

*RAPID DETERMINATIONS OF PREFERENCE IN  
MULTIPLE CONCURRENT-CHAIN SCHEDULES*

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With concurrent chains arranged for a pigeon's key pecks, pecks on two concurrently available initial-link keys (left and right) respectively produce separately operating terminal links (A and B). Preferences for terminal link A over terminal link B are usually calculated as deviations of relative initial-link response rates (left divided by total pecks) from those during baseline conditions, when A equals B. Baseline preferences, however, are often variable and typically are determined indirectly (e.g., with unequal A and B, reversing left-right assignments of A and B over sessions and estimating the baseline from differences between the relative rates generated). Multiple concurrent-chain schedules, with components each consisting of a pair of concurrent chains, speed the determination of preferences by arranging A and B and their reversal within sessions. In two experiments illustrating the feasibility of this procedure, one component operated with circles projected on initial-link keys and the other with pluses; when left and right initial-link pecks respectively produced terminal links A and B in one component, they produced B and A in the other. Even as the baselines fluctuated, preference was observable within sessions as the difference between relative initial-link response rates in the two components. The first experiment demonstrated the rapid development of preferences when terminal links A and B consisted of fixed-interval 15-s and 30-s schedules. The second demonstrated the sensitivity of the procedure to preference for a fixed-interval 30-s schedule operating for pecks on either of two keys (free choice) over its operating for pecks on only a single key (forced choice).

*Key words:* multiple schedules, concurrent-chain schedules, relative rate, baseline relative rate, preference, fixed interval, free choice, key peck, pigeon

As concurrent-chain schedules are typically arranged for pigeons, two response keys are concurrently available in initial links; according to equal but independent variable-interval (VI) schedules, pecks on these keys respectively produce separate terminal links within which pecks may produce food (e.g., see Herrnstein, 1964). The terminal links may entail different types or parameters of schedules and different properties of behavior. To the extent that one initial-link key maintains more pecking than the other, the terminal link produced by pecks on that key is said to be preferred to the terminal link produced by pecks on the other. Preference is often expressed in terms of relative rate of responding: left initial-link responses divided by total initial-link responses.

In simple concurrent schedules, preference is confounded with the variables that deter-

mine the rates of the concurrent responses. For example, in concurrent schedules that differentially reinforce high (DRH) and low (DRL) rates of responding, relative response rates will be determined largely by the high-rate and low-rate contingencies and therefore cannot be taken as preferences. Concurrent-chain schedules, however, separate preferences for different conditions (observed during initial links) from the contingencies that maintain responding in those conditions (terminal links). For this reason, concurrent chains have been a procedure of choice in the study of preference.

Concurrent-chain schedules typically examine relative rates of responding over extended periods of exposure to terminal-link variables. It might be assumed that a relative rate of .5, when initial-link rates are equal, is the baseline against which preferences should be measured. But baseline relative rates often depart substantially from .5 and also vary over sessions. Although baseline rates can be assessed directly by setting terminal link A equal to terminal link B (e.g., Alsop & Davison, 1986; Davison, 1983; Fantino & Davison, 1983), they are often dealt with indirectly if

