**CONCURRENT SCHEDULES OF RESPONSE-
INDEPENDENT REINFORCEMENT: DURATION
OF A REINFORCING STIMULUS¹**

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Presentations of grain to three pigeons were determined by two response-independent schedules. Interpresentation intervals varied with a mean interval of 1.5 min for each schedule. Both were concurrently operative, but grain was presented by one only when the chamber was illuminated with blue light and by the other only during amber illumination. A response on a white key, the only key in the chamber, alternated the stimulus conditions and the effective schedule. Grain presentation durations associated with the illumination conditions were varied from 1.5 to 4.5 sec. The proportion of the total session time spent in an illumination condition closely approximated the relative grain presentation duration provided in that illumination. For two of the birds, the proportion of the total number of grain presentations obtained in an illumination condition was an increasing function of the presentation duration in that illumination.

Brownstein and Pliskoff (1968) showed that many aspects of performance related to frequency of reinforcement in concurrent variable-interval schedules can be reproduced with analogous schedules in which a reinforcing stimulus is presented independently of the organism's behavior (concurrent schedules of response-independent reinforcement). Baum and Rachlin (1969) reported similar findings with an alternative procedure for arranging concurrent variable-interval schedules of response-independent reinforcement.

Reinforcement duration is functionally similar to reinforcement frequency in concurrent VI schedules. (Catania, 1963*a, b*; Rachlin and Baum, 1969). This paper demonstrates the same functional equivalence for concurrent VI schedules of response-independent reinforcement.

METHOD

Subjects and Apparatus

Three adult White Carneaux pigeons were maintained at 80% of their free-feeding weights. The birds had served in a previous study involving concurrent schedules of response-in-

dependent reinforcement (Brownstein and Pliskoff, 1968).

The experimental chamber was a modified Lehigh Valley Electronics pigeon box containing two jewel lights, one blue and one amber, centrally mounted on the wall containing a response key and an opening through which grain could be presented. The illumination in the box corresponded to the color of the illuminated jewel.

Procedure

Briefly, the relevant prior experimental treatment of the subjects (Brownstein and Pliskoff, 1968) was as follows. Initially, the illumination in the chamber was regularly alternated. Two schedules that operated concurrently and independently, arranged grain presentations independently of the birds' behavior. Access to grain provided by one of them occurred only when the blue jewel light was illuminated; access provided by the other occurred only during amber illumination. Grain presentations assigned during an inappropriate stimulus condition were preserved until the stimulus conditions were alternated. The regular alternations of chamber illuminations were then replaced by alternations produced by key pecks. Each peck on the response key changed the illumination in the box. With this paradigm, the previous study determined how the time spent in each illumination and the rate of changeover were affected by the fre-

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quencies of grain presentations associated with the illumination conditions and the changeover delay (COD) (Herrnstein, 1961). A COD specifies the minimum time between a changeover and the presentation of grain. The present study focused on the effects of the duration of grain presentations associated with the illumination conditions.

Two schedules that operated concurrently and independently arranged grain presentations with a mean interpresentation interval of 1.5 min for each schedule. The interpresentation intervals used were an arithmetic series of 13 terms with the first term equal to zero and the progression constant equal to 15 sec. The 13 intervals were randomly ordered on the tapes. As mentioned above, access to grain provided by each schedule occurred only during the associated illumination condition. Each peck on the response key alternated the illumination conditions. The response key was trans-illuminated with white light at all times, except during grain presentations. Changeover delays of 2, 5, and 7.5 sec were used with Birds 93, 6494, and 787 respectively. In previous work with these COD values, the relative time spent in each illumination approximated the relative frequency of grain presentations in that illumination for each bird.

Each experimental session lasted until 60 presentations of grain occurred. Initially, hopper-up durations, which provided access to grain, were 3 sec in each illumination. After the birds' behavior appeared stable, they were exposed to several hopper durations in each illumination condition. The sequence of durations and the number of experimental sessions

at each duration are shown for each bird in Table 1. The sessions for Bird 93 were conducted on alternate days, as described earlier (Brownstein and Pliskoff, 1968).

RESULTS

A primary concern of the present study was to determine the relationship between relative time spent in the presence of a given schedule's color and the relative reinforcer duration arranged for that color. 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 time spent in both colors. The relative reinforcer duration associated with each color was obtained by dividing the scheduled hopper duration in each color by the total of the durations in both colors. Columns 4 and 5 of Table 1 show the corresponding values of those two variables for each of the hopper durations studied. The entries that are given in Column 5 are means for the relative time spent in each stimulus condition of the final eight sessions of each hopper duration condition.

Figure 1 shows relative time plotted against relative hopper duration for each bird. Each pair of concurrent schedules contributed two points, an O and an X. Hence, only the Xs or the Os are independent 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 the relative hopper duration arranged for that color.

