

**PERFORMANCE OF HUMANS IN CONCURRENT
AVOIDANCE/POSITIVE-REINFORCEMENT SCHEDULES**

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Performance maintained under concurrent schedules consisting of a variable-interval avoidance component and a variable-interval positive-reinforcement component was studied in three human subjects using points exchangeable for money as the reinforcer. The rate of responding in the avoidance component increased, and the rate of responding in the positive-reinforcement component declined, as a function of the frequency of point-losses avoided in the avoidance component. The performance of all three subjects conformed to equations proposed by Herrnstein to describe behavior in concurrent schedules. The logarithms of the ratios of the response rates in the two components, and the logarithms of the ratios of the times spent in the two components, were linearly related to the logarithms of the ratios of the frequency of loss avoidance in the avoidance component to the frequency of reinforcement in the positive-reinforcement component. When a changeover delay of 5.0 sec was imposed, the slopes of the linear functions were close to 1.0 in the case of two subjects, whereas the third subject exhibited significant undermatching. For two subjects the changeover delay was then reduced to 2.0 sec; in both cases the slopes of the linear functions were lower than under the 5.0-sec condition. One subject participated in a third phase, in which no changeover delay was imposed; there was a further reduction in the slopes of the linear functions.

Key words: Herrnstein's equation, matching law, concurrent avoidance/positive-reinforcement schedules, changeover delay, button pressing, humans

Herrnstein (1970, 1974) has proposed equations of the following forms to describe performance in concurrent schedules of positive reinforcement:

$$R_A = R_{\max} \cdot r_A / (K_H + r_A + r_B) \quad (1)$$

$$R_B = R_{\max} \cdot r_B / (K_H + r_A + r_B), \quad (2)$$

where R is response rate, r is reinforcement frequency, and the subscripts A and B designate the two components of the concurrent schedule; R_{\max} and K_H are both constants. If the reinforcement frequency in Component B (r_B) is kept constant, Equation 1 predicts that the rate of responding in Component A will be an increasing hyperbolic function of the frequency of reinforcement in Component A (r_A), whereas Equation 2 predicts that the rate of responding in Component B will be a decreasing hyperbolic function of the frequency

of reinforcement in Component A. If the values of R_{\max} and K_H are assumed to be the same in Equations 1 and 2, the two equations may be combined to yield the Matching Law (Herrnstein, 1970):

$$R_A / R_B = r_A / r_B. \quad (3a)$$

Baum (1974), Lander and Irwin (1968), and Staddon (1968) have proposed a modification to Equation 3a:

$$R_A / R_B = k(r_A / r_B)^a. \quad (3b)$$

Equation 3b, often termed the 'Generalized Matching Law' (Baum, 1974), allows for two types of deviation from the ideal matching relationship defined by Equation 3a. Values of k deviating from unity indicate a *bias* in favor of one or other of the component schedules. Values of a less than unity indicate *undermatching*, a weaker preference for the component with the higher reinforcement frequency than would be predicted by Equation 3a; values of a greater than unity indicate *overmatching*, a stronger preference for the component with the higher reinforcement frequency than would be predicted by Equation

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3a. The same relationship may also be used to describe the distribution of time (T) between the two components of a concurrent schedule:

$$T_A/T_B = k(r_A/r_B)^a. \quad (3c)$$

Experiments with animals have provided a considerable body of evidence in support of these equations (for review, see de Villiers & Herrnstein, 1976; de Villiers, 1977; Baum, 1979). Experiments carried out using human subjects have, with few exceptions, also yielded results consistent with the equations (for review, see Bradshaw, Ruddle, & Szabadi, 1981; Szabadi, Bradshaw, & Ruddle, 1981; McDowell, 1981).

The experiment described here was concerned with the application of these equations to performance maintained by negative as well as positive reinforcement. A number of writers have discussed the possibility that positive and negative reinforcement are functionally "symmetrical" (de Villiers, 1977, 1981; Farley & Fantino, 1978; Herrnstein, 1969; Herrnstein & Hineline, 1966; Hineline, 1977; Morse & Kelleher, 1966; Schuster & Rachlin, 1968). Support for this suggestion has been provided by the demonstration that performance maintained by negative reinforcement can be described by analogues of the equations, listed above, that described performance maintained by positive reinforcement (e.g., de Villiers, 1974; Logue & de Villiers, 1978). For example, Logue and de Villiers (1978) studied the behavior of rats in two-component concurrent "variable-interval avoidance" schedules, in which electric shocks were programmed to occur at unpredictable moments in time according to variable-time schedules, and lever presses served to cancel impending shocks. They found that the ratios of the response rates in the two components conformed to the following analogue of Equation 3b:

$$R_A/R_B = (p_A/p_B)^a, \quad (4)$$

where p is the frequency of shocks successfully avoided.

