*SOME EFFECTS OF RELATIVE REINFORCEMENT RATE
AND CHANGEOVER DELAY IN RESPONSE-INDEPENDENT
CONCURRENT SCHEDULES OF REINFORCEMENT¹*

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Reinforcements were arranged independently of the pigeon's behavior by concurrent variable-interval schedules. The reinforcements arranged by one of the schedules occurred when the chamber was illuminated with amber light, and the reinforcements arranged by the other schedule occurred when the chamber was illuminated with blue light. Both schedules functioned concurrently, but reinforcers were delivered by each only in the presence of the appropriate stimulus condition. A response on a white key, the only key in the chamber, alternated the stimulus condition and the effective schedule. The results of this procedure were similar to those obtained with concurrent response-dependent variable-interval schedules of reinforcement. The proportion of the total session time spent in the presence of a schedule component approximated the proportion of the total number of reinforcements in the component. Changeover rate was a decreasing function of the changeover delay and of the difference between the relative rates of reinforcement for each pair of concurrent schedules.

Concurrent variable-interval (VI) schedules of reinforcement are arranged by assigning a VI schedule to each of two response keys so that availability of reinforcement on one key is unaffected by the availability on the other. With such an arrangement, the pigeon typically distributes its responses between both keys. One way in which the distribution of responses has been examined quantitatively has been to determine the rate of responding on each key relative to the overall rate of responding. Customarily, the time base for determining the response rate for each key is taken as equal to the total session time, since both keys are available throughout the session; then, the relative response rates reduce simply to the proportions of the total responses emitted on each key. Herrnstein (1961) showed that the relative response rate on a given key closely approximates the relative reinforcement rate for that key if a changeover delay (COD) is scheduled. (The relative reinforcement rate is determined in a manner similar to relative response rate, except that the number of reinforcements is substituted for the number of responses for each of the keys.) The COD speci-

fies a minimum delay between a changeover from responding on one key to responding on the other and the next possible reinforcement.

An alternative procedure for concurrent scheduling was described by Findley (1958). Both VI schedules of the concurrent pair are assigned to a single response key. Each schedule is paired with a distinctive exteroceptive stimulus, and only one or the other stimulus and associated schedule are available at a given time. The exteroceptive stimulus and schedule may be changed by responding on a second key, the changeover or CO key. Under these conditions, relative response rate again approximates relative reinforcement rate (Catania, 1963).

Using the CO-key procedure, it is convenient to obtain the relative time spent in the presence of each of the stimulus conditions, i.e., time spent in a stimulus condition divided by the total time. Catania (1966) showed that the relative time spent in a stimulus condition approximated the relative rate of reinforcement in that stimulus condition, suggesting that the approximation of relative response rate to relative reinforcement rate may be a consequence of a relation between relative time and relative reinforcement rate. Assuming a uniform absolute rate of responding, the relative rate of responding in a given stimulus condition will be the same as the relative time spent in that stimulus condition. Thus, if

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relative time spent in a stimulus condition approximates relative reinforcement rate, so too will relative response rate.

The present study examined the effect of relative reinforcement rate on the relative time spent in each of two stimulus conditions, each of which is associated with a variable-interval schedule of response-independent or "free" reinforcement. The approximate equivalence of relative time and rate of reinforcement under these conditions might indicate that the distribution of time is not a simple by-product of induced rates of responding brought about by specifying a response requirement for the VI schedules. In other words, the experiment attempted to determine if the time spent in each schedule was a simple consequence of reinforcement factors determining how the bird must respond in each schedule and of necessity, therefore, distribute its time between them.

METHOD

Subjects and Apparatus

Three adult White Carneaux pigeons were maintained at 80% of their free-feeding weights. Two (787 and 6494) had extensive key-peck experience; the third (93) was experimentally naive.

The apparatus consisted of a standard LeHigh Valley Electronics pigeon box. Two jewel light receptacles were mounted on the front wall, one on each side of the centrally mounted house light at a distance of 1 in. Westinghouse auto bulbs #W-304 were used with one blue and one amber jewel, each 1-in. in diameter. The intensity of the auto bulbs was such that the illumination in the box corresponded to the color of the jewel. No attempt was made to equate for brightness; the amber illumination appeared brighter to the experimenters.

Procedure

During 14 daily sessions of preliminary training, each session consisting of 60 reinforcements (3-sec access to mixed grain), two VI tape programmers operated concurrently and delivered response-independent reinforcers. The means of the VI schedules were 1 min and 3 min. The interreinforcement intervals used in all VI schedules was a random ordering of an arithmetic series of 13 terms with the first

term equal to zero and the progression constant equal to one-sixth of the mean interval. Reinforcements scheduled by the 1-min programmer occurred only when the blue jewel light was illuminated; reinforcements scheduled by the 3-min programmer occurred only when the amber jewel light was illuminated. A reinforcement assigned during an inappropriate stimulus condition was preserved until the stimulus conditions were alternated. The illumination in the box was alternated every 2 min. The average number of reinforcements per session in the presence of the amber light was 17 and in the presence of the blue light, 43.

