.61	0.64	0.07	1.3	1.00
	2	10	7	17	0.57	0.66	0.71	0.14	0.9	0.83
	avg	13	9	22	0.57	0.64	0.67	0.10	1.1	0.94
	Go 1	14	22	36	0.38	0.37	0.67	0.29	2.2	0.89
	2	16	14	30	0.54	0.53	0.63	0.09	2.2	1.00
	avg	15	18	33	0.46	0.45	0.65	0.19	2.2	0.96
(4) <i>Conc</i> VI 150-sec VI 750-sec	S 1	7	4	11	0.64	0.64	0.79	0.15	1.1	0.76
	2	3	68	71	0.05	0.12	0.76	0.71	1.7	0.67
	avg	5	36	41	0.34	0.38	0.77	0.43	1.4	0.72
	Gi 1	51	21	72	0.71	0.80	0.86	0.15	8.5	0.98
	2	58	12	70	0.83	0.88	0.82	0.01	4.7	1.00
	avg	54	16	71	0.77	0.84	0.84	0.08	6.6	1.00
	B 1	51	4	55	0.93	0.93	0.82	0.11	0.9	1.00
	2	50	4	53	0.93	0.93	0.84	0.09	0.9	1.00
	avg	51	4	54	0.93	0.93	0.83	0.10	0.9	1.00
	J 1	14	12	26	0.53	0.57	0.83	0.30	1.1	0.95
	2	4	3	8	0.58	0.73	0.83	0.25	0.6	0.95
	avg	9	8	17	0.56	0.65	0.83	0.27	0.9	0.95
	Go 1	18	8	26	0.70	0.76	0.81	0.11	1.6	0.95
	2	15	12	26	0.55	0.62	0.86	0.31	1.6	0.97
	avg	16	10	26	0.62	0.69	0.83	0.21	1.6	0.96

ules for three of the subjects. For the other two, rates were substantially higher on the short-interval schedules than on the long-interval ones. Relative response rate is the absolute response rate per minute on the schedule with the shorter mean interreinforcement interval (column i) divided by the sum of the rates of responding on both schedules (column iii). The relative reinforcement rate shown in column vi is the proportion of total reinforcements obtained on the schedule with the shorter interreinforcement interval. Obtained relative reinforcement rates closely matched scheduled rates (0.67 or 0.83). Column vii shows the extent to which relative response rates matched relative reinforcement rates.

The relation between the overall means is shown in Figure 2. The discrepancies were large for all schedules. For the *conc* VI 15-sec VI 30-sec and *conc* VI 15-sec VI 75-sec schedules, mean deviations were 0.12 and 0.25 respectively. For the *conc* VI 150-sec VI 300-sec and *conc* VI 150-sec VI 750-sec schedules (excluding Subject S), mean deviations were 0.14 and 0.16 respectively. In most instances, relative response rates were lower than relative rates of reinforcement. Neither the increase in relative reinforcement rate produced by changing from the *conc* VI 15-sec VI 30-sec to the *conc* VI 15-sec VI 75-sec schedule, nor the increase produced by changing from the *conc* VI 150-sec VI 300-sec to the *conc* VI 150-sec VI

Fig. 2. Relative response rate for component schedule with the shorter interreinforcement interval as a function of relative reinforcement rate on that schedule. Rates are the averages from the two presentations of each schedule.

750-sec schedule, resulted in marked or even consistent corresponding increases in relative response rate.

Column v shows the relative proportion of time during which the subject had his switch set to the component schedule with the shorter mean interreinforcement interval. In general, relative time and relative response rate were nearly identical. Where differences occurred, relative time tended to be closer to the relative rate of reinforcement. Examination of relative response rate and relative time by 30-min blocks indicated that neither increased or decreased systematically over time.

Column viii shows the mean number of changeovers per minute from one of the component schedules to the other. Changeover rates for each subject were higher on the short-interval schedules than on the long-interval ones. Changeover rate and relative response rate were not related.

Column ix shows the proportion of sched-

uled reinforcers received. This proportion is the total number of reinforcements obtained by the subject divided by the total number he could have received if he were responding optimally on each of the component schedules. In no case did subjects receive less than 0.72 of the reinforcers scheduled. Proportions tended to be higher on the long-interval schedules. Proportion of scheduled reinforcers received was not related to relative response rates.