Further evidence for functional symmetry between positive and negative reinforcement could be provided by studies of choice between the two types of reinforcement in concurrent schedules. For example, if an organism is exposed to a concurrent schedule in which one component is an avoidance and the other

a positive reinforcement schedule (concurrent avoidance/positive-reinforcement schedule), it may be predicted that the absolute response rates in the two components should conform to the following analogues of Equations 1 and 2:

$$R_A = R_{\max} \cdot p_A / (K_H + p_A + r_B) \quad (5)$$

$$R_B = R_{\max} \cdot r_B / (K_H + p_A + r_B). \quad (6)$$

Furthermore the ratios of the response rates and the times spent in the two components should conform to the following analogues of Equations 3b and 3c:

$$R_A/R_B = k(p_A/r_B)^a \quad (7a)$$

$$T_A/T_B = k(p_A/r_B)^a. \quad (7b)$$

There do not appear to have been any previous attempts to test these predictions using animal subjects. We decided to use humans in the present experiment because, in contrast to animals, they afford the possibility of using commensurable positive and negative reinforcement (i.e., money; see Bradshaw *et al.*, 1979a); any quantitative asymmetry between the effects of the positive and negative reinforcement should be reflected in a bias in favor of one or other of the two component schedules. In a previous experiment (Ruddle, Bradshaw, & Szabadi, 1981) in which the performance of three human subjects in concurrent avoidance/positive-reinforcement schedules was studied, no systematic bias in favor of either component was observed; however all three subjects exhibited marked undermatching. The present experiment sought to extend these observations and also to explore one possible reason for the undermatching found in the previous study.

METHOD

Subjects

Three female subjects, H.A. (51 years old), M.C. (55 years old), and F.A. (40 years old), were recruited by advertisement from the domestic staff of this university. All were experimentally naive at the start of training and had had no previous instruction in psychology.

Apparatus

Experimental sessions took place in a small room. A diagram of the apparatus used has

been published previously (Bradshaw, Szabadi, & Bevan, 1979a). The subject sat at a desk facing a sloping panel, 40 cm wide and 30 cm in height. Mounted on the panel were three rows of indicator lamps, the upper row orange, the middle row blue, and the lower row white; the lamps in each row were numbered 1 through 5 from left to right. Below the row of white lamps was a digital counter, on either side of which was mounted an additional lamp—one green and one red. A button, which could be depressed by a force of approximately 6 N (600 g), was located in front of the panel. A relay situated behind the panel provided auditory response feedback.

Except on the first two days of training, a small auxiliary box was also present on the desk. Mounted on this box were three lamps (from left to right: orange, blue, and white) and a button that could be depressed by a force of approximately 2 N (200 g).

Conventional electromechanical programming and recording equipment was situated in another room judged to be out of earshot from the experimental room.

Procedure

Table 1 summarizes the procedure for the entire experiment. Sessions took place at the same time each day on successive working days. Before the start of the experiment proper there were two preliminary training sessions.

First preliminary session. On the first day of training the subjects received the following instructions:

This is a situation in which you earn money. You earn money simply by pressing

this button. Sometimes when you press the button the green light will flash on; this means you will have earned one penny. The total amount of money you have earned is shown on this counter. Every time the green light flashes, it adds one point to the total score. (Please ignore the red light; it will not apply to you today.) When operating the button, make sure you press hard enough. You can tell whether you have pressed hard enough by listening for a slight click coming from inside the box. Now look at these orange lights (you don't have to worry about the blue and white lights). When one of the orange lights is on, it means that you are able to earn money. At the beginning of the session, one of the lights will come on and stay on for 10 minutes, and throughout this time you may earn money. At the end of 10 minutes, the light will go off for 5 minutes, and during this time you should rest. After the rest period, another light will come on, again for 10 minutes, and you may earn some more money. Then there will be another rest period, and so on, until each of the five orange lights has been presented. At the end of the session we will take the reading from the counter and note down how much you have earned. You will be paid in a lump sum at the end of the experiment.