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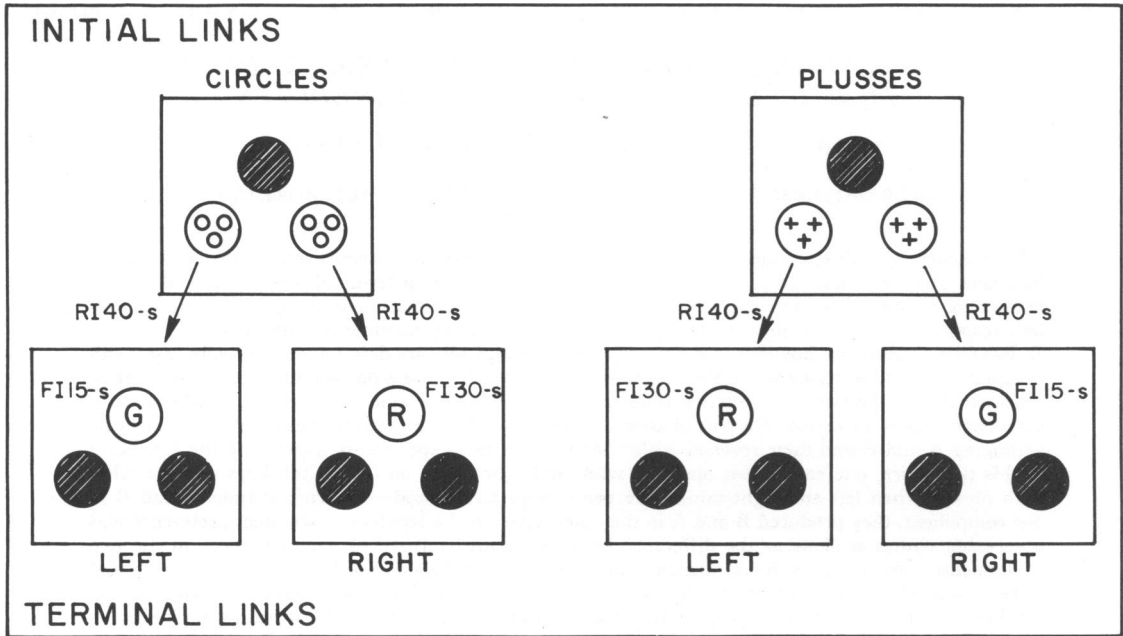


Fig. 1. Multiple concurrent-chain schedules with FI 15-s (green) and FI 30-s (red) terminal links. During initial links, the two lower keys were lit with either circles or pluses. According to independent RI 40-s schedules, pecks on these keys produced their respective terminal links, during which the top key was lit green (G) or red (R). Initial links were reinstated after food deliveries. With initial-link circles, pecks on the left produced an FI 15-s terminal-link schedule accompanied by green, and pecks on the right produced an FI 30-s terminal-link schedule accompanied by red; with pluses, left and right terminal links were reversed.

at all (e.g., Catania, 1980; Green & Snyderman, 1980; Horney & Fantino, 1984; Leung & Winton, 1985; Moore, 1984; Navarick & Fantino, 1972; Poniewaz, 1984; Rachlin & Green, 1972; Rider, 1983; Snyderman, 1983). For example, terminal links A and B may be reversed over successive conditions; preference is then given by the difference between relative rates when terminal link A is produced by the left initial-link response and those when A is produced by the right initial-link response (strictly, half the difference may be taken as the shift in either direction from an assumed baseline midway between the two obtained values).

The present procedure was designed to assess preference within sessions and thereby to eliminate the need for baseline determinations or sequential reversals in terminal-link contingencies. Pigeons were exposed to pairs of concurrent-chain schedules arranged in the two components of a multiple schedule. The initial links, accompanied by circles or pluses on both initial-link keys, alternated randomly every 30 s with a probability of .5. During

one of the two types of initial-link stimuli, the correlation of initial-link keys with terminal links was reversed relative to that during the other. The advantage of this arrangement was that preference could be observed within individual sessions as the difference between relative initial-link response rates in the two multiple-schedule components. This measure remained valid even if the baseline shifted.

#### EXPERIMENT 1: SHORT FI VERSUS LONG FI PREFERENCE

If a schedule procedure generates performances that vary with parameter changes, the effectiveness of a new form of the procedure can be judged by whether it generates performances varying similarly with equivalent parameter changes. A large body of evidence, including much of the literature already cited, shows that relative response rates in concurrent chains are sensitive to the relative time from the onset of a terminal link to the delivery of a reinforcer, as in fixed-interval (FI) schedules. The first experiment therefore ex-

amined multiple concurrent-chain schedules in which FI 15-s and FI 30-s schedules operated in the respective terminal links.