DISCUSSION

The data from the five subjects clearly departed from the expected relation between relative rate of reinforcement and relative rate of responding. Discrepancies between the two relative rates were typically large on all schedules. The results are thus discrepant from those obtained with non-human organisms and from those of Schroeder and Holland (1969) with humans.

Several points of comparison with these earlier studies should be noted. First, with regard to both mean interreinforcement intervals and COD values, the present experiment falls within the bounds in which matching between relative reinforcement rate and relative response rate has been found previously. Fantino *et al.* (1972) investigated concurrent schedules with equivalent relative reinforcement rates but different interreinforcement interval lengths. Absolute differences between relative response rate and relative reinforcement rate ranged from 0.00 to 0.11 (mean 0.04) for the three schedules (*conc VI 6-sec VI 12-sec*, *conc VI 60-sec VI 120-sec*, and *conc VI 600-sec VI 1200-sec*). The length of the COD (1.5 sec) was identical to that used in the present study. Schroeder and Holland's human subjects worked under several sequences of equal and unequal variable-interval concurrent schedules. The unequal schedules included *conc VI 9-sec VI 60-sec*, *conc VI 9-sec VI 30-sec*, and *conc VI 30-sec VI 60-sec*. For five of six subjects, absolute differences between relative response rate and relative reinforcement rate ranged from 0.00 to 0.09 (mean 0.03) when the COD was 1 sec or 2.5 sec. Apart from the common use of human subjects, however, there are various procedural differences between Schroeder and Holland's study and the present one. First, eye movements rather than button presses were studied. Second, subjects worked

a maximum of 125 min under a given schedule, compared with a minimum of 270 min in the present study. Third, subjects were paid a flat hourly wage rather than on the basis of points earned on the schedules. The lack of response-contingent reinforcement represents a major departure from the procedure commonly employed with non-human subjects.

Although subjects failed to match relative response rates to relative reinforcement rates, they were clearly responsive to the scheduled contingencies. Subjects maintained response and changeover rates that were effective in obtaining nearly the maximum number of scheduled reinforcers. For the short-interval schedules, the mean proportion of scheduled reinforcers obtained was 0.85; for the long-interval schedules the mean was 0.93. For the short-interval schedules, changeover delay was a larger proportion of the average length of the interreinforcement intervals than for the long-interval schedules. Thus, subjects were necessarily prevented from obtaining as high a proportion of scheduled reinforcers on the short-interval schedules. The proportions of reinforcers obtained in the present study can be compared with proportions calculated from data of Schroeder and Holland (1969). On those schedules of the Schroeder and Holland study in which a COD was used, the proportion of scheduled reinforcers obtained by the five subjects for whom close matching occurred ranged from 0.65 to 1.00 (mean: 0.86). A sixth subject for whom matching did not occur obtained proportions ranging from 0.38 to 0.83.

While not measured systematically, an additional aspect of the subjects' behavior in the present study appeared to depart from that found with non-human organisms. Subjects' response rates tended to remain constant on a given component schedule. In particular, local response rates did not appear to vary after changeovers. This contrasts with the pattern found by Silberberg and Fantino (1970) with pigeons. Over several COD values, they found rapid response bursts during the delay. Neither the proportion of responses during the delay nor the proportion after the delay matched the proportion of reinforcements on the component schedule. But, since the two separate proportions deviated from matching in the opposite direction, matching on the average level resulted. In the present study, the behavior of the subjects did not appear to be distinguished

simply by the absence of a response burst during the COD. If that were so, relative response rates should have mismatched relative rates of reinforcement by predictable amounts. This was not the case.

Why a matching strategy did not appear with greater frequency with the present subjects is not readily apparent from the data. Nor, apart from the use of human subjects, is the reason apparent from a comparison of the present study with previous ones using non-human organisms. The various effective response patterns observed here raise the equally relevant alternative question: why should a matching strategy be expected? It has not been shown that the scheduled contingencies themselves differentially reinforce a matching strategy. A high proportion of scheduled reinforcers will be obtained if response rates and, in particular, changeover rates are sufficient to avoid long delays in receiving reinforcers as they become available. In the present study, major rate variations in response and changeover rates occurred when short-interval schedules were replaced by long-interval schedules and *vice versa*. However, response and changeover rates were not sensitive to the much smaller changes in reinforcement rate between component schedules.

