

MATCHING AND CONTRAST ON SEVERAL CONCURRENT TREADLE-PRESS SCHEDULES

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Four White King pigeons pressed treadles for food reinforcement on several concurrent variable-interval variable-interval schedules. The rate of reinforcement available for responding in one of the two component schedules was held constant at 30 reinforcers per hour. The rate of reinforcement available for responding in the other was varied from 120 to 60 to 15, and then to 30 reinforcers per hour. The relative rate of responding in each component schedule equalled the relative rate of reinforcement that the component provided. And, behavioral contrast, defined as an inverse relationship between the rate of responding in the constant component and the rate of reinforcement obtained by responding in the other component, occurred for all schedules.

A number of authors have suggested that different behavioral laws may govern responses of different forms (*e.g.*, Bolles, 1970; Rachlin, 1973; Seligman, 1970). Hemmes (1973) and Westbrook (1973) provided preliminary evidence in favor of this position when they showed that the rate of bar pressing in one component of a multiple variable-interval variable-interval schedule did not increase when the other component was placed on extinction. An increase in the rate of responding is typically found for key-peck responding under similar circumstances, and is called behavioral contrast (Reynolds, 1961).

The present experiment extended this research. It investigated the properties of treadle-press responding on concurrent variable-interval variable-interval schedules. In particular, it asks if concurrent treadle pressing obeys the Matching Law and shows behavioral contrast. Concurrent behavioral contrast, defined as an inverse relationship between the rate of responding in one component and the rate of reinforcement provided by the other component, is usually found in concurrent key-peck situations (*e.g.*, Catania, 1963). Key-peck responding also usually obeys the Matching Law, which states that the relative rate of responding in either component of a concurrent schedule equals the relative rate of reinforcement it provides (Herrnstein, 1970).

METHOD

Subjects

Four White King pigeons, maintained at 80 to 85% of their free-feeding weights, all had experience with key pecking for food reinforcement. None had experience with treadle-press responding.

Apparatus

Two floor treadles were added to a standard 31- by 31- by 29-cm Lehigh Valley Electronics experimental enclosure. Each treadle, a 5- by 3-cm piece of aluminum, was held in a resting position 2 cm above the enclosure floor by a strip of aluminum that connected it to the wall containing the magazine. Each aluminum strip was 10 cm long by 1 cm wide, and each entered the magazine wall 7 cm from the intersection of this wall with one of the side walls of the compartment. Each treadle provided a brief feedback click when operated by a force greater than approximately 0.70 N, applied to its center. The large force requirement was chosen to prevent the subjects from operating the treadles by pecking them. Visual observation of the subjects, both before and after the experiment, assured that the subjects did press with their feet.

A light, shining through a 5- by 2-cm white Plexiglas panel, illuminated each treadle. Each panel was located directly above the point where one of the metal strips, which supported the treadles, entered the magazine wall. A houselight, located near the ceiling, directly

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over the magazine, illuminated the experimental enclosure constantly during the experimental sessions. The magazine, accessed through a 5- by 5-cm hole in the center of one wall, was located 10 cm above the enclosure floor. It was illuminated by a single light bulb whenever it was presented.

Although two standard response keys were also present in the enclosure, directly above the treadles, they were never illuminated, and pecks on them were not recorded.

Procedure

All subjects were trained to press the treadles with their feet by a successive-approximation procedure. Shaping continued until the subjects responded at equal rates for equal rates of reinforcement on the two treadles. This required three or four sessions for each subject. Each session consisted of 40, 4-sec food reinforcers.

When shaping was completed, the subjects were exposed to a series of concurrent variable-interval variable-interval (*conc VI VI*) schedules. The schedules were presented in the following order: *conc VI 30-sec VI 2-min*, *conc VI 1-min VI 2-min*, *conc VI 2-min VI 4-min*, and *conc VI 2-min VI 2-min*. The VI 2-min component of each schedule was presented on the treadle illuminated with white light, which was located to the subject's left as it faced the magazine. The other component schedule was presented on the treadle illuminated with blue light, located to the subject's right. The variable-interval schedules were presented according to a 12-interval Fleshler and Hoffman

(1962) series, by two variable-interval timers that ran independently of each other.