## METHOD

### *Subjects*

Three White Carneaux pigeons were individually housed in a facility with a 12-hr-on 12-hr-off light-dark cycle and were maintained at about 80% of their free-feeding weights. Each pigeon had an experimental history consisting only of the shaping of pecks on a white key.

### *Apparatus*

Sessions were conducted in the three-key chamber described in Jans & Catania (1980); the three keys were centered above the feeder and arranged in the form of an apex-up equilateral triangle (see Figure 1). Stimuli were projected by in-line display units (Industrial Electronics Engineers Model 10) mounted behind each key. Purina pigeon pellets were presented by a Gerbrands feeder. Scheduling and recording were arranged by an APPLE® II microcomputer connected to the chamber by a John Bell Engineering 6522 Parallel Interface and solid-state switching circuitry.

### *Procedure*

The multiple concurrent-chain schedules were arranged as illustrated in Figure 1. Initial links were scheduled on the two bottom keys. The two multiple-schedule components were distinguished by a pattern of circles or of plus signs projected on both initial-link keys; in "circle components," three 6-mm-diameter white circles in a base-up triangular configuration were projected on each key; in "plus components," three white plus signs, 6 mm high and 6 mm wide with arms 1.5 mm thick, were projected in the same triangular configuration.

Pecks on initial-link keys produced the respective terminal links according to independent random-interval (RI) 40-s schedules. The schedule for each initial-link key continued to operate even when one or more terminal links had already been arranged for subsequent pecks on that key; terminal links not yet produced accumulated separately within each multiple-schedule component (circles and pluses) but were not saved from one session

to another. The two multiple-schedule components were presented in random alternation with a probability of .5 after every 30 s of initial link. No changeover contingencies were arranged for initial-link responding.

Both terminal links were scheduled on the single top key; an FI 15-s schedule operated in the presence of green on the top key, and an FI 30-s schedule in the presence of red. (For convenience, these will sometimes be referred to respectively as the green or FI 15-s and the red or FI 30-s terminal links.) Terminal-link key pecks were reinforced by 5-s operations of a white-lit food hopper, during which other chamber lights were off. A house-light was lit during initial links and was off during terminal links.

The multiple concurrent-chain schedules were arranged for 30 sessions. During the first 10 sessions, contingencies were as shown in Figure 1. With circles projected on initial-link keys, left-key pecks produced green FI 15-s terminal links and right-key pecks produced red FI 30-s terminal links according to independent RI 40-s schedules. With pluses projected on initial-link keys, opposite terminal-link contingencies were arranged: left-key pecks produced the red FI 30-s terminal links and right-key pecks produced the green FI 15-s terminal links. The contingencies in the two multiple-schedule components, circles and pluses, were reversed after the 10th and again after the 20th session.

The first two sessions for each pigeon lasted for 60 min of initial links; thereafter, with increased initial-link response rates, they were reduced to 40 min for Pigeon 53 and to 20 min for Pigeons 54 and 55, with one or two temporary adjustments of session duration by increments or decrements of 10 min to minimize postsession feeding while maintaining consistent body weights. For the same reason, a further reduction of session duration to 30 min was made for Bird 53 after the 15th session.

These sessions were preceded by about 3 weeks of preliminary sessions in which an FI 15-s schedule operating on a green key alternated irregularly with an FI 30-s schedule operating on a red key, using only the upper key. The time intervals separating these response-independent FI presentations were arranged to approximate those that were to occur with the FI schedules incorporated as