EXPERIMENT II: EFFECTS OF REINFORCER MAGNITUDE ON CHOICE

METHOD

Subjects and Apparatus

Three female and two male college students, who volunteered via a recruitment notice, served. The apparatus described in Experiment I was used.

Procedure

The effects of four pairs of reinforcer magnitudes were investigated using equal variable-interval schedules. Two of the magnitude pairs—0.8 cent and 0.4 cent, and 1 cent and 0.2 cent—were studied in turn using a *conc* VI 15-sec VI 15-sec schedule. The two other pairs—8 and 4 cents, and 10 and 2 cents—were studied in turn using a *conc* VI 150-sec VI 150-sec schedule. Thus, on both the short- and long-interval schedules, the same two magnitude ratios, 2:1 and 5:1, were investigated. With

these reinforcer amounts, a maximum of \$2.88 per hour was scheduled in each condition, the same amount as in Experiment I.

Table 4
Sequence of Conditions—Experiment 2

Schedule	Reinforcers (cents)	Duration (min)
(a) VI 15-sec	1.0	30
(b) VI 15-sec	1.0	30
(c) conc VI 15-sec VI 15-sec	0.8, 0.4	180*
(d) conc VI 15-sec VI 15-sec	1.0, 0.2	180*
(e) conc VI 15-sec VI 15-sec	0.8, 0.4	90*
(f) conc VI 15-sec VI 15-sec	1.0, 0.2	90*
(g) VI 150-sec	10	30
(h) VI 150-sec	10	30
(i) conc VI 150-sec VI 150-sec	8, 4	180*
(j) conc VI 150-sec VI 150-sec	10, 2	180*
(k) conc VI 150-sec VI 150-sec	8, 4	90*
(l) conc VI 150-sec VI 150-sec	10, 2	90*

*Minimum deviation if stability criterion was met. Otherwise, additional 30-min periods were studied until criterion was met.

Each subject responded in six or seven 2-hr sessions scheduled over approximately two weeks. The sequence in which the schedules and magnitudes were presented is shown in Table 4. The minimum length of time each schedule remained in effect and the stability criterion determining change were identical to those in Experiment I. The instructions used in Experiment I were modified to note the appropriate reinforcer magnitudes. With the two different schedules, the colored lenses paired with each schedule were changed once. The magnitude of the reinforcers for each VI schedule was posted on the wall chart and was changed with each new condition.

RESULTS

Most subjects met the stability criterion for a given condition in close to the minimum duration specified. Subjects worked an average of 196.5 min in the first presentation and an average of 102 min in the second. Table 5 shows the separate (1,2) and averaged (avg) data from the final three 30-min periods of the two presentations of each pair of reinforcer magnitudes. No systematic changes in behavior were apparent in the repetitions, although variability was often substantial.

Columns i-iv of Table 5 show the absolute and relative response rates in the four conditions. For three of the five subjects, total re-

sponse rates were substantially higher on the short-interval schedule than on the long-interval one. For the other two subjects, response rates were approximately constant over the conditions.

Column vi shows the relative proportion of the total amount of reinforcement received by the subjects on the schedule with the larger reinforcer. Relative proportion of reinforcers received closely approximated the scheduled proportion (0.67 or 0.83).

Column vii shows the extent to which relative response rate matched relative proportion of reinforcers received (column iv minus vi). As Figure 3 shows, the discrepancies were large across all schedules, ranging from 0.05 to 0.50 (mean 0.2). In all cases but one, relative response rate was lower than the relative proportion of reinforcers received.

Comparison of the relative proportion of time spent on the schedule with the larger reinforcer (column v) with relative response rate (column iv) reveals a number of substantial

Fig. 3. Relative response rate for component schedule with the larger reinforcer as a function of relative proportion of reinforcers obtained on that schedule. Rates are the averages from the two presentations of each reinforcer pair.

discrepancies. The largest occurred on the long-interval schedules. In general, relative time exceeded relative response rate. Thus, relative time tended to approximate more closely the relative proportion of reinforcers received. Examination of relative time and relative response rate by 30-min blocks did not reveal systematic changes over time. For four of the subjects, changeover rates (column viii) were

substantially higher on the short-interval schedules than on the long-interval ones. Proportion of scheduled reinforcers received (column ix) exceeded 0.74 in all cases, and tended to be higher on the long-interval schedules.

