*HUMAN CONCURRENT PERFORMANCES:
THE EFFECTS OF EXPERIENCE, INSTRUCTIONS, AND
SCHEDULE-CORRELATED STIMULI*

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In order to investigate the effects of separate exposures to single schedules, of unique schedule-correlated stimuli, and of independency-informing instructions upon choice under concurrent variable-interval schedules, 28 human subjects were divided into eight groups. Each subject was exposed to a baseline procedure, an experimental procedure, and a return to the baseline procedure. Different combinations of these three manipulations were applied to the different groups only during the experimental phase (except for the independency-informing instructions, which were given to half of the groups at the start of training). For the group of subjects exposed to the combination of all three manipulations, the logarithms of the ratios of response frequencies tended to be linearly related to the logarithms of the ratios of reinforcement frequencies during the experimental phase. These orderly effects were not obtained with subjects in the other groups. The results suggest that human choice was well described by the generalized matching law when the three manipulations were simultaneously in effect, and that unreported differences in the use of these three procedural variables might partly account for contradictions between results in previous studies of human concurrent performance.

Key words: matching law, concurrent variable-interval schedules, instruction, discriminative stimulus, lever pressing, humans

Herrnstein (1961) proposed the following equation to describe the relationship between responding and reinforcement under concurrent variable-interval schedules of reinforcement (concurrent VI VI):

$$\frac{B_1}{B_1 + B_2} = \frac{r_1}{r_1 + r_2}, \quad (1)$$

where B_1 and B_2 are the frequencies of responding on alternatives 1 and 2, and r_1 and r_2 are the frequencies of reinforcement produced. Baum (1974) has proposed a more generalized form of Equation 1 in terms of a power function:

$$\frac{B_1}{B_2} = k \left(\frac{r_1}{r_2} \right)^a, \quad (2)$$

where k and a are empirically determined constants. The parameter k is thought to index any constant proportional bias toward a given response alternative, and the parameter a is thought to be an index of a subject's sensitivity to the ratio of reinforcements on the two alternatives. Values of a less than unity indicate "undermatching"—that is, proportional changes in behavior that are systematically smaller than the proportional changes in reinforcement rates that produced them; values of a greater than unity indicate "overmatching"—that is, proportional changes in behavior that are systematically greater than the proportional changes in reinforcement rates that produced them.

Although the matching law has been extensively supported in experiments with infra-human subjects in a wide variety of experimental situations (for a review, see de Villiers, 1977; for contrary interpretations, see Iwamoto & Takahashi, 1982; Myers & Myers, 1977; Takahashi & Iwamoto, 1982), studies with humans have produced results that give conflicting evaluations of that formulation. To our knowledge, there have been 17 such studies with humans reported in the literature.

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For eight of these, the results differing from the remaining nine human studies could be attributed to particular features of the experiments. In some cases, subjects were from abnormal populations (Cliffe & Parry, 1980; Oscar-Berman, Heyman, Bonner, & Ryder, 1980; Schroeder, 1975). In other cases, two-operanda situations analogous to those typically used in animal studies were not utilized (Conger & Killeen, 1974; Pierce, Epling, & Greer, 1981; Schroeder & Holland, 1969). In still others, vigilance tasks were used, under which human performances are likely to be inconsistent with those of humans under other tasks (Baum, 1975; Buskist & Miller, 1981; Schroeder & Holland, 1969); the former performances are said to have stronger tendencies to conform to the same behavioral law as animals (Holland, 1958). However, the remaining nine relevant studies with humans (and the normal-subject group of the study by Oscar-Berman et al., 1980) do not produce a consistent pattern, even though they used normal subjects and two-operanda situations that were not vigilance tasks. In some studies, all subjects showed systematic variations of choice ratios with reinforcement ratios and were consistent with matching (Bradshaw, Ruddle, & Szabadi, 1981; Bradshaw, Szabadi, & Bevan, 1976, 1979; Bradshaw, Szabadi, Bevan, & Ruddle, 1979; Ruddle, Bradshaw, & Szabadi, 1981; Ruddle, Bradshaw, Szabadi, & Bevan, 1979; Ruddle, Bradshaw, Szabadi, & Foster, 1982). However, other studies included results from subjects who did not show systematic variations of choice ratios with reinforcement ratios (Schmitt, 1974; Wurster & Griffiths, 1979).