The five orange lights were each associated with a different variable-interval positive-reinforcement schedule. Constant-probability schedules were used, similar to those described by Catania and Reynolds (1968); there were thirty intervals in each variable-interval sequence. The mean interreinforcement inter-

Table 1
Summary of Procedure

Phase of Experiment	Component A (main box)		Component B (auxiliary box)		Change-over Delay
	Schedules	Lights	Schedules	Light	
Preliminary sessions					
Session 1	VI positive-reinforcement (1-5)*	Orange	—	—	—
Session 2	VI avoidance (1-5)	White	—	—	—
Phase I (15 sessions)	VI avoidance (1-5)	White	VI positive-reinforcement (standard)	Orange	5.0s
Phase II (10 sessions)	VI avoidance (1-5)	White	VI positive-reinforcement (standard)	Orange	2.0s
Phase III (10 sessions)	VI avoidance (1-5)	White	VI positive-reinforcement (standard)	Orange	None

*See text for values of individual schedules.

vals specified by the schedules were as follows (numbers in parentheses are the scheduled reinforcement frequencies, in pence earned per hour): Light 1: 8 sec (445); Light 2: 17 sec (211); Light 3: 51 sec (70); Light 4: 171 sec (21); Light 5: 720 sec (5).

Second preliminary session. On the second day of training the subjects received the following instructions:

Today we start a new procedure. Instead of the orange lights you will be working with these white lights. As was the case with the orange lights, in the course of the session each of the white lights will come on for a 10-minute period. However, the green light no longer applies. Instead, you will start the session with 200 pence on the counter, and whatever is left on the counter at the end of the session constitutes your earnings for the day. Now look at this red light. Sometimes this red light will flash on and this means you will have lost one penny. Each time the red light flashes it subtracts one point from your total score shown on the counter. Whenever one of the white lights is on there is a possibility of the red light flashing and thus of your losing money. You will quickly discover what the function of the button is in this case.

The five white lights were each associated with a different variable-interval avoidance schedule. These schedules were similar to those described by de Villiers (1974). Constant-probability variable-time sequences were used to program monetary losses, there being thirty intervals in each sequence. At the end of each interval, provided that no response had been emitted during the interval, the red light on the panel was illuminated for 100 ms and one penny was subtracted from the score displayed on the counter. If the subject emitted a response during an interval, the programmed monetary loss and illumination of the red light did not occur at the end of the interval. Thus, in the absence of any responding by the subject, monetary losses occurred at a rate determined by the mean interval duration specified by the schedule; however, by emitting at least one response in each interval the subject could avoid all the scheduled monetary losses. The mean inter-loss intervals specified by the schedules were as follows (numbers in

parentheses are the scheduled loss frequencies, in pence lost per hour); Light 1: 2.5 sec (1440); Light 2: 5.7 sec (630); Light 3: 10 sec (360); Light 4: 25 sec (144); Light 5: 200 sec (18).

Phase I. On the third day of training (i.e., the first session of Phase I), the subjects received the following instructions:

From today onward, there will be a slight change in the situation. For the next fifteen sessions the white lights will be in operation on the main box. In addition to the main box, you can see that we have introduced this small extra box. Whenever one of the white lights on the main box is on, you may, whenever you wish, change over to the orange light on the extra box. You change over simply by pressing this button on the extra box. This turns the light on the main box off and at the same time turns the light on the extra box on. In order to go back to the light on the main box, you just press the button on the extra box a second time. The button on the extra box is only for changing over; the button on the main box continues to have the same function as in previous sessions. Today and every day from now on, you will be able to change over to the extra orange light; you can ignore the blue and white lights on the extra box, as they will not apply to you at all in this experiment.

The five white lights on the main box were associated with the same variable-interval avoidance schedules as had been used during the second preliminary session. The orange light on the auxiliary box was associated with a standard variable-interval positive-reinforcement schedule, identical to that which had been associated with Light 3 during the first preliminary session (mean scheduled inter-reinforcement interval: 51 sec). (Hereafter, the component schedules associated with the main box will be referred to as Component A, and the schedule associated with the auxiliary box as Component B.) A changeover delay (Herrnstein, 1961) of 5.0 sec was imposed; the imposition of the changeover delay entailed that responses emitted during the first 5.0 sec following a changeover from one component to the other had no scheduled consequences. In the first session of Phase I the five schedules were presented in the order 1, 2, 3, 4, 5; in

subsequent sessions they were presented in a quasirandom sequence, with the constraint that each schedule occurred in a different ordinal position in successive sessions. Phase I consisted of 15 sessions.