DISCUSSION

Relative response rate failed to match relative proportion of reinforcers received in any

Table 5

Absolute and relative response rates per minute, relative time, relative proportion of reinforcers received, difference between relative response rate and relative proportion of reinforcers received, changeovers per minute, and proportion of scheduled reinforcers received by each subject working under four pairs of reinforcer magnitudes. Data shown for the first (1) and second (2) presentation of each magnitude pair are the averages from the final three 30-min periods of each presentation. The average of (1) and (2) is also given (avg). Relative rates refer to the component schedule with the larger reinforcers. The COD was 1.5 sec for both concurrent schedules.

Schedule	Subject	i	ii	iii	iv	v	vi	vii	viii	ix
		Response Rates/Min		TOTAL	Relative				Changeovers/Min	Prop. Scheduled Reinf. Received
		Larger Reinf.	Smaller Reinf.		Response Rate	Time	Prop. Reinf.	Absolute Deviations (iv-vi)		
(1) Conc VI 15-sec 15-sec (2:1 reinf ratio)	Sh 1	15	12	27	0.57	0.55	0.68	0.11	7.3	0.79
	2	32	21	53	0.61	0.61	0.70	0.09	9.8	0.84
	avg	24	17	40	0.59	0.58	0.69	0.10	8.6	0.82
	Hu 1	12	12	25	0.50	0.64	0.67	0.17	11.2	0.77
	2	21	19	40	0.53	0.72	0.69	0.16	12.0	0.82
	avg	17	16	32	0.52	0.68	0.68	0.16	11.6	0.81
	Ho 1	7	8	16	0.47	0.52	0.67	0.20	6.1	0.74
	2	7	7	13	0.50	0.51	0.67	0.17	12.9	0.76
	avg	7	7	15	0.48	0.52	0.67	0.19	9.5	0.75
	Sa 1	8	7	15	0.52	0.55	0.68	0.16	13.8	0.78
	2	10	9	19	0.52	0.56	0.68	0.16	14.6	0.79
	avg	9	8	17	0.52	0.55	0.68	0.16	14.2	0.78
	L 1	19	17	36	0.54	0.55	0.68	0.14	6.9	0.76
	2	13	11	24	0.54	0.54	0.68	0.14	7.0	0.78
	avg	16	14	30	0.54	0.55	0.68	0.14	7.0	0.77
	Sh 1	29	17	46	0.63	0.64	0.86	0.23	7.9	0.84
(2) Conc VI 15-sec VI 15-sec (5:1 reinf ratio)	2	44	27	71	0.62	0.62	0.88	0.26	12.7	0.88
	avg	36	22	59	0.62	0.63	0.87	0.25	10.3	0.86
	Hu 1	17	13	30	0.56	0.77	0.85	0.29	9.8	0.80
	2	18	13	31	0.57	0.79	0.85	0.28	10.5	0.81
	avg	17	13	31	0.56	0.78	0.85	0.29	10.1	0.80
	Ho 1	8	8	15	0.51	0.51	0.83	0.32	11.3	0.78
	2	9	9	18	0.49	0.38	0.83	0.34	17.4	0.79
	avg	8	8	17	0.50	0.44	0.83	0.33	14.3	0.78
	Sa 1	10	10	20	0.49	0.58	0.84	0.35	16.2	0.80
	2	9	7	17	0.55	0.67	0.86	0.31	11.8	0.75
	avg	10	9	18	0.52	0.62	0.85	0.33	14.0	0.77
	L 1	17	13	30	0.56	0.58	0.84	0.28	7.4	0.81
	2	18	10	28	0.64	0.66	0.86	0.22	6.5	0.82
	avg	17	12	29	0.60	0.62	0.85	0.25	6.9	0.81