Each subject worked on each schedule until five days of stable responding had been recorded. Responding was considered to be stable when the rate of responding during each of the last five sessions fell within the range set by the earlier sessions; *i.e.*, when there was no upward or downward trend. This usually required 10 to 15 sessions. Sessions were conducted daily, five to six times per week. Each session terminated when 40 reinforcers had been presented; each reinforcer consisted of 4-sec access to the magazine containing grain. The treadle lights were extinguished and no presses were recorded during magazine presentation.

Changes from one treadle to the other were not penalized on any schedule, except *conc VI 2-min VI 4-min*. On this schedule, changes from one treadle to the other initiated a 2-sec changeover delay (COD) period, during which no responses were reinforced. The changeover delay was introduced because the relative rates of pressing on the components of this schedule did not equal the relative rates of reinforcement they provided. Also, it has been found that introduction of a COD restores this relationship for pigeons responding on concurrent key-peck schedules (Herrnstein, 1970).

RESULTS

Table 1 contains the rate of responding (presses per minute) and the rate of reinforcement (reinforcers per hour) generated by each

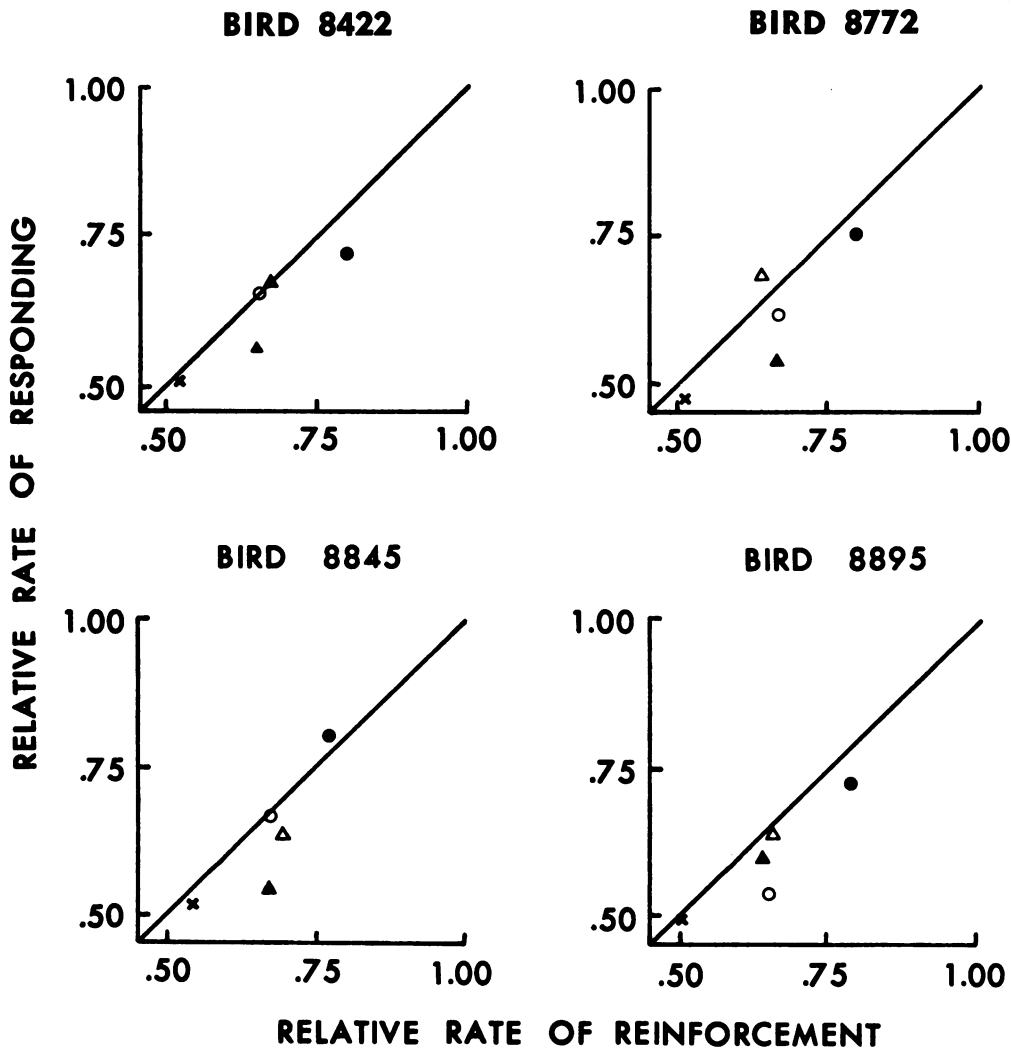
Table 1

Rates of responding (presses per minute) and rates of reinforcement (reinforcers per hour) for each subject on each concurrent schedule.

Bird		Schedule									
		Conc		Conc		Conc		Conc		Conc	
		VI	VI	VI	VI	VI	VI	VI	VI	VI	VI
		30-sec	2-min	1-min	2-min	2-min (no COD)	4-min (no COD)	2-min (COD)	4-min (COD)	2-min	2-min
8422	responses	17.1	6.8	17.8	9.7	14.7	11.6	16.2	8.4	12.2	12.5
	reinf.	107.5	30.3	57.8	31.8	30.5	15.4	32.1	16.2	30.7	31.4
8772	responses	20.3	6.7	23.0	14.4	23.3	19.9	25.2	12.1	17.0	18.9
	reinf.	110.8	29.8	58.3	28.7	30.2	13.1	29.6	17.3	30.6	29.8
8845	responses	16.8	5.0	14.8	7.7	10.4	8.5	12.3	7.0	10.1	9.4