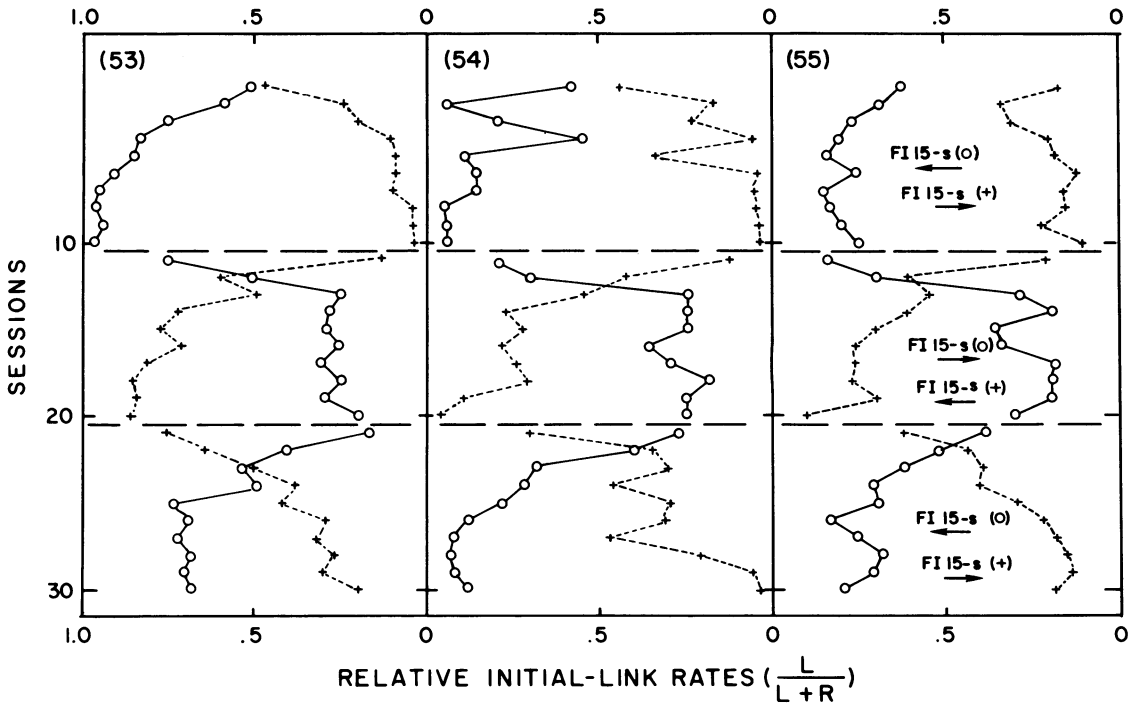


Fig. 2. Relative initial-link response rates in the multiple concurrent-chain schedules for Pigeons 53, 54, and 55. Sessions are shown from top to bottom; left or right displacements of points correspond to respective shifts of relative rate toward left or right terminal links. At the horizontal dashed lines, the terminal links correlated with circle and plus initial-link components were reversed. Arrows accompanying circles and pluses (shown for Bird 55, but valid for all 3 birds) point toward the initial-link key (left or right) that produced FI 15-s terminal links.

terminal links in the concurrent chains; that is, the two FI schedules were presented according to concurrent variable-time schedules (VT 40-s VT 40-s). During these preliminary sessions, the houselight was lit and all keys were dark between FI components.

#### RESULTS AND DISCUSSION

For Pigeons 53, 54, and 55, relative rates (left initial-link responses divided by left plus right initial-link responses) are shown over sessions in Figure 2; circles and pluses identify data from the corresponding multiple-schedule components. The  $x$  axis is arranged so that left and right displacements of data points represent respective left and right shifts in relative rate, with sessions shown from top to bottom. Successive reversals of terminal links are separated by dashed lines; for each component, the arrows point in the direction of the initial-link key that produced FI 15-s terminal links.

For each pigeon, preference for FI 15-s developed rapidly during the first few sessions.

By the end of the first condition, Pigeons 53 and 54 were each distributing about 95% of their initial-link pecks in each component to the key that produced FI 15-s terminal links; as a result, about 60% rather than 50% of their terminal-link entries were into the FI 15-s schedule. During the same period, Pigeon 55 distributed about 80% of its initial-link pecks to the key that produced FI 15-s terminal links, and it entered the FI 15-s and FI 30-s terminal links about equally often. Thereafter, over the two reversals of terminal links, relative initial-link responding followed the location of the FI 15-s terminal link. Magnitudes of preference became more similar across pigeons during the second and third conditions, as the initial-link responding of Pigeons 53 and 54 changed in ways that produced the FI 15-s and FI 30-s terminal links about equally often.

