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# *EFFECTS OF REINFORCEMENT CONTEXT ON CHOICE*

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Two experiments investigated the effects of successive reinforcement contexts on choice. In the first, concurrent variable-interval schedules of primary reinforcement operated during the initial links of concurrent chains. The rate of this reinforcement arranged by the concurrent schedules was decreased across conditions: When it was higher than the terminal-link rate, preference for the higher frequency initial-link schedule increased relative to baseline. (During baseline, a standard concurrent-schedule procedure was in effect.) When the initial-link reinforcement rate was lower than the terminal-link rate, preference converged toward indifference. In the second experiment, a chain schedule was available on a third key while a concurrent schedule was in effect on the side keys. When the terminal link of the chain schedule was produced, the side keys became inoperative. Availability of the chain schedule did not affect choice between the concurrent schedules. These results show that only when successive reinforcement contexts are *produced* by choice responding do those successive contexts affect choice in concurrent schedules.

*Key words:* concurrent schedules, concurrent chains, successive reinforcement context, choice, key peck, pigeons

Contextual variables have been shown to be important determiners of behavior (e.g., Fantino & Dunn, 1983; Gibbon, 1981; Heyman & Bouzas, 1980; Rescorla, 1982; Reynolds, 1961; Williams, 1981). For example, the effects of reinforcement context on response rate have been demonstrated in experimental situations involving one (Rachlin & Baum, 1972), two (Catania, 1963; Duncan & Silberberg, 1982; Lobb & Davison, 1977; Rachlin & Baum, 1969; Wilkie, 1973), or three response keys (Davison & Hunter, 1976; Davison & Temple, 1974; Nevin, Mandell, & Yarensky, 1981). In the above experiments, an alternative source of reinforcement—the reinforcement context—varied in reinforcer amount (Rachlin & Baum, 1969) or rate (e.g., Catania, 1963), or the alternative reinforcers were delayed (e.g., Rachlin & Baum, 1972), signaled (e.g., Nevin et al., 1981), or delivered freely as opposed to response contingently (e.g., Duncan & Silberberg, 1982). The general finding has been that rate of responding on a constant reinforcement schedule varies inversely with amount and rate of reinforcement available in the surrounding context.

The effect of contextual reinforcement upon choice per se has also been investigated (Davison, 1982; Davison & Hunter, 1976; Davison & Temple, 1974; Fantino & Dunn, 1983; Lobb & Davison, 1977; McLean & White, 1983; Miller & Loveland, 1974; Pliskoff & Brown, 1976; Pliskoff, Shull, & Gollub, 1968; Prelec & Herrnstein, 1978). In these studies, contextual reinforcement consisted of a schedule of primary reinforcement, operating in the presence of, and uniquely correlated with, an exteroceptive stimulus. The contextual-reinforcement schedule constituted an additional source of primary reinforcement, above and beyond that which maintained the choice responding under study. The reinforcement context was provided in one of two ways. In one group of studies, it consisted of a third choice alternative, added to the original two-alternative choice. The added choice alternative was arranged by means of a third key, and typically involved the same type of reinforcement schedule as the original alternatives—a variable-interval (VI) schedule added to a concurrent VI VI schedule or a chain schedule added to a two-key concurrent-chains schedule. In the other group of studies, the contextual-reinforcement schedule was not available at the same time as choice was taking place, but instead followed the choice situation. Lobb and Davison (1977) referred to the reinforcement context in this latter type of procedure as a successive-reinforcement context.

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When a third choice alternative was added, the critical question was whether or not the addition of the third alternative changed preference for the original alternatives. A related question concerns whether the relation between relative rate of responding and relative rate of reinforcement was affected. Most of the prior studies of this kind involved concurrent schedules of reinforcement (Davison, 1982; Davison & Hunter, 1976; Fantino & Dunn, 1983, Experiment 4; Miller & Loveland, 1974; Pliskoff & Brown, 1976; Prelec & Herrnstein, 1978), but some used concurrent-chains schedules (Davison & Temple, 1974; Fantino & Dunn, 1983). When concurrent schedules were used, in most cases the function relating relative rate of responding to relative rate of reinforcement (i.e., matching) did not change. Prelec and Herrnstein (1978) obtained different results with VI and variable-ratio (VR) schedules of reinforcement as original alternatives and with a VI schedule of reinforcement as context. As pointed out by Fantino (1981) and Davison (1982), Prelec and Herrnstein's (1978) discrepant results were probably due to their use of a VR schedule as one of the original alternatives.

At issue in all studies involving a comparison of two- and three-alternative choices is that preference should be stable, a common assumption in operant research (Catania, 1966), and preference should be independent of irrelevant alternatives, a similar principle of formal choice theories (Luce, 1959, 1977). The principle of independence of irrelevant alternatives, also called the constant-ratio rule, states that preference between two choices, for example, should be unaffected by the addition and variation of a third, irrelevant alternative. Prelec and Herrnstein's (1978) study showed violations of this rule. On the other hand, the results of Davison (1982) and Fantino and Dunn (1983, Experiment 4) were consistent with it. The other studies do not allow a direct comparison of the choice proportions obtained with two versus three alternatives.