	reinf.	110.9	33.9	57.9	28.5	31.6	13.3	31.2	14.5	31.2	28.7
8895	responses	24.1	8.8	10.8	9.2	20.0	12.7	24.2	12.9	11.4	11.2
	reinf.	110.1	30.8	58.3	32.1	30.2	14.0	29.8	15.1	30.4	31.0

subject in each component of each concurrent schedule. The rates are the means of the last five sessions of responding on each schedule. Table 1 shows that the rates of pressing in the component schedules were controlled by the rates of reinforcement they provided. Within any one concurrent schedule, the component that provided the higher rate of reinforcement also generated the higher rate of responding.

However, Table 1 also shows that the total rates of responding generated by the concurrent schedules were not controlled by their total rates of reinforcement. The sum of the rates of responding on the two component schedules did not decrease with decreases in the sum of the rates of reinforcement they provided. This finding differs from the findings of Catania (1963), who reported that the total rate of re-



- VI 30-SEC VI 2-MIN ▲ VI 2-MIN VI 4-MIN (NO COD)
- VI 1-MIN VI 2-MIN △ VI 2-MIN VI 4-MIN (COD)
- * VI 2-MIN VI 2-MIN

Fig. 1. Relative rate of pressing as a function of the relative rate of reinforcement generated by the component of each concurrent schedule that provided the higher rate of reinforcement.

sponding increased with increases in the total rate of reinforcement, when pigeons pecked for food reinforcers on concurrent schedules.

Figure 1 presents the relative rate of pressing as a function of its relative rate of reinforcement, for the component of each concurrent schedule that provided the higher rate of reinforcement. Each set of coordinates represents an individual subject. Each point represents the mean of the last five days of responding. All points that fall on the diagonal lines conform perfectly to the Matching Law. The relative rate of responding is approximately equal to the relative rate of reinforcement for all subjects and all schedules, except the *conc* VI 2-min VI 4-min schedule without a changeover delay.