Phase II. On the first day of Phase II the subjects were informed that there would be a "slight change in the situation." During Phase II the duration of the changeover delay was 2.0 sec; in every other respect the procedure was identical to that employed during Phase I. Phase II consisted of 10 sessions.

Phase III. On the first day of Phase III the subject was informed that there would again be a "slight change in the situation." During

Phase III no changeover delay was imposed; in every other respect the procedure was identical to that employed during Phases I and II. Phase III consisted of 10 sessions.

RESULTS

Phase I

All three subjects participated in the first phase, in which the duration of the changeover delay was 5.0 sec.

The mean response rates in each component (R_A and R_B) recorded in each schedule during the last three sessions of Phase I were calculated individually for each subject and were plotted against the frequency of avoidance of loss in Component A (p_A). The data obtained from the three subjects are shown in Figure 1. In each case the response rate in Component A increased, and the response rate in Component B declined as a function of the frequency of avoidance of loss in Component A. Curves having the forms defined by Equations 5 and 6 were fitted to the data obtained in Components A and B respectively, using an iterative procedure based on the method of Wilkinson (1961) (see Bradshaw et al., 1979a). The indices of determinations (p^2) were calculated for the curves derived for each subject [p^2 expresses the proportion of the variance in the y-values that can be accounted for in terms of x in a curvilinear function (Lewis, 1960; see Bradshaw et al., 1979a, for a discussion of the use of this procedure in fitting hyperbolic functions to behavioral data)]. The values of p^2 for the data obtained in Component A were .920 (H.A.), .975 (M.C.), and .994 (F.A.), and the corresponding values for the data obtained in Component B were .989 (H.A.), .974 (M.C.), and 1.000 (F.A.).

Figure 2 (left hand column) shows, for each subject, the ratios of the response rates in the two components (R_A/R_B) as a function of the ratios of the frequency of avoidance of loss in Component A to the frequency of positive-reinforcement in Component B (p_A/τ_B). The data have been plotted on double logarithmic coordinates (Baum, 1974), and best-fit linear functions derived by the method of least squares; the equations derived for each subject, together with the values of the coefficient of determination (r^2), are shown in the graphs. The slope of the linear function (a in Equation 7a) was significantly less than 1.0 in the

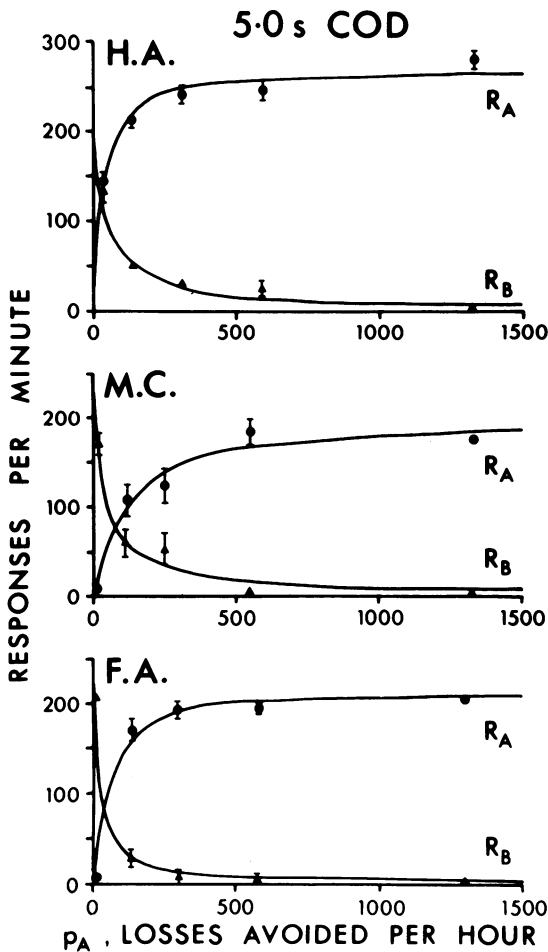


Fig. 1. Absolute response rates in Component A (R_A) and Component B (R_B) plotted against the frequency of avoidance of loss in Component A (p_A), for three subjects. Points are mean response rates (\pm s.e.m.), where this was greater than ± 10 responses per min, for the last three sessions of Phase I. Curves are best-fit hyperbolic functions.