These reversals confirm that behavior in the initial links of multiple concurrent-chain schedules is sensitive to terminal-link contingencies.

## EXPERIMENT 2: FREE-CHOICE PREFERENCE

Some concurrent-chain experiments are concerned with variables that have small effects compared to those of the FI 15-s and FI 30-s schedules of Experiment 1. An example is the preference for free choice over forced choice (e.g., Catania, 1980), which occurs when the availability of two or more keys in one terminal link (free choice) is pitted against restriction to a single key in the other (forced choice). As a shift in relative initial-link response rates, the magnitude of the preference for free choice is typically less than .1. In standard concurrent chains, such preferences are easily masked by baseline shifts or other sources of variability. Experiment 2 therefore examined whether the free-choice preference could be obtained within multiple concurrent-chain schedules.

### METHOD

#### *Subjects*

One White Carneau pigeon (51) and two Silver King pigeons (94 and 2) were individually housed in a facility with a 12-hr-on 12-hr-off light-dark cycle and were maintained at about 80% of their free-feeding weights. Each pigeon had served in previous research on free-choice preference in standard concurrent chains.

#### *Apparatus*

Sessions were conducted in a six-key chamber, similar to that used by Catania and Sagvolden (1980), in which initial links were arranged on a bottom horizontal row of two keys and terminal links on a top horizontal row of four keys. As in Experiment 1, stimuli were projected by in-line display units behind each key, Purina pigeon pellets were presented by a Gerbrands feeder, and scheduling and recording were arranged by an APPLE® II microcomputer interfaced to the chamber.

#### *Procedure*

The initial-link schedules operated on the two bottom keys. As in Experiment 1, circles and pluses were correlated with the two multiple-schedule components, and pecks on each key produced the respective terminal links according to independent RI 40-s schedules. Details of the schedules (e.g., accumulation of

terminal links not yet produced, alternation of components, changeover contingencies) were as in Experiment 1, except that no houselight was used.

The initial-link schedules produced FI 30-s terminal links on the top row of keys. In free-choice terminal links, two keys were lit, and a peck on either lit key operated the feeder at the end of the fixed interval. In forced-choice terminal links, a single key was lit, and a peck on this key operated the feeder at the end of the interval. With circles projected on the initial-link keys (bottom), left-key pecks produced free-choice terminal links (the FI schedule operated for the two left-most top keys, both lit green) and right-key pecks produced forced-choice terminal links (the schedule operated for the right-most top key, lit green). With pluses projected on initial-link keys, terminal-link contingencies were reversed: Left-key pecks produced forced-choice terminal links (single left-most key, lit green) and right-key pecks produced free-choice terminal links (two right-most top keys, both lit green). Fifteen sessions of the multiple concurrent-chain schedules were arranged; session durations of 30 or 40 min of initial links for each bird were temporarily adjusted once or twice by increments or decrements of 10 min to reduce feeding outside of the session while maintaining consistent body weights.

### RESULTS AND DISCUSSION

Relative rates for Pigeons 2, 51, and 94 are shown in Figure 3. As in Figure 2, relative initial-link responding is plotted along the  $x$  axis, with sessions shown from top to bottom. Apex-left triangles represent schedules with free choice in left terminal links and apex-right triangles those with free choice in right terminal links. Left and right displacements of data points correspond respectively to shifts of relative rate toward left or right terminal links or, in other words, toward the initial-link key that produced the free-choice terminal link. If the two data triangles for a given bird and session are each displaced from a common baseline located somewhere between them, then they will be pointing away from each other when relative rates have shifted in the direction of a preference for free-choice terminal links.