When concurrent chains were used, Davison and Temple (1974) showed that preference between two chains became more extreme when a third chain was added (see their Figure 3). The relative rate of responding was .25 when only two keys were available; it varied from .05 to .15 as the rate of reinforcement for the third alternative was decreased across conditions. Some of the results obtained by Fantino and Dunn (1983) were consistent with the constant-ratio rule and some were not.

An alternative formulation, the delay-reduction hypothesis (Fantino, 1981) permits substantial departures from the constant-ratio rule. According to that formulation, the strength of a stimulus as a conditioned reinforcer is a function of the reduction in time to reinforcement correlated with the onset of that stimulus (Fantino, 1981). Thus, according to this hypothesis preference for one of the alternatives in a concurrent-chains schedule should match the relative delay reduction correlated with entry into the terminal link of that alternative. When a third alternative chain is added, the delay-reduction hypothesis predicts that preference for the original alternatives will (a) diverge when the added alternative provides the highest rate of reinforcement, (b) converge when the added alternative provides a sufficiently lower rate of reinforcement than the original alternatives, and (c) not change when the addition of the third alternative does not change the overall delay to reinforcement in the situation. Thus, only in the latter case do the delay-reduction hypothesis and the constant-ratio rule make the same prediction of no change in preference with the addition of a third chain. Fantino and Dunn (1983) conducted three experiments in which a two-key concurrent-chains schedule was changed to a three-key concurrent-chains schedule. Their results confirmed the above predictions: Preference changed consistently with the delay-reduction hypothesis, even when such consistency required substantial deviations from the constant-ratio rule.

When the effects of successive-reinforcement context on choice were investigated (Lobb & Davison, 1977; McLean & White, 1983; Pliskoff et al., 1968), the typical procedure involved two keys. Two VI schedules alternated on one key, each correlated with a specific key color, while on the second key a VI schedule was continuously available. The alternating schedules on the first key will be designated M1 and M2. The common VI schedule on the second key operating during M1 will be designated C1, and during M2 will be designated C2. Of interest for the issue of contextual reinforcement is whether the relative rate of responding on the concurrently available schedules, M1 and C1, will match the relative reinforcement rate for these schedules regardless of the rate of reinforcement available in C2 and M2—the successive-reinforcement context. In all three studies, the relative rate of responding (M1/M1 + C1) or the response ratio (M1/C1) matched the corresponding relative reinforcement rate or reinforcement ratio. McLean and White (1983) and Lobb and Davison (1977) showed that the obtained slopes of the lines representing the functions relating responses to reinforcers were close to the slopes commonly reported for concurrent VI schedules (except for two subjects in McLean and White's study, which showed an extreme degree of undermatching). Pliskoff et al. (1968) also concluded that their data showed matching, but these authors did not calculate the slopes of the lines fitted to the data points.

In summary, studies investigating the effects of contextual reinforcement on choice have indicated that when concurrent chains are used, preferences change depending on whether or not the added alternative affects the overall delay to reinforcement in the situation (Fantino & Dunn, 1983). As concluded by Lobb and Davison (1977), when concurrent VI VI schedules have been used, "concurrent schedule response allocation [was] unaffected by both the successive reinforcement context in which it occur[red] and the concurrent reinforcement context in which it occur[red] . . ." (p. 37).

The present experiments further explore the effects of reinforcement context on choice in concurrent VI VI schedules. They differ from previous studies in several ways. In previous studies of successive-reinforcement context, there was never a contingency between choice responding and contextual-reinforcement availability. Presentation of the contextual-reinforcement schedule occurred independently of the subjects' responses, and was programmed on the basis of passage of time only. Here, in one study contextual reinforcement was presented contingently on the subjects' responding—a contingency for context presentation was added so that contextual reinforcement was produced by choice responding. In the second study, the contingency for presentation of contextual reinforcement was separated from choice responding, so that the production of contextual reinforcement was under the subjects' control.

Also unlike prior studies, the contextual-reinforcement schedule in the present experiments was not of the same kind as that of the original choice alternatives. Terminal links of chain schedules provided the reinforcement context to choice between concurrent VI VI schedules. Finally, whereas previous studies have focused on the effects of context on the relationship between choice responding and its direct reinforcement, here the effects of context will also be assessed by comparing the relative rate of responding before and after the introduction of contextual reinforcement.

In the first experiment reported here, a concurrent VI VI schedule either was presented without an explicit context or was embedded within the initial links of a concurrent-chains schedule. Responding in the initial links thus had two consequences: reinforcement according to the concurrent VI VI schedule, and terminal-link entries according to an independent concurrent VI VI schedule. The effects of terminal-link production on choice were explored for cases in which the transitions from initial to terminal links enhanced rate of reinforcement and for cases in which those transitions decreased rate of reinforcement. In the second experiment, the concurrent VI VI schedule was again presented either with or without an explicit context, except that this time the context was a chain schedule arranged on a third key. Depending on the condition, responding on the chain schedule resulted in a transition to an outcome correlated with a higher or lower reinforcement density than that which accompanied the concurrent VI VI. A central issue in each study concerns any changes in the distribution of choice responses as a function of (a) the presence or absence of contextual reinforcement; and (b) whether the outcomes of the contextual-reinforcement schedules were correlated with increases or decreases in reinforcement density.