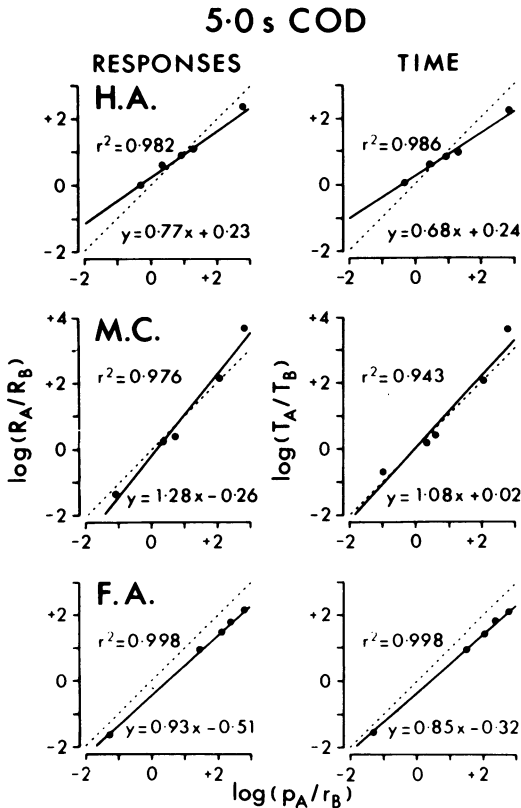


Fig. 2. Ratios of response rates in the two components (R_A/R_B : left hand graphs) and ratios of times spent in the two components (T_A/T_B : right hand graphs), plotted against ratios of the frequency of avoidance of loss in Component A to the frequency of positive-reinforcement obtained in Component B (p_A/r_B), using double-logarithmic coordinates. Data were obtained from the last three sessions of Phase I. Broken lines show ideal matching relationship. Continuous lines are best-fit linear functions derived by the least-squares method; the equations for these functions, and the proportion of the data variance for which they account (r^2) are shown in the graphs.

case of H.A. [$t(4) = 3.83, p < .05$]; in the case of the other two subjects, the slope did not differ significantly from 1.0 [M.C.: $t(4) = 2.33, p > .05$; F.A.: $t(4) = .47, p > .05$]. One of the subjects exhibited a significant bias in favor of Component B (the positive-reinforcement schedule component), as indicated by a significant negative value of the intercept of the linear function [F.A.: $t(4) = 5.10, p < .01$]; the other two subjects showed no significant bias in favor of either component [H.A.: $t(4) = .82, p > .05$; M.C.: $t(4) = .42, p > .05$].

Figure 2 (right hand column) shows, for each subject, the ratios of the times spent in

the two components (T_A/T_B) as a function of the ratios of the frequency of avoidance of loss in Component A to the frequency of reinforcer delivery in Component B (p_A/r_B), the data being displayed on double logarithmic coordinates. The equations for the best-fit linear functions, and the values of the coefficients of determination are shown in the graphs. In two subjects the slope of the linear function was significantly less than 1.0 [H.A.: $t(4) = 6.40, p < .01$; F.A.: $t(4) = 7.50, p < .01$]; in the remaining subject the slope did not deviate significantly from 1.0 [M.C.: $t(4) = .53, p > .05$]. In each case the value of the slope of the linear function derived for the subject's distribution of time between the components was less than that of the slope of the function derived for the distribution of responses between the components. One subject showed a significant bias in favor of Component B [F.A.: $t(4) = 2.91, p < .05$]; however the other two subjects showed no significant bias in favor of either component [H.A.: $t(4) = 1.14, p > .05$; M.C.: $t(4) = .02, p > .05$].

Phase II

Two subjects (H.A. and M.C.) participated in the experiment during the second phase, in which the duration of the changeover delay was 2.0 sec.

Figure 3 shows for each subject the absolute response rates recorded during the last three sessions of Phase II. The values of p^2 for the hyperbolic curves fitted to the data obtained in Component A were .965 (H.A.) and .998 (M.C.), and the corresponding values for Component B were .777 (H.A.) and .988 (M.C.).