According to this measure, the pigeons' free-choice preference developed by the third ses-

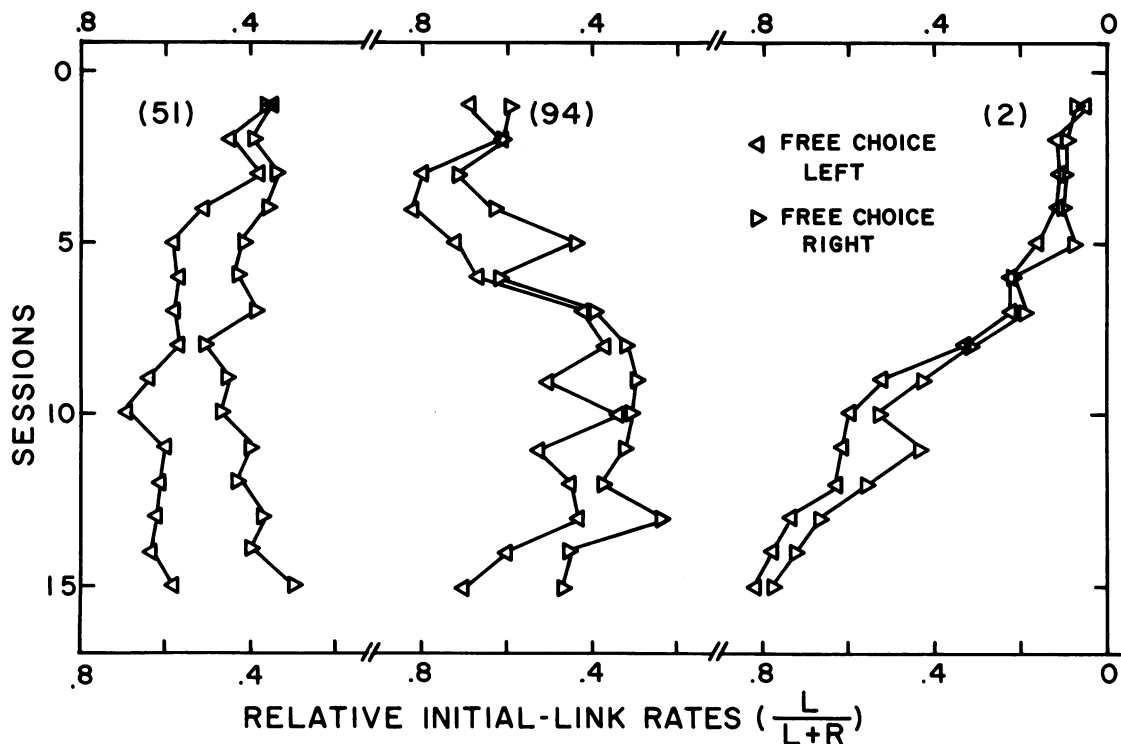


Fig. 3. Relative initial-link response rates for Pigeons 2, 51, and 94. Triangles show relative initial-link response rates in each initial-link component, with sessions from top to bottom. Left or right shifts of points correspond to respective shifts of relative rate toward left or right terminal links. During one initial-link component (apex-left triangles), left pecks produced free-choice terminal links; during the other (apex-right triangles), right pecks produced free-choice terminal links.

sion. Free-choice terminal links were preferred to forced-choice terminal links in 41 of the 45 sessions; of the four exceptions, three occurred during the first two sessions of the procedure (Session 1 for Birds 51 and 2, and Session 2 for Bird 94; the other was in Session 8 for Bird 2). The preference was observable with baseline shifts over sessions that ranged from about .4 to .55 for Pigeon 51, .35 to .75 for Bird 94, and .1 to .8 for Pigeon 2. Furthermore, the magnitudes of the free-choice preferences were comparable to those observed with standard concurrent chains in previous research (e.g., Catania, 1980).