Table 1

Bird	Hopper Duration (sec)		Relative Hopper Time in Amber	Relative Time Spent in Amber	Relative Frequency of Grain Presentations in Amber	Changeover Rate (R/min)	Number of Sessions
	Amber	Blue					
787	3	3	0.50	0.55	0.53	3.6	17
	1.5	4.5	0.25	0.28	0.42	3.0	18
	2	4	0.33	0.32	0.45	2.4	14
	4.5	1.5	0.75	0.74	0.59	3.0	12
6494	3	3	0.50	0.56	0.52	1.8	23
	2	4	0.33	0.32	0.44	1.8	29
	1.5	4.5	0.25	0.26	0.42	1.2	24
93	3	3	0.50	0.47	0.51	8.4	15
	2	4	0.33	0.36	0.50	9.6	14
	1.5	4.5	0.25	0.29	0.51	8.4	15

For Bird 787, the 0.25 relative duration was first scheduled in the presence of the amber light and subsequently 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 relative hopper durations are reversed.

Column 6 of Table 1 shows the means of the relative frequency of grain presentations in the amber illumination for the final eight days under each hopper duration condition. The relative frequency of grain presentations was obtained for each session by dividing the number of presentations in each stimulus condition by the total number of presentations (60). For Birds 787 and 6494, the relative frequencies deviate slightly from the scheduled 0.5 value. This deviation is systematically related to the scheduled hopper duration. The proportion of the total grain presentations obtained in the presence of an illumination condition is positively related to the relative hopper duration in that illumination. For Bird 93, the relative frequency of grain presentations is close to 0.5 for all durations.

The mean rates of illumination alternations for the final eight days of each hopper duration condition are shown in Table 1 in the column headed Changeover rate. For each bird, the changeover rates are fairly constant. Variations in changeover rates that do exist do not appear to be systematically related to hopper durations.

DISCUSSION

The data reported clearly show that the relative time spent in each component of a pair of concurrent schedules of response-independent reinforcement closely approximates the relative duration of the reinforcing stimulus provided in each component. The present results are consistent with and extend the research reported by Brownstein and Pliskoff (1968) in which a similar relationship involving relative time and relative rate of response-independent reinforcement was found. The present findings, together with earlier work, clearly indicate a strong functional similarity between reinforcement rate and duration in concurrent schedules of reinforcement. Catania (1963*b*) showed that relative rates of responding approximate relative durations of reinforcement in concurrent schedules of reinforcement. The same relationship is well documented for relative response rates and relative reinforcement rates (Catania, 1963*a*; Herrnstein, 1961).

Fig. 1. Relative time spent in the presence of a given schedule's stimulus as a function of the relative duration of reinforcement provided by that schedule.

Rachlin and Baum (1969), using a signalled reinforcement procedure, found response rate in the standard component of a pair of concurrent schedules to be inversely related to reinforcement duration in the signalled component. Earlier work by Catania (1963a) demonstrated the inverse relationship between response rate in the standard component and reinforcement rate in the signalled component. Finally, the present study demonstrated that the distribution of time spent in each component of concurrent schedules of response-independent reinforcement varies with the relative duration of the reinforcing stimulus, as has already been shown with rate of presentation of a reinforcing stimulus (Brownstein and Pliskoff, 1968).

The functional similarities of reinforcement rate and duration are consistent with the possible interchangeability of reinforcement rate and duration in concurrent schedules of reinforcement. Neuringer (1967) showed that relative choice responses in a concurrent chains procedure closely approximate relative total access to reinforcement. The relative total access measure interchanges frequency and duration of reinforcement, weighting each equally. Neuringer found, as was the case with two of the three present subjects, that the number of reinforcements obtained in each component varied with the reinforcer durations assigned to both components. The obtained relative reinforcement rates in the present study are approximately equal to those found by Neuringer for comparable relative durations of reinforcement. The range of relative durations used in the present study was not as great as that employed by Neuringer; hence, the obtained rates of reinforcement did not depart as drastically from the scheduled equal rates. As such, the relative duration measure and the relative total access measure do not differ markedly. The present experiment therefore does not provide a very definite test of the proposed simple interchangeability (Baum and Rachlin, 1969; Neuringer, 1967). However, in the few instances where the two measures diverge, the relative time measures are more in accord with the relative duration measure.

The present results may also be viewed as further demonstrating equivalent effects in concurrent schedules with and without a specified response requirement. As such, they are consistent with the notion that the distribution

of time may be of critical significance in concurrent schedules of reinforcement (Brownstein and Pliskoff, 1968; Catania, 1966) and choice behavior (Baum and Rachlin, 1969).

The rates at which the pigeons changed from one component to the other were not systematically related to the reinforcer durations arranged for the component. Changeover rate has been shown to be inversely related to the disparity between relative rates of reinforcement in the two components (Herrnstein, 1961; Brownstein and Pliskoff, 1968). The basis for the failure to find a similar relationship involving reinforcer duration is not immediately evident. The extensive experience of the pigeons may serve to attenuate any effect. The long-range recoverability of the relationship between changeover rate and reinforcement rate has yet to be demonstrated. More positively, the data indicate that the close approximation of time spent in each component to relative reinforcer duration need not be accompanied by associated changes in absolute rates of changeover.

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