Close examination reveals that procedures used in these 10 studies were different in many ways (as they necessarily must be) from those in animal studies, which have produced a consistent pattern of results. First, in the human studies on choice, subjects were given verbal instructions with respect to the availability of two alternative tasks on which they could work. In all but Wurster and Griffiths' (1979) study, the tasks were explicitly described as independent, but even in that case there were two counters, one correlated with each alternative, and this might have suggested the independence of the alternatives. In animal studies on choice, of course, such instructions are not employed. Second, in some of the hu-

man studies on choice (Bradshaw et al., 1981; Bradshaw, Szabadi, & Bevan, 1976, 1979; Bradshaw, Szabadi, Bevan, & Ruddle, 1979; Ruddle et al., 1979, 1981, 1982), there were exteroceptive discriminative stimuli, each uniquely correlated with a particular schedule (and thus with its rate of reinforcement). For example, a red lamp is always illuminated on a key when VI 30 s is in effect on the key, blue when VI 60 s, and so on; the red lamp accompanies only the VI 30-s schedule. Therefore, there are always two stimuli, each of which is associated with a schedule component that is currently in effect and never with other rates of reinforcement. Animal studies on choice typically do not utilize such stimuli. Distinctive stimuli are correlated with particular schedules, but those correlations are consistent only within phases, and not across a whole experiment. Third, in some of the human studies on choice (Bradshaw et al., 1981; Bradshaw, Szabadi, & Bevan, 1976, 1979; Bradshaw, Szabadi, Bevan, & Ruddle, 1979; Ruddle et al., 1979, 1981, 1982; Schmitt, 1974), subjects had been exposed to single VI schedules successively before being exposed to them concurrently. In experiments with animals, subjects are experimentally naive in some cases and not in others.

The procedures used in different studies involve the presence or absence of these three factors, and such differences might account, at least in part, for the pattern of results obtained. Without exception, the studies in which all three features were present (those of both Bradshaw and his colleagues and Ruddle and his colleagues) were consistent with the matching law, but others did not always support matching. The present study divided 28 human subjects into eight groups and exposed them to different combinations of the above three features, in order to compare directly the effects of these three procedural variables with a single experimental setting.

METHOD

Subjects

Subjects were 28 undergraduate students of Hokkaido University (10 female and 18 male). All were volunteers obtained through a recruitment notice to participate in a psychological experiment and all were experimentally naive at the start of training.

Apparatus

Experimental sessions took place in a small darkened room. Subjects sat at a desk surrounded on three sides by boards and faced a panel (45 cm in width and 40 cm in height) that was embedded in the front board (Figure 1). On the panel, 6 cm above the desk, were set two levers (2.2 by 2.0 by 0.6 cm), spaced 20 cm apart center to center. Each lever operated at a minimum force of approximately 0.05 N. Each effective response activated a microswitch behind the panel, producing an audible click. One orange lamp was located 3 cm above the left lever, and three orange lamps were located 3 cm above the right lever. Centered 20 cm above the desk was a digital counter with a red lamp 3 cm below. A houselamp was mounted centrally, 65 cm above the desk, and provided ambient illumination during the sessions. White masking noise (70 dB) was presented through a headphone (TRIO, KH-71) worn by the subject. All experimental contingencies and data recording were implemented by a PDP®-11/03 computer located in an adjacent room.

Procedure

Each experimental session lasted 10 min, and consecutive sessions were separated by 5-min rest periods. Several sessions were held on a given day. Subjects worked 3 to 4 days per week, for approximately 3 consecutive weeks.