Figure 4 (left hand graphs) shows the ratios of the response rates in the two components recorded during the last three sessions of Phase II. In both subjects the value of the slope of the linear function was less than the value obtained in Phase I (cf. Figure 2). The slope obtained for H.A. was significantly less than 1.0 [$t(3) = 10.61, p < .01$]; however, the slope obtained for M.C. did not deviate significantly from 1.0 [$t(4) = .46, p > .05$]. H.A. exhibited a significant bias in favor of Component A [$t(3) = 3.43, p < .05$], whereas M.C. showed no significant bias in favor of either component [$t(4) = .72, p > .05$].

The linear functions derived for the subjects' distribution of time between the two components were similar to those derived for

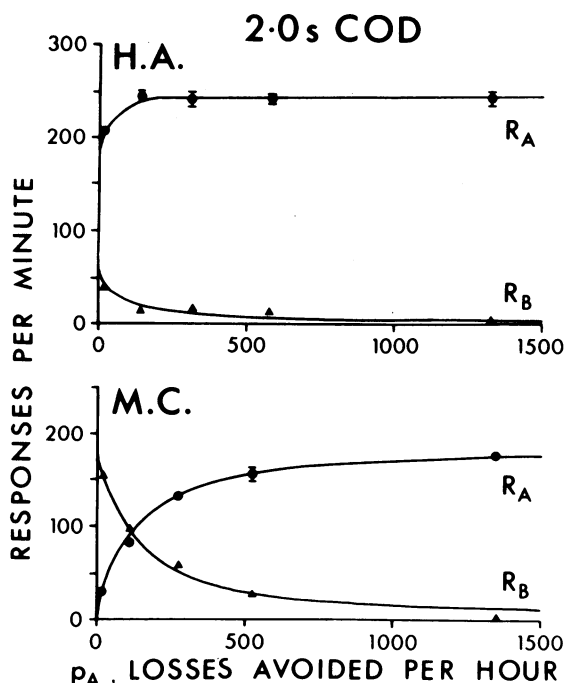


Fig. 3. Absolute response rates obtained during the last three sessions of Phase II. Conventions as in Figure 1.

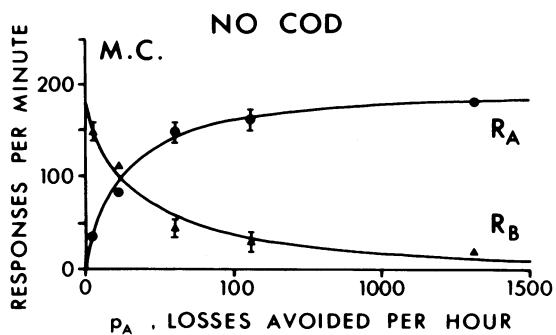


Fig. 5. Absolute response rates obtained during the last three sessions of Phase III. Conventions as in Figure 1.

their distribution of responses (see Figure 4, right hand graphs). H.A. showed a statistically significant tendency towards undermatching [$t(3) = 12.57, p < .01$], whereas the slope of the function derived for M.C. did not deviate significantly from 1.0 [$t(4) = 1.57, p > .05$]. H.A. displayed a significant bias in favor of Component A [$t(3) = 3.95, p < .05$], whereas M.C. did not show a significant bias in favor of either component [$t(4) = .69, p > .05$].

Phase III

M.C. participated in the third phase of the experiment, in which no changeover delay was imposed.

Figure 5 shows the mean response rates in the two components recorded in each schedule during the last three sessions of Phase III plotted against the frequency of avoidance of loss in Component A. The values of p^2 for the fitted hyperbolic functions were .980 (Component A) and .974 (Component B).

Figure 6 shows the ratios of the response rates (left hand graph) and the times spent in the two components (right hand graph), dur-