Table 5 Continued

Schedule	Subject	i	ii	iii	iv	v	vi	vii	viii	ix
		Response Rates/Min		TOTAL	Relative			Absolute Deviations (iv-vi)	Changeovers/min	Prop. Scheduled Reinf. Received
		Larger Reinf.	Smaller Reinf.		Response Rate	Time	Prop. Reinf.			
(3) <i>Conc</i> VI 150-sec VI 150-sec (2:1 reinf ratio)	Sh 1	38	26	63	0.60	0.59	0.67	0.07	5.1	0.94
	2	31	17	48	0.65	0.64	0.68	0.03	5.4	0.95
	avg	34	21	56	0.62	0.61	0.68	0.05	5.2	0.94
	Hu 1	12	17	28	0.42	0.78	0.69	0.27	10.6	0.94
	2	14	23	36	0.37	0.70	0.68	0.31	15.5	0.98
	avg	13	20	32	0.39	0.74	0.68	0.29	13.1	0.96
	Ho 1	1	1	2	0.51	0.89	0.66	0.15	1.9	0.81
	2	1	1	2	0.50	0.90	0.67	0.17	2.0	0.86
	avg	1	1	2	0.50	0.90	0.66	0.16	1.9	0.84
	Sa 1	8	4	12	0.64	0.68	0.67	0.03	3.2	0.94
	2	8	2	10	0.76	0.89	0.68	0.08	2.3	0.93
	avg	8	3	11	0.70	0.78	0.68	0.06	2.7	0.93
	L 1	9	6	15	0.60	0.66	0.69	0.09	1.2	0.92
	2	8	8	16	0.52	0.53	0.69	0.17	1.5	0.92
	avg	9	7	16	0.56	0.60	0.69	0.13	1.4	0.92
	Sh 1	27	14	41	0.65	0.64	0.84	0.19	5.8	0.99
(4) <i>Conc</i> VI 150-sec VI 150-sec (5:1 reinf ratio)	2	42	13	55	0.77	0.79	0.84	0.07	5.2	1.00
	avg	34	13	47	0.71	0.72	0.84	0.13	5.5	1.00
	Hu 1	8	17	25	0.32	0.77	0.85	0.53	14.9	0.93
	2	10	17	27	0.36	0.74	0.83	0.47	11.1	0.92
	avg	9	17	26	0.34	0.75	0.84	0.50	13	0.92
	Ho 1	1	1	2	0.50	0.91	0.84	0.34	1.9	0.85
	2	1	1	2	0.50	0.90	0.85	0.35	1.9	0.87
	avg	1	1	2	0.50	0.91	0.84	0.34	1.9	0.86
	Sa 1*	11	2	13	0.86	0.94	0.85	0.01	1.8	0.98
	2	4	2	6	0.68	0.91	0.86	0.18	1.9	0.92
	avg	7	2	9	0.77	0.92	0.86	0.09	1.9	0.95
	L 1	13	7	20	0.64	0.67	0.84	0.20	1.8	0.88
	2	9	7	16	0.59	0.60	0.84	0.25	1.5	0.91
	avg	11	7	18	0.62	0.64	0.84	0.22	1.6	0.90

*Last 60 min

of the four conditions. Subjects tended to respond similarly on the same concurrent schedule regardless of the reinforcer magnitude ratios. As in the previous experiment, high proportions of scheduled reinforcers were obtained by subjects using a wide variety of response and switching patterns.

The failure to obtain matching between relative response rate and relative reinforcer magnitude is consistent with results obtained by Fantino *et al.* (1972) but inconsistent with matching found by Catania (1963) and Brownstein (1971). Of these studies, only Fantino *et al.*'s, investigated a range of schedules (*conc* VI 600-sec VI 600-sec, *conc* VI 60-sec VI 60-sec,

conc VI 10-sec VI 10-sec) using a constant (1.5 sec) COD. Reinforcer durations (magnitudes) on each schedule were 1.5 and 6.0 sec. The present findings are also consistent with those from a study by Todorov (1973) in which reinforcer frequency and duration were co-varied. Reinforcement frequency but not duration was predictive of relative response rate.

As in the previous experiment, changeover rate was related to overall reinforcement frequency on the concurrent schedules. Subjects tended to change over more often on the short-interval schedule than on the long-interval one. In contrast to the previous experiment, occasional large discrepancies were found be-

tween relative response rate and relative time. In these instances, subjects responded at a higher rate when switched to the lower-paying than the higher-paying component schedule.

In conclusion, the results from the two experiments using human subjects have only partially replicated previous findings derived primarily from non-human organisms. While the procedural differences characterizing the present study may ultimately account for the discrepancies, the results suggest that simple application of previous generalizations regarding the effects of reinforcement rate on choice among variable-interval schedules does not accurately predict human behavior in this situation.

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