The subjects were divided into eight groups, identified as Group-Control ($n = 3$), Group-C ($n = 4$), Group-S ($n = 4$), Group-CS ($n = 4$), Group-I ($n = 3$), Group-IC ($n = 3$), Group-IS ($n = 3$), and Group-ICS ($n = 4$). "S" denotes separate exposures to single schedules; "C" denotes exposure to unique schedule-correlated stimuli; and "I" denotes exposure to instructions regarding independence of the two alternative schedules that were available in the concurrent procedure. With one exception, subjects in all groups were exposed to three phases consisting of Baseline-1, Experimental Phase, and Baseline-2, successively; the 4 subjects in Group-C were not exposed to Baseline-2 because they were given some instruction about schedules in a psychology course during the training days.

General procedure. In each phase, subjects were exposed to (1) concurrent VI 60 s VI

Fig. 1. A diagram of the apparatus.

60 s, (2) concurrent VI 60 s VI 30 s, and (3) concurrent VI 60 s VI 120 s. For a given subject, the sequence of exposure to these schedules was either 1-2-3-1 or 1-3-2-1. All VI schedules were constructed according to the progression described by Catania and Reynolds (1968). Each pair of concurrent schedules remained in effect until relative response rates in three consecutive 10-min sessions differed by no more than 10% and showed no directional trend. If this criterion was not met within seven sessions, the next concurrent schedule was introduced. Responding usually stabilized within four sessions, and the mean numbers of sessions under each concurrent schedule were 4.0 for Group-Control, 4.4 for Group-C, 4.3 for Group-S, 3.6 for Group-CS, 3.8 for Group-I, 3.8 for Group-IC, 3.6 for Group-IS, and 4.1 for Group-ICS. The seven-session rule was used in only seven cases. Throughout the experiment, a 5-s changeover delay was imposed; responses emitted during the first 5 s following a changeover from one component to the other had no scheduled consequences.

Baseline-1. On the first day of Baseline-1, subjects in the groups that were not given the independency-informing instructions (Group-Control, Group-C, Group-S, and Group-CS) were given the following instructions:

Your task is to increase this counter by pressing these levers. Sometimes when you press the lever the red lamp will flash on and the counter will increase. Please ignore the orange lamps; they will not apply to you. [A] Each count is worth 5 yen [equal to about 2 cents, U.S.]. Do not press the two levers at the same time. Press the right lever with your right hand and the left lever with your left hand. At the beginning of the session, this light [the experimenter indicates the houselamp] will turn on and stay on for 10 minutes, and throughout this period you can earn money. At the end of 10 minutes, the lamp will go off. Please get as much money as you can.

The instructions for subjects in Group-I, Group-IC, Group-IS, and Group-ICS were slightly different from those above; at point [A] there were the following additional instructions regarding the independence of the two alternatives:

There are two levers, each of which can increase the counter independently. You can choose between them freely.

After receiving the above instructions, the subjects in all eight groups were exposed to the series of concurrent VI VI schedules described in *General procedure*.

Experimental Phase. The subjects of Group-Control and Group-I were trained in the same procedure as in Baseline-1. No additional instructions were given.

On the first day of the Experimental Phase, the subjects of Group-S and Group-IS ("S" denotes exposure to single schedules) received the following instructions:

Today we will start a new procedure. You can press only the right lever. At the beginning of the session, this lamp [experimenter indicates the houselamp] will turn on and stay on for 10 minutes, and throughout this period you can earn money. At the end of 10 minutes, the lamp will turn off. Please get as much money as you can.

Then they were exposed to single VI sched-

ules—that is, VI 30 s, VI 60 s, and VI 120 s—on the right lever in quasi-random order; all the orange lamps remained off. Each schedule was effective for only one session (10 min). After these single-schedule exposures, subjects were exposed to the same concurrent VI VI schedules as in Baseline-1.