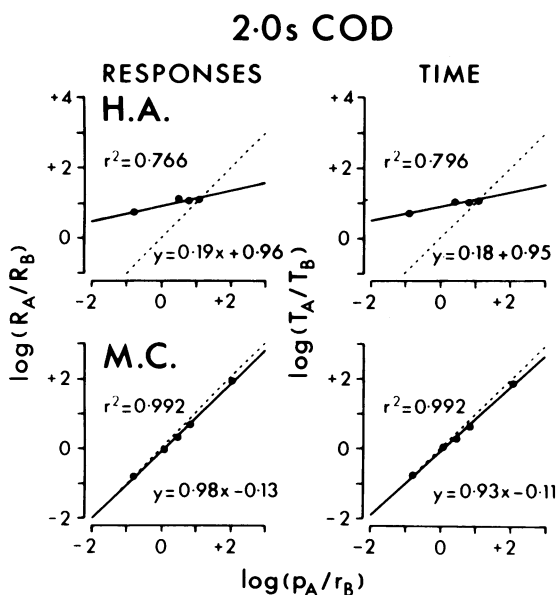


Fig. 4. Ratios of response rates and times spent in the two components during the last three sessions of Phase II. Conventions as in Figure 2. Note that there are only four data points in the case of H.A. since this subject showed exclusive preference for Component A in the schedule with the highest scheduled loss frequency.

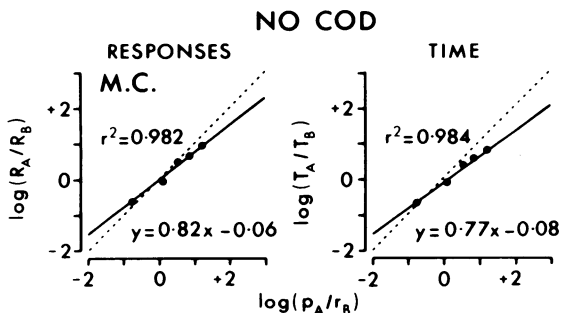


Fig. 6. Ratios of response rates and times spent in the two components during the last three sessions of Phase III. Conventions as in Figure 2.

ing the last three sessions of Phase III. The values of the slopes of the linear functions were both lower than the corresponding values obtained with this subject during Phase II; in the case of time distribution, the value of the slope was significantly less than 1.0 [responses: $t(4) = 2.73$, $p > .05$; time: $t(4) = 3.91$, $p < .05$]. The subject showed no significant bias towards either component, either with respect to her distribution of responses [$t(4) = .35$, $p > .05$] or with respect to her distribution of time between the two components [$t(4) = .60$, $p > .05$].

DISCUSSION

On the basis of Herrnstein's (1970) quantitative account of operant performance, and the presumed symmetry between positive and negative reinforcement (the "symmetrical law of effect"; see de Villiers, 1977, 1981), it was possible to derive a number of predictions about behavior in concurrent schedules consisting of an avoidance schedule component and a positive-reinforcement schedule component ("concurrent avoidance/positive-reinforcement schedules"). In the present experiment a range of schedule frequencies of loss was employed in the avoidance schedule component (Component A), and a standard variable-interval reinforcement schedule was used to program monetary earnings in the positive-reinforcement schedule component (Component B). It was predicted that the absolute response rate in the avoidance component would be an increasing function of the frequency of avoidance of loss (cf. Equation 5), whereas the response rate in the positive reinforcement component would be a decreasing function of the frequency of avoidance of loss (cf. Equation 6). Both predictions were confirmed in all three subjects, the two equations accounting for more than 90% of the data variance in each case.

It was predicted (see Introduction) that the ratios of the response rates in the two components and the ratios of the times spent in the two components would conform to the power-ratio matching equations (Equations 7a and 7b). The data displayed in Figure 2 provide support for this prediction, in that $\log(R_A/R_B)$ and $\log(T_A/T_B)$ were linearly related to $\log(p_A/r_B)$. The slopes of the linear functions ranged between .68 and 1.28, and the

functions accounted for more than 90% of the data variance in each case. These findings with concurrent avoidance/positive-reinforcement schedules may be regarded as complementary to previous studies of human performance in concurrent positive-reinforcement/positive-reinforcement schedules, the majority of which have yielded support to the applicability of the power-ratio matching equations (Equations 3b and 3c) to human operant behavior (for reviews, see Bradshaw *et al.*, 1981; Cliffe & Parry, 1980).

Comparison of the results obtained in Phases I, II, and III suggests that the change-over delay played an important role in establishing conformity to the matching relationship. Both the subjects studied in Phases I and II showed lower values of the slope of the linear functions under the 2.0-sec changeover delay condition (Phase II) than under the 5.0-sec changeover delay condition (Phase I) (see Figures 4 and 2, respectively). The single subject who participated in Phase III showed a further reduction in the slope of the linear function during this phase, when the change-over delay was removed altogether (Figure 6).