Figure 2 presents the rate of pressing in the VI 2-min component of each concurrent schedule as a function of the rate of reinforcement obtained by pressing in the other component. The 15 reinforcers per hour point corresponds to the *conc* VI 2-min VI 4-min schedule, the 30 reinforcers per hour to the *conc* VI 2-min VI 2-min schedule, the 60 reinforcers per hour to the *conc* VI 2-min VI 1-min schedule, and the 120 reinforcers per hour to the *conc* VI 2-min VI 30-sec schedule. The points that represent the *conc* VI 2-min VI 4-min schedule are the means of the points generated by this schedule with and without a changeover delay. The rates of pressing presented for the *conc* VI 2-min VI 2-min schedule are those from the treadle associated with the white light. Both posi-

tive and negative behavioral contrast occurred. Positive contrast occurred when the rate of responding in the constant VI 2-min component increased with decreases in the rate of reinforcement on the variable component, from 120 to 60 to 15 reinforcers per hour. Negative contrast occurred when the rate of responding in the constant VI 2-min component decreased with increases in the rate of reinforcement in the variable component, from 15 to 30 reinforcers per hour.

DISCUSSION

The relative rate of concurrent treadle pressing resembles the relative rate of concurrent key pecking in two ways. First, treadle-press responding usually conforms to the Matching Law. Second, deviations from the Matching Law can be corrected by introducing a changeover delay. Fifteen of the 20 relative rates of treadle pressing presented in Figure 1 fall within $\pm 5\%$ of their relative rates of reinforcement; three of the five deviant points occurred for the *conc* VI 2-min VI 4-min schedule before the changeover delay was introduced. Introduction of the changeover delay had the same effect on treadle-press responding as it has on key-peck responding. It increased the relative rate of responding on the component schedule that provided the higher rate of reinforcement until it equalled its relative rate of reinforcement (Herrnstein, 1970).

Positive and negative behavioral contrast also occurred for concurrent treadle-press responding. Figure 2 shows that the rate of pressing in the VI 2-min component of each concurrent schedule decreased as the rate of reinforcement provided by the other increased, and increased as this rate of reinforcement decreased. These are not transient contrast effects. The data represent the rates of responding generated after subjects had responded on each schedule for several days.

The contrast effects found in the present experiment appear to contradict Hemmes' and Westbrook's failure to find contrast when pigeons pressed treadles for food reinforcers on multiple schedules (Hemmes, 1973; Westbrook, 1973). Two ways of reconciling the findings of these studies will be considered.

First, the differences may be a product of one or more procedural differences between the studies. Westbrook's procedure and apparatus

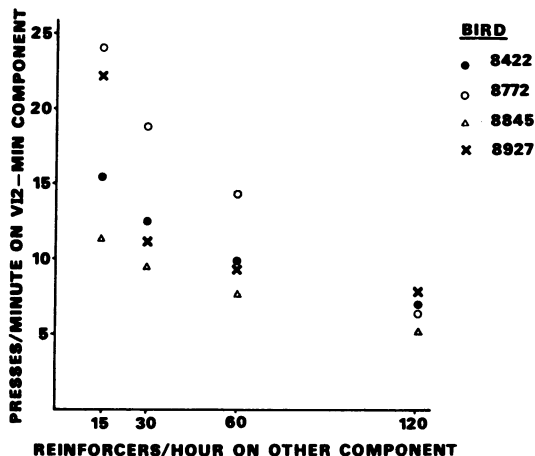


Fig. 2. Rate of pressing in the VI 2-min component of each concurrent schedule as a function of the rate of reinforcement obtained by pressing in the other component.

differed from the present ones in a large number of ways. His bars were located on the wall of the chamber and were operated by a smaller, 0.12-N force. His discriminative stimuli were auditory and there was little evidence that the subjects discriminated between them. However, these differences cannot account for Hemmes' findings. Hemmes produced a discrimination using visual stimuli and floor treadles comparable in size and stiffness to the present treadles. If both Hemmes' and Westbrook's findings are to be attributed to the same procedural detail, then it must be one of the following. One, both Hemmes' and Westbrook's subjects began the experiment on multiple schedules with equal rates of reinforcement in the two components. The present subjects received only a short period of equal reinforcement, during shaping, before they began the concurrent schedules with their unequal programmed rates. Two, Hemmes and Westbrook studied contrast produced by introducing extinction in one component. The present study reduced but did not eliminate all reinforcement from the variable component.