On the first day of the Experimental Phase, the subjects of Group-C and Group-IC ("C" denotes exposure to unique schedule-correlated stimuli) were informed that there would be "a slight change in the situation." During the Experimental Phase, each orange lamp was correlated with a different VI schedule (i.e., a different reinforcement rate). The orange lamp above the left lever was always on, indicating that the left lever was always correlated with VI 60. One of the orange lamps on the right lever was turned on according to the schedule that was in effect on the right lever: The left lamp was on when VI 30 was in effect, the center lamp when VI 60 was in effect, and the right lamp when VI 120 was in effect. No instructions were given about these orange lamps.

The subjects of Group-CS and Group-ICS were given the same instructions used for Group-S and Group-IS (see above) on the first day of the Experimental Phase. Then they were exposed to the three single VI schedules in quasi-random order. Each single schedule was in effect for only one session (10 min). During these single-schedule exposures, one of the orange lamps above the right lever was turned on in accordance with the schedule in effect: The left lamp was on when VI 30 was in effect, the center lamp was on when VI 60 was in effect, and the right lamp was on when VI 120 was in effect. No instructions were given regarding these orange lights. After these single-schedule exposures, the subjects were exposed to the same concurrent schedules (with schedule-correlated stimuli) used in the Experimental Phase of Group-C and Group-IC.

Baseline-2. On the first day of Baseline-2, the subjects of the six groups except Group-Control and Group-I were informed that there would be "a slight change in the situation." Then they were exposed to the same concurrent schedules used in Baseline-1 of each group. The subjects of Group-Control and Group-I were trained in the same procedures as in Baseline-1, and no additional instructions were given.

Table 1
Regression line slopes and coefficients of determination.

Group	Sub- ject	Response						Time					
		Baseline-1		Exp. Phase		Baseline-2		Baseline-1		Exp. Phase		Baseline-2	
		<i>a</i>	<i>r</i> ²	<i>a</i>	<i>r</i> ²	<i>a</i>	<i>r</i> ²	<i>a</i>	<i>r</i> ²	<i>a</i>	<i>r</i> ²	<i>a</i>	<i>r</i> ²
Cont.	C.H.	-.77	.850	.28	.308	-.63	.955	-.19	.739	.35	.921	-.34	.781
	Y.S.	.24	.093	.29	.858	.45	.970	.21	.045	.29	.987	.06	.537
	H.T.	-.09	.043	-1.19	.711	-.69	.924	-.21	.975	-.60	.786	-.62	.951
C	K.N.	-.30	.836	-.35	.950			-.40	.961	-.23	.918		
	T.M.	.15	.132	-.22	.990			-.19	.727	-.25	.999		
	T.N.	.00	.000	-.06	.986			-.01	.247	-.09	1.000		
	A.M.	-.24	.852	.12	.073			-.17	.987	-.04	.078		
S	S.O.	-.19	.739	-.64	.745	-1.36	.952	-.25	.865	-.60	.918	-1.66	.903
	K.N.	.10	.360	.24	.989	-.13	.711	.10	.366	-.15	.988	-1.01	.997
	K.I.	.52	.351	.08	.066	1.36	.955	.52	.338	.12	.974	1.17	.996
	H.S.	-.19	.650	-.09	.212	-.22	.938	-.19	.441	-.22	.928	-.26	.839
CS	N.M.	.02	.007	.11	.662	-.10	.914	.01	.042	.07	.462	-.17	.607
	N.I.	-.57	.889	-.48	.534	-.93	.996	-.69	.908	-.69	.726	-.89	.998
	G.M.	.35	.919	.17	.917	-.56	.966	.36	.978	.23	.883	-.54	.956
	T.A.	-.02	.100	.15	.897	.15	.335	.03	.420	.25	.938	.27	.758
I	M.T.	-.40	.958	-.80	.862	-2.25	.999	-.52	.758	-.72	.871	-2.12	.999
	J.G.	-.20	.312	.07	.808	-.91	.855	-.22	.594	-.02	.223	-.84	.847
	J.O.	.16	.045	-.44	.994	-.12	.937	.03	.014	-.30	1.000	-.02	.604
IC	O.K.	.36	.943	-.11	.679	-.03	.054	.31	.916	-.16	.641	-.02	.032
	Y.O.	-.05	.025	-.41	.935	-.44	.979	-.07	.188	-.30	.810	-.26	.989
	N.Y.	-.76	1.000	-.39	.999	.09	.111	-.69	.964	-.46	1.000	.14	.253
IS	T.M.	.69	.777	.36	.908	-.16	.998	.53	.625	.40	.956	-.25	.944
	E.T.	-.00	.000	-.11	.309	.18	.563	-.10	.306	-.27	.913	.02	.058
	T.S.	.67	.973	.29	.978	.54	.993	.02	.030	.25	1.000	.34	.937
ICS	N.T.	-.03	.003	.78	.887	-.46	.997	.03	.004	.78	.909	-.44	.999
	R.I.	.29	.588	.68	.896	.37	.710	.25	.467	.67	.889	.39	.727
	T.Y.	-.33	.480	.42	.481	-.22	.506	-.47	.555	.51	.801	-.11	.130
	T.O.	-2.24	.921	.45	.996	-1.28	1.000	-2.27	.908	.50	.949	-1.38	.999