After preliminary training, the key on the panel was exposed and transilluminated with white light. Throughout the remainder of the experiment, each peck on this key, *the only key available*, changed the illumination in the box. Reinforcements occurred as in the preliminary sessions, *i.e.*, independent of responses, and the only change was to substitute the birds' peck on the changeover key for the clock to determine when the illumination was to change. Both birds with previous key-peck experience pecked during the first session with the new procedure. Bird #93, the inexperienced bird, required shaping. The shaping procedure consisted of changing the illumination whenever the bird's behavior approximated key-pecking. The initial changes in illumination were usually accompanied by grain presentation, because reinforcements were often assigned in the other condition of illumination during the initially large inter-response times. Shaping was completed within one session.

With the VI 1-min and VI 3-min schedules still in effect, each bird was exposed to an ascending series of changeover delays. A COD value, timed from the changeover, specified the minimum time between a changeover and reinforcement. All reinforcements scheduled to occur before the COD expired were held and delivered when the COD terminated. Each bird was maintained at each of the COD values until the relative time spent in each illumination appeared stable. For each bird a COD value was found at which the relative time spent in each illumination approximated the relative rate of reinforcement in that illumination. That COD value was maintained, and the VI schedules associated with the dif-

Table 1

Subject	VI with Amber (min)	VI with Blue (min)	COD (sec)	Relative Time Spent in Amber	Relative Reinf. Rate in Amber	No. of Sessions
787	3	1	0	0.45	0.26	11
	3	1	0.2	0.50	0.26	22
	3	1	1	0.38	0.25	13
	3	1	1.5	0.41	0.25	15
	3	1	3	0.39	0.25	23
	3	1	5	0.40	0.25	10
	3	1	7.5	0.27	0.23	35
	2	1	7.5	0.54	0.51	30
	1.5	1.5	7.5	0.55	0.53	14
	Ext.	0.75	7.5	0.03	0.00	32
6494	3	1	0	0.43	0.26	11
	3	1	0.2	0.36	0.24	22
	3	1	1	0.44	0.25	31
	3	1	2	0.35	0.25	30
	3	1	3	0.36	0.25	11
	3	1	5	0.27	0.23	16
	1	1	5	0.49	0.50	21
	2	2	5	0.52	0.53	17
	1.5	1.5	5	0.51	0.53	11
	Ext.	0.75	5	0.05	0.00	35
93	3	1	0	0.47	0.25	19
	3	1	2	0.27	0.25	10
	1	3	2	0.81	0.78	12
	1	1	2	0.50	0.51	13
	2	2	2	0.50	0.50	30
	1.5	1.5	2	0.49	0.51	10
	Ext.	0.75	2	0.04	0.00	16

ferent illuminations were then varied. Table 1 shows the order in which the different COD and VI values were used for each bird. For Birds #787 and #6494, experimental sessions were on consecutive days. For Bird #93, the entry in the "No. of Sessions" column indicates the number of sessions for which it was actually exposed to the conditions, but consecutive sessions were administered every other day. Initially, sessions were administered on consecutive days, but under these conditions this bird stopped responding midway in the session, and grain presented after the bird stopped responding was never eaten. Administering experimental sessions every other day eliminated these problems.

RESULTS

During each session, time spent and number of reinforcements in the presence of each color were recorded, as was the number of changeovers. The relative time spent in the presence of a given schedule's color was obtained for each session by dividing the time spent in the presence of each color by the total session time.

Relative reinforcement rate also was computed each day by dividing the number of reinforcements in each stimulus condition by the total number of reinforcements.

A major concern of the present study was to determine the relationship between relative rate of reinforcement and relative time. The fifth and sixth columns of Table 1 show the corresponding values of those two variables for each of the experimental conditions studied. Each entry is a mean for the final eight sessions under the condition.

Figure 1 shows relative time plotted against relative reinforcement rate under the final COD duration employed with each bird. Only those combinations of VI schedules for which the overall rate of reinforcement was 80 reinforcements per hour have been plotted, *i.e.*, Conc VI 1.5-min VI 1.5-min, Conc VI 3-min VI 1-min, Conc Ext VI 0.75-min. Each pair of concurrent schedules contributed two points, an O and an X. Hence, only the Xs or the Os are independent points in the statistical sense. All of the points are close to the diagonal line, which represents the perfect correlation between relative time spent in a schedule color

and relative reinforcement rate in that color.