Second, the differences in the results of the three studies may indicate that the factors producing behavioral contrast on multiple schedules are not the same as the factors producing behavioral contrast on concurrent schedules. Rachlin (1973) suggested that this is true. He observed that the change in the rate of responding that is labelled contrast is measured in different ways for concurrent and multiple schedules.

The rate of responding in a component of a multiple schedule is calculated by dividing the number of responses emitted on that component (R_1) by the amount of time for which the component is available (T_1). If contrast occurs, one of these statistics must have changed. Rachlin argued that R_1 changes because a transition from a stimulus that signals a low rate of reinforcement to one that signals a high rate, excites extra, autoshaped responses. Conversely, a transition from a stimulus that signals a high rate of reinforcement to one that signals a low rate inhibits these responses. If these extra responses have the same form as the instrumental responses, they will either add to or subtract from the recorded number of responses, producing positive or negative behavioral contrast. If they do not have the same form as the instrumental responses they will

not be recorded, and thus no contrast will be observed. According to this argument, multiple-schedule contrast will not be observed when pigeons press treadles for food reinforcement. The extra responses will be unrecorded pecks (Brown and Jenkins, 1968), not recorded treadle presses.

The rate of responding in a component of a concurrent schedule is calculated by dividing the number of responses emitted on that component (R_1) by the total session time (T). Rachlin noted that R_1/T is the mathematical product of two other factors: the actual rate of responding as it is calculated for multiple schedules (R_1/T_1), and the proportion of the total session time spent responding on that component (T_1/T). Concurrent contrast could result from a change in either of these statistics. But, Rachlin argued that a change in T_1/T is responsible. According to his theory, R_1/T_1 is a constant that does not change with changes in the distribution of reinforcers across the component schedules. However, T_1/T does depend on this distribution. Using the equalizing principle, formulated by Killean (1972), Rachlin predicted that T_1/T changes whenever the rate of reinforcement provided by either component schedule changes. When either rate of reinforcement varies, subjects redistribute their time between the component schedules so that the rates of reinforcement (number of reinforcers obtained in component 1 divided by T_1) obtained in each are equal. Thus, a decrease in the rate of reinforcement in component 2 of a concurrent schedule will reduce the amount of time spent in that component. The decrease in T_2 will produce an increase in T_1 , and thus in T_1/T . The increase in T_1/T will result in an increase in R_1/T , which is called positive contrast. By a similar argument, an increase in the rate of reinforcement in component 2 will result in a decrease in R_1/T , which is called negative contrast. Therefore, concurrent contrast should occur for treadle-press responding. It should occur whenever the rate of reinforcement in one component changes, regardless of the nature of the response required.

The present results cannot test Rachlin's theory directly. The time spent responding in each component schedule was not recorded. However, it should be noted that Rachlin's theory does predict the results of all three treadle-press studies.

The constancy of the sum of the absolute rates of treadle pressing, across changes in the sum of the rates of reinforcement they provide, may be one difference between treadle-press and key-peck responding. Catania (1963) found that the total rate of responding increased with increases in the total rate by reinforcement for pigeons pecking keys. However, the Catania study used a Findley concurrent procedure. Thus, the difference could also represent a difference between Findley and two-key concurrent procedures.

Preliminary evidence suggests that it does represent a difference between the Findley and two-key procedures. Catania's findings have been replicated for several different forms of responses and species when Findley procedures are used (Findley, 1958; Killeen, 1972; Schmitt, 1974). But, Fantino, Squires, Delbrück, and Peterson (1972) failed to find an increase in the total rate of pecking with increases in the total rate of reinforcement when pigeons were placed on two-key concurrent schedules. They conducted three different schedules and varied the total rate of reinforcement from approximately nine to 900 reinforcers per hour. If it were replicated, this difference between the constancy of the total rate of responding generated by the two-key concurrent, and the orderly change in the total rate of responding generated by the Findley concurrent, would represent the first known difference between the two procedures.

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