RESULTS

Figure 2 shows the logarithms of the choice ratios as a function of the logarithms of the reinforcement ratios for subjects in Group-Control, Group-C, and Group-S; Figure 3 shows those for subjects in Group-ICS (the results for Group-CS, Group-I, Group-IC, and Group-IS are not shown by graphs because, as noted later, they showed almost the same patterns as those shown in Figure 2). In these figures, the left graph in each pair shows plots relating the logarithms of the ratios of the response frequencies at the two alternatives (R_R/R_L) to the logarithms of the ratios of the reinforcement frequencies at the two alternatives (r_R/r_L). The right graphs show similar plots relating the logarithms of the ratios of the amounts of time allocated to the two alternatives (T_R/T_L) to the logarithms of the ratios of the reinforcement frequencies at

the two alternatives. The topmost graphs in each group panel indicate the data during Baseline-1; the middle graphs indicate those during Experimental Phase; and the bottom graphs show those during Baseline-2. (As noted earlier, subjects in Group-C were not exposed to the second baseline condition.) In each graph, one symbol represents the data during the last three 10-min sessions under each concurrent schedule, and the symbols for a given subject are connected by broken lines. The data under concurrent VI 60 VI 60 schedules are averaged between two exposures, and the ranges of these data are also shown. The diagonal lines represent the locus of perfect matching between responses and reinforcement ratios.

Functions corresponding to Equation 2, and based on the data from each subject under each condition for all eight groups, were fitted

Fig. 2. Ratios of response rates in the two components (R_R/R_L : left-hand graphs) and ratios of time spent in the two components (T_R/T_L : right-hand graphs), plotted against the ratios of the reinforcement frequencies in the two components (r_R/r_L) using double logarithmic coordinates (base 10), for the subjects in Group-Control, Group-C, and Group-S. The topmost graphs in each group panel indicate the data during Baseline-1, the middle graphs indicate those during Experimental Phase, and the bottom graphs those during Baseline-2. In each graph one symbol represents the data obtained from 1 subject during the last three sessions under each concurrent schedule. The diagonal lines show the ideal matching relationship. See text for further details.

by the method of least squares (Baum, 1974). The values of their slopes and correlation coefficients for both response-distribution and time-distribution measures are shown in Table 1. (The values of their intercepts are not shown; most of them were approximately equal to unity and no systematic effects were found on this variable in the present study.)