For Bird #93, Conc VI 1-min VI 3-min was first scheduled with the VI 1-min in the presence of the amber light and then with the VI 1-min in the presence of the blue light. This bird's performance in Fig. 1 indicates that the relative time spent in the colors is easily reversed if the schedules of reinforcement are reversed.

Figure 2 shows that the changeover rate also is related to the distribution of reinforcements in the two illuminations. The vertical axis shows changeovers per minute. The horizontal axis represents relative reinforcement rates for the stimulus condition of a pair in whose presence reinforcement was less frequent, with overall reinforcement rate constant at 80 reinforcements per hour. Thus, 0.50 corresponds to zero difference in relative rate of reinforcement, 0.25 to a difference of 50% and 0 to a difference of 100%. The data are from the same sessions used for Fig. 1. Changeover rate is an approximately linear function of the difference between the relative reinforcement rates associated with the two colors.

The consistently higher changeover rates in Fig. 2 for Bird #93 may in part be due to the briefer COD used. The relationship between changeover rate and COD duration is examined more closely in Fig. 3.

Figure 3 shows changeovers per minute as a function of each of the COD durations on the original VI 1-min VI 3-min concurrent pair. Changeover rates plotted are the means for the last eight sessions at each COD value. Both birds' changeover rates are inversely related to COD value. Bird #93 was not included in Fig. 3 because 2 sec was the only COD value larger than 0 sec used for this bird. The changeover rates for this bird at 0 and 2 sec were 21.2 and 5.4 responses per minute, respectively.

DISCUSSION

The purpose of the present experiment was to examine the effects of relative reinforcement rate in response-independent concurrent VI schedules. The data showed that: (1) relative time spent in the presence of a given schedule's stimulus approximated the relative rate of reinforcement provided by that schedule; (2) changeover rate was inversely related to the difference between the relative reinforcement rates of the concurrent schedules; and (3)

Fig. 1. Relative time spent in the presence of a given schedule's stimulus as a function of the relative rate of reinforcement provided by that schedule. The overall rate of reinforcement was 80 per hr. The CODs were 2, 7.5, and 5 sec for Birds #93, 787, and 6494 respectively.

Fig. 2. Changeover rate as a function of the smaller relative rate of reinforcement of the concurrent pair. The overall rate of reinforcement was 80 per hr. The CODs were 2, 7.5, and 5 sec for Birds #93, 787, and 6494 respectively.

changeover rate was inversely related to COD duration.

These relationships have been observed also in concurrent VI schedules in which reinforcement is response dependent. Catania (1966), using pigeons and a CO-key procedure, required a main-key response; he showed that the relative time spent in the presence of a

Fig. 3. Changeover rate as a function of changeover delay (sec). The schedules were Conc VI 1-min, VI 3-min.

given schedule's stimulus approximated the relative rate of reinforcement provided by that schedule.

Herrnstein (1961), using pigeons with the two-key procedure, found that the changeover rate was inversely related to the difference between the relative rates of reinforcement obtained by responding on the two keys. Herrnstein's data indicated an approximately linear relationship, as do the present data.

An inverse relationship between changeover rate and COD duration has been reported by Herrnstein (1961) and by Shull and Pliskoff (1967). Herrnstein, using the procedure described above, found that the number of changeovers per session was smaller with a 1.5-sec COD than without a COD. Shull and Pliskoff, using rats with a CO-key procedure and a main-key response, varied COD duration up to 20 sec. They found changeover rate to be a negatively accelerated decreasing function of COD duration, as did the present study.

The present findings, using response-independent concurrent VI schedules, parallel those of studies in which a response requirement for the VI schedules is specified. This parallel strongly suggests that these relationships in the response-dependent situation are not an indirect consequence of the effects of reinforcement rate and COD on a main-key response. The view questioned is that the relation between the time spent in a component and the relative reinforcement rate for that component is a result of the matching of main-key response outputs. This view assumes that the primary effect of the COD and relative reinforcement rate is to influence the relative response outputs. The distribution of time is assumed to result as a by-product of this process. In other words, a greater proportion of time must be spent in a given situation if some factor demands that a greater proportion of the total response output be made in that situation. Such an account is not feasible in the present study, since no response output was required.

The conjecture that the distribution of time was mediated by "superstitious" behavior is unattractive for both empirical and logical reasons. Observations of the pigeons' behavior indicated that they were active between changeovers, but no consistent pattern of activity was readily discernible for any of the

birds. On logical grounds this argument requires that the temporal constraints imposed on changeover behavior by the response characteristics of the "superstitious" behavior are the same for both schedules and very similar to those imposed by some usually specified response, such as a key-peck.

The present study provides no basis for critically evaluating the possibility that the correlation between relative response rates and relative reinforcement rates is a consequence of purely temporal factors. The present results are consistent with this notion to the extent that they indicate the reverse dependency does not exist.

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