The free-choice preference cannot be derived from single components of the multiple concurrent-chain schedule. Consider, for example, the data from Pigeon 2. If comparable data had been obtained in a standard concurrent chain with free choice on the left arranged for the first seven sessions followed by a reversal of the terminal links for the re-

maining eight sessions, relative rates of less than .3 with free choice on the left would have been followed by relative rates increasing to .8 with free choice on the right (left-pointing triangles for Sessions 1 to 7 and right-pointing triangles for Sessions 8 to 15). Without the internal evidence of a shifting baseline provided by the multiple concurrent-chain procedure, such data might have been taken as consistent with a forced-choice rather than a free-choice preference.

#### GENERAL DISCUSSION

With the multiple concurrent-chain procedure, pigeons' preferences developed rapidly and could be calculated within single sessions as the displacement of two relative rates from an intermediate baseline. These findings demonstrate the utility of the multiple concurrent-chains schedule for studying preference. Relative rates closely followed reversals of

terminal links for Pigeons 53, 54, and 55. The reversals were included only to confirm that initial-link responding was controlled by the terminal links arranged for each pair of initial-link schedules. The demonstration showed that sequential reversals are unnecessary to observe preferences because they are already incorporated in the multiple concurrent-chain procedure (see Figure 1).

The present schedule offers other advantages besides speed. For example, the availability of free choice is not a reinforcer of large magnitude, and yet free-choice preference was demonstrated with Pigeons 2, 51, and 94 without sequential reversals of terminal links. Given the substantial shifts in baseline for Pigeons 2 and 94, a free-choice preference might not have been detected at all with standard concurrent-chain schedules even over a greater number of sessions with some reversals of terminal links. Not only do effects emerge rapidly; this procedure is also sensitive to small differences. It will therefore be useful to explore other terminal-link variables with the multiple concurrent-chain procedure, including some for which consistent preferences have not been demonstrated with standard concurrent-chain procedures (e.g., response requirements in terminal links: Fantino, 1968; Killean, 1968).

The present experiments have shown that directions of preference in multiple concurrent-chain schedules are consistent with those obtained in standard concurrent chains. The procedures have also shown some sensitivity to the magnitude of preference, but this finding does not guarantee that data obtained with this procedure will agree quantitatively with those obtained with standard concurrent chains. Performances maintained by multiple concurrent-chain schedules may be affected by various parameters of the schedules. For example, magnitudes of preference may vary with changeover contingencies (e.g., Davison, 1983), and interactions across multiple-schedule components may vary with component duration (but see Lobb & Davison, 1977, and McLean & White, 1983; note also that identical terminal links are available as reinforcers in the two multiple-schedule components).

It may also be important to explore how shifts in relative rate are affected by baseline relative rates. A shift in relative rate of .1 from a baseline of .5 (.5 to .6) is probably not equiv-

alent to one from a baseline of .8 (.8 to .9). This also implies that the baseline in the present multiple concurrent-chain schedules cannot be assumed to be midway between the relative rates obtained in the two components. One possibility is that preferences produce shifts in either direction proportional to the maximum available shifts (e.g., given a baseline at a relative rate of .6, the maximum available shift to the left is .4 and to the right is .6; thus, half maximum shifts to the left and to the right would produce respective relative rates of .8 and .3). Given a relative rate of  $L$  with some variable added to the left terminal link and  $R$  when the same variable is added to the right terminal link, a calculation of the baseline that satisfies this proportionality is:  $R/(1 - L + R)$ . In the preceding example, with  $L = .8$  and  $R = .3$ , the calculation yields .6 as the baseline.

But the calculation of preference as a mean shift from baseline,  $(L - R)/2$ , is independent of the particular value of the baseline. Thus, the behavioral properties of these preparations may be more critical than their quantitative analysis. The viability of a preparation should not be judged merely on the basis of the quantitative manipulations it allows. Even a well established preparation must be tested occasionally against variables with known effects. For example, the discrimination between the circles and pluses of the initial-link multiple-schedule components may not be maintained over extended sessions that involve only small differences between terminal-link schedules. If, for some purposes, the present schedules become established as improvements over standard concurrent chains, it will still be necessary to demonstrate that individual performances have remained sensitive to the variables of interest throughout the course of an experiment.

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