In Group-Control, 1 subject (Y.S.) showed systematic variations of responding with reinforcement ratios (i.e., higher choice ratios for the schedule that provided the higher reinforcement frequency) in time ratios during the Experimental Phase and response ratios during Baseline-2, and the values of a in these cases were 0.29 ($r^2 = 0.987$) and 0.45 ($r^2 =$

0.970), respectively. The remaining 2 subjects (C.H. and H.T.), however, did not show such a tendency during any of the three phases.

None of the 4 subjects in Group-C showed such a tendency in either response or time ratios during either of the two phases to which they were exposed.

In Group-S, K.N. showed such systematic variations of responding in response ratios during the Experimental Phase, and K.I. also showed such a tendency in both response and time ratios in Baseline-2. However, these data did not seem reliable because the ratios of responding under concurrent VI 60 VI 60 were quite different during the two exposures to that schedule.

Data from the three groups for which two procedural features were combined were similarly unsystematic, so they are not presented in graphic form. In Group-CS, T.A. showed positive relationships to reinforcement ratios in both response and time ratios only during the Experimental Phase; the values of a in these cases were 0.15 ($r^2 = 0.897$) and 0.25 ($r^2 = 0.938$), respectively. G.M. also showed such a tendency in both response and time ratios during Baseline-1 and the Experimental Phase, and the values of a were 0.35 ($r^2 = 0.919$), 0.36 ($r^2 = 0.978$), 0.17 ($r^2 = 0.917$), and 0.23 ($r^2 = 0.883$), respectively. In Group-IC, 1 subject (O.K.) showed systematic variations of responding during Baseline-1, and the values of a were 0.36 ($r^2 = 0.943$) in response ratios and 0.31 ($r^2 = 0.916$) in time ratios. In Group-IS, T.M. showed such a tendency in response and time ratios during the Experimental Phase, and the values of a were 0.36 ($r^2 = 0.908$) in response ratios and 0.40 ($r^2 = 0.956$) in time ratios. T.S. also showed such a tendency in response ratios during Baseline-1, and in both response and time ratios during the Experimental Phase and Baseline-2. The values of a in these cases were 0.67 ($r^2 = 0.973$) during Baseline-1, 0.29 ($r^2 = 0.978$) and 0.25 ($r^2 = 1.000$) during the Experimental Phase, and 0.54 ($r^2 = 0.993$) and 0.34 ($r^2 = 0.937$) during Baseline-2. None of the 3 subjects in Group-I showed such systematic variations in either measure during any of the three phases.

In contrast with the results from the above seven groups, 3 of the 4 subjects in Group-ICS (N.T., R.I., and T.O.) showed systematic variations of choice ratios with reinforcement

Fig. 3. Ratios of response rates in the two components (R_R/R_L : left-hand graphs) and ratios of time spent in the two components (T_R/T_L : right-hand graphs), plotted against the ratios of the reinforcement frequencies in the two components (r_R/r_L) using double logarithmic coordinates (base 10), for the subjects in Group-ICS. See text and the caption of Figure 2 for further details.

ratios in both response and time ratios only during the Experimental Phase, and values of a in these cases were 0.78 ($r^2 = 0.887$) and 0.78 ($r^2 = 0.909$) for N.T., 0.68 ($r^2 = 0.896$) and 0.67 ($r^2 = 0.889$) for R.I., and 0.45 ($r^2 = 0.996$) and 0.50 ($r^2 = 0.949$) for T.O. The remaining subject in that group (T.Y.) also showed such variations only during the Experimental Phase, but only in time ratios, and the value of a in this case was 0.51 ($r^2 = 0.801$).

In summary, in the seven groups other than Group-ICS, no more than 1 or 2 subjects in any group showed systematic variations of choice ratios with reinforcement ratios (higher choice ratios for the schedules that provided the higher ratios of reinforcement frequency), and such effects were not confined to the Experimental Phase. In contrast, in Group-ICS, 3 of the 4 subjects showed such variations in both response and time ratios only during the Experimental Phase, with relatively high val-

ues of *a*. The remaining 1 subject also showed such performance in time ratios. In other words, only during the Experimental Phase for Group-ICS were measures of schedule preference well described by the matching law.