The present results are of relevance to the hypothesis that positively reinforcing and aversive contingencies are functionally symmetrical within the context of the matching relationship ("symmetrical law of effect": see Introduction). Evidence so far amassed in support of this hypothesis derives mainly from two different experimental paradigms. First, several studies have demonstrated that choice between two sources of negative reinforcement (for example, two free-operant avoidance schedules) can be described by an analogue of the matching equation (Equation 4) (Baum, 1973; de Villiers, 1974; Logue, 1978; Logue & de Villiers, 1978). Second, evidence compatible with the hypothesis has been provided by a number of studies of the effects of a punishment contingency superimposed on the two components of a concurrent positive-reinforcement/positive-reinforcement schedule. In general the results of such studies have been compatible with a model that assumes the aversive stimulus diminishes the efficacy of the positive reinforcer according to a simple subtractive principle (de Villiers, 1977, 1980, 1981; Farley, 1980; Farley & Fantino, 1978).

A third strategy was adopted in a recent experiment by Logue and de Villiers (1981).

These authors exposed rats to a series of two-component concurrent schedules in which one component consisted of a variable-interval schedule of food reinforcement, and the other of a conjoint variable-interval-food-reinforcement/variable-interval-shock-avoidance schedule. The results were consistent with a model in which the effects of positive and negative reinforcement are simply additive.

The concurrent avoidance/positive-reinforcement schedules used in the present study offer a fourth, and in some ways less complex, approach. The finding that performance in these schedules was generally compatible with the equations derived from Herrnstein's (1970) model (Equations 5, 6, 7a, and 7b) is consistent with the evidence reviewed above in lending support to the hypothesis that positive and negative reinforcement are functionally symmetrical.

The role of the changeover delay in maintaining matching in concurrent schedules is controversial (for review, see de Villiers, 1977). Catania and Cutts (1963) proposed that a changeover delay served to prevent the development of "concurrent superstitions" and thus ensure the functional independence of the component schedules. Previous studies of human performance in concurrent positive-reinforcement/positive-reinforcement schedules have indicated that changeover delays can have variable effects on performance in these schedules. In some studies (Baum, 1975; Schroeder, 1975; Schroeder & Holland, 1969) the presence of a changeover delay appeared to be a prerequisite for observing matching, performance in the absence of a changeover delay being characterized by marked undermatching. However, in experiments carried out in this laboratory, matching has generally been observed despite the absence of a changeover delay (Bradshaw et al., 1976, 1979a, 1979b, 1981; Ruddle et al., 1979), although undermatching has been observed in some subjects (see Bradshaw et al., 1981; Ruddle et al., 1979). It is possible that human subjects are more prone to develop "concurrent superstitions" in concurrent avoidance/positive-reinforcement schedules than they are in concurrent positive-reinforcement/positive-reinforcement schedules. Although the present results provide no direct evidence for this suggestion, it is a noteworthy feature of concurrent avoidance/positive-reinforcement sched-

ules that most of the losses actually incurred are likely to occur while the subject is responding in the positive-reinforcement schedule component; this might provide a basis for the development of concurrent superstitions. It is of interest in this context that Sidman (1958) also observed marked interactions between the two components of a concurrent avoidance/positive-reinforcement schedule, using rhesus monkeys as subjects. Some supporting evidence for the role of the changeover delay in maintaining conformity to the matching relationship in concurrent avoidance/positive-reinforcement schedules is provided by a previous experiment carried out in this laboratory (Ruddle et al., 1981). In one phase of that experiment, three human subjects were exposed to concurrent avoidance/positive-reinforcement schedules with no changeover delay: all three exhibited marked undermatching.

To our knowledge, concurrent avoidance/positive-reinforcement schedules have not been used previously in any studies of the matching relationship employing animal subjects. The use of human subjects, as in the present experiment, would seem to offer some advantage in this kind of experiment, since they afford the possibility of using commensurable positive and negative reinforcement (i.e., money). In this context it is of interest to note that the three subjects studied in this experiment did not exhibit consistent bias in favor of either the avoidance or the positive-reinforcement component.

REFERENCE NOTE

1. R_{max} is the theoretical maximum response rate, and K_H is the reinforcement frequency needed to maintain the half-maximal response rate in a single variable-interval schedule (Herrnstein, 1970, 1974; for discussion of the notation, see Bradshaw, Szabadi, & Bevan, 1976).

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