Previous studies with animals (Brownstein & Pliskoff, 1968; Herrnstein, 1961; Stubbs & Pliskoff, 1969) have shown that the number of changeovers decreases as a function of the difference between the reinforcement frequencies of the two alternatives in a concurrent scheduling task. Such an effect was not consistently found in the present study. Some subjects showed such a tendency during the Experimental Phase (T.M. in Group-C, J.G. in Group-I, E.T. in Group-IS), whereas some subjects showed it during Baseline-1 (C.H. in Group-Control, N.T. and R.I. in Group-ICS) or Baseline-2 (C.H. in Group-Control, M.N. and T.A. in Group-CS, and T.O. in Group-ICS). Moreover, two exposures to concurrent VI 60 VI 60 yielded quite different changeover rates in most cases.

A detailed analysis of the data revealed that no subjects showed systematic patterns of changeover, such as spending x s on Schedule 1 and then y s on Schedule 2 with fixed x and y values. Rather, these values (interchange-over time) tended to vary from moment to moment.

DISCUSSION

The present experiment was designed to examine the effects of three procedural variables—independency-informing instructions (I), unique schedule-correlated stimuli (C), and single-schedule exposure (S)—on human concurrent performances, with the other variables held constant. The results showed that human allocation of time and responses tended to conform to the matching law only when all three manipulations were combined (Experimental Phase of Group-ICS).

Several factors restrict the generality of the finding, however. In the present experiment, the I factor was introduced in Baseline-1, and the S and C factors were introduced in the Experimental Phase. Consequently, we could not assess the effect of the I variable within subjects, although we could do so for the S and C variables. Hence, further research is needed to examine the effect of the I variable alone within subjects.

Moreover, in Group-CS and Group-ICS, the C and S variables were confounded. During the single-schedule exposures in Group-CS and Group-ICS, the three different schedules were correlated with the three different lights; during the same procedure in Group-S and Group-IS, the three schedules were correlated with only one stimulus. In other words, the S manipulation was not studied in the same way in all four groups exposed to it. Therefore, in order to specify more exactly the conditions necessary for the systematic variations of choice ratios with reinforcement ratios, the effect of the S *with* C on choice *without* C, and the effect of the S *without* C on choice *with* C, should be examined.

The present study yielded no information on human choice between extremely disparate reinforcement frequencies such as VI 51 s and VI 720 s, which Bradshaw et al. (1976) used in their experiment, because a restricted range of reinforcement ratios (2:1, 1:1, 1:2) was used in the present experiment. Recently, Navarick and Chellsen (1983) reviewed studies of human performance and concluded that sensitivity of human choice to reinforcement ratios is correlated with the range of the reinforcement ratios encountered. Interestingly, the undermatching obtained during the Experimental Phase of Group-ICS in the present study is consistent with other human studies that have used a restricted range of reinforcement ratios. However, Navarick and Chellsen would predict the same degree of undermatching during all three phases of all eight groups of the present study, and this prediction is not consistent with our findings. Therefore, it would seem that the above three variables predict human choice between variable-interval schedules more accurately.

Although the data during the Experimental Phase of Group-ICS showed that with the above three manipulations combined, human choice tended to conform to the matching law within several brief sessions, performances under the other conditions might show matching after more extended periods of training—such as more than ten 10-min sessions under each schedule, which Bradshaw and his colleagues (1976, 1979, 1981) and Ruddle et al. (1979, 1981, 1982) adopted. Recently, Todorov, Oliveira Castro, Hanna, Bittencourt de Sa, and Barreto (1983) discussed studies of human and animal concurrent performance

and concluded that measured sensitivity of choice is correlated with the number of days of training and the number of previous experimental conditions in the subject's history. This conclusion, coupled with our adopting a fairly lenient basis for changing conditions (three 10-min sessions with less than 10% variation, or seven sessions maximum), suggests that the absence of matching in the present study might be mainly the result of insufficient exposure to the experimental conditions. The orderly result for Group-ICS (for which all manipulations were combined) partly mitigates this judgment, but the possibility remains that more extended exposure would have produced orderly results for other conditions as well.

Values of a in the linear regression equations for each subject during the Experimental Phase of Group-ICS are lower than those obtained in the previous human studies with the three manipulations combined (Bradshaw et al., 1981; Bradshaw, Szabadi, & Bevan, 1976, 1979; Bradshaw, Szabadi, Bevan, & Ruddle, 1979; Ruddle et al., 1979, 1981, 1982). Such a difference between values of a could be due to many unknown factors, although the differences discussed above (schedule values or periods of training) might account for much of the discrepancy. Values of a noted for subjects in the other groups are, of course, much lower than those obtained by Bradshaw and his colleagues, and well below the range observed in animal data (see Baum, 1979; Wearden & Burgess, 1982). To our knowledge, a relationship inverse to that of matching is unknown in animal data when the same reinforcer is used in both concurrent alternatives (although there is the possibility that nonmatching animals might be discarded in early sessions of experiments), but this has been found in humans by Pierce et al. (1981). Therefore, further systematic research is needed before conclusions can be reached about the general applicability of the matching law to human behavior.

For Group-ICS, the data consistent with the matching law were found in the Experimental Phase, but not in Baseline-2. The only change in procedure in Baseline-2 was the removal of lights, so the unique schedule-correlated stimuli may be necessary for producing sensitivity to the manipulations of reinforcement ratios. This finding might be

relevant to the results of previous studies that used schedules other than concurrent VI VI with humans and examined the effects of unique schedule-correlated stimuli (e.g., Galizio, 1979; Wearden & Quinn, 1982). The studies of Galizio and Wearden and Quinn employed temporally constrained schedules (avoidance or interresponse-time contingencies) with stimuli that differed according to schedule value, and neither obtained clear differentiation of performance depending on schedule. Galizio then added "instructional labels" that gave subjects more information about the schedules, and the differentiation of responding appeared. In the present study, unique schedule-correlated stimuli produced the differentiation of responding, but only when combined with "independency-informing instructions" and "single-schedule exposures." Hence, combination of unique schedule-correlated stimuli with the latter two manipulations might have had the same effect as the "instructional labels" used by Galizio. This speculation suggests that human choice would conform to the matching law with "instructional labels" that inform the subjects of reinforcement rates accompanying each alternative.

A great many experimental studies have indicated that human schedule performances are not always the same as those of animals (see Lowe, 1979; Matthews, Shimoff, Catania, & Sagvolden, 1977). The present study, which showed that the above three manipulations might be needed in order for human choice to conform to the same behavioral law as that of animals, may be in close agreement with these studies. Although it is not clear why there are major differences between human and non-human behavior, Bentall, Lowe, and Beatty (1985) have recently suggested that many such differences might be accounted for by human subjects' covert verbal behavior. Covert verbal behavior in adult humans may strongly govern their overt operant behavior, and when they formulate their own rules of their environment upon verbal descriptions, their behavior may be no longer affected directly by contingencies of reinforcement. On the other hand, animals and preverbal human infants may be directly controlled by environmental contingencies because they do not have relevant verbal skills (Bentall et al., 1985).

All of the three manipulations examined in

the present study may have helped the subjects to correctly describe contingencies and the rates of reinforcement in concurrent VI VI schedules. If this speculation is correct, it is suggested that when human subjects correctly formulate the contingencies and the rates of reinforcement by some manipulation, their choice might be well described by the matching law.

In conclusion, human performances under concurrent VI VI schedules can be said to have a tendency to conform to the matching law when the above three manipulations are combined. Hence, we might conclude that absence or presence of these three manipulations can partly account for the contradiction in the results of the previous 10 studies with humans, in which experimenters have manipulated such procedural variables without adequately describing them or noting their importance.

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