## EXPERIMENT 1

This experiment included three types of conditions. In all conditions, pigeons responded on concurrent VI VI schedules in which one VI had a mean value of twice the other. In baseline conditions, this was the only schedule presented. In another set of conditions, responses on the concurrently available keys also produced entries into mutually exclusive terminal-link schedules in which the mean time to reinforcement was greater than that on the concurrent VI VI schedules (negative transition). In the third set of conditions, responses on the concurrently available keys produced entries into mutually exclusive terminal-link schedules in which the mean time to reinforcement was less than that in the concurrent VI VI schedules (positive transition). The terminal-link schedules were always unequal. Moreover, responding that led to the longer terminal-link VI was always that which produced higher rates of primary reinforcement on the concurrent VI VI schedules. Thus, responding in the choice phase had two consequences with opposing values: Responding on one key produced a lower rate of primary reinforcement but a short terminal-link VI; responding on the other key produced a higher rate of primary reinforcement but a longer terminal-link VI. Because responding maintained by conditioned reinforcement is weaker than responding maintained by primary reinforcement (Nevin et al., 1981), it was expected that choice would be affected more by the distribution of primary reinforcement in the choice phase than by the relative distribution of reinforcement in the terminal links. This study assessed this expectation and also examined the differential effects on choice of the negative and positive transitions.

## METHOD

### *Subjects*

Five White Carneau pigeons (R77, R78, R79, R81, and Y19), all with varied and extensive experimental histories, served as subjects. Bird R77 died after four conditions and was replaced by Bird Y19. The subjects were kept at 80% of their ad-lib weights through restricted feeding. Water was continuously available in the home cages.

### *Apparatus*

Two conventional two-key operant conditioning chambers were used. Each was constructed of clear Plexiglas and was 31 cm long, 30 cm wide, and 37 cm high. The translucent response keys were 2 cm in diameter, mounted side by side 20 cm from the floor and 9 cm apart, and each required a force of approximately 0.15 N for operation. The hopper opening was located below and midway between the two response keys, 5.5 cm from the floor. Each reinforcer consisted of 3.5 s of access to mixed grain. Illumination in the chamber was provided by a white 28-V dc light located in the upper corner of the back wall. Each chamber was housed in a wooden enclosure and masking noise was continuously present. Standard electromechanical equipment was used to schedule experimental events and record data.

### *Procedure*

Responding was maintained by a concurrent VI VI schedule of primary reinforcement, on which a concurrent-chains schedule was sometimes superimposed. The concurrent schedule of reinforcement was in effect during the initial links of the concurrent chains (choice phase). When the choice phase was in effect, both keys were white. Responding on each produced reinforcement according to a VI schedule and, according to an independent VI schedule, transition to the terminal link. Thus, four independent schedules were in effect during the initial link. Whenever one of the VI schedules arranged for the occurrence of an event—either food or access to the terminal link—its timer stopped, restarting after a response on the appropriate key produced the scheduled event. The food schedules operated continuously until an entry into a terminal link occurred. Then, all VI schedules stopped. These initial-link schedules restarted after reinforcement occurred in the terminal link. Available food reinforcers, or opportunities to enter a terminal link on one key, were not lost by a terminal link being produced on the other key.

If both primary reinforcement and an opportunity to enter a terminal link were available at the same time on one key, the next response on that key produced food delivery, followed by entry into the terminal link.

When a terminal link was produced, the key on which this occurred changed color (to green, if on the left key; to red, if on the right key). A VI schedule correlated with that terminal link started, and the other key became dark and inoperative. A changeover delay was in effect in the initial link, whereby responses on either key after a changeover were ineffective for 2 s.

Table 1 presents the sequences of experimental conditions, the schedules in effect in each, and the number of sessions per condition

Table 1

Conditions, numbers of sessions, and order (within parentheses) in which each determination of preference was conducted for every subject in Experiment 1.

| | Conditions | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Initial-link schedules | | | Terminal-link schedules | | Number of sessions (order) | | | | |
| | Food | | | | | | | | | |
| | L | R | Chain both | L | R | Y19 | R77 | R78 | R79 | R81 |
| 1 | VI 15 | VI 30 | — | — | — | 17 (1) | — | 18 (13) | 15 (13) | 19 (13) |
| | VI 30 | VI 15 | — | — | — | 18 (2) | — | 15 (14) | 17 (14) | 22 (14) |
| 2 | VI 15 | VI 30 | VI 60 | VI 60 | VI 30 | 27 (3) | — | 20 (15) | 17 (15) | 18 (15) |
| | VI 30 | VI 15 | VI 60 | VI 30 | VI 60 | — | — | 24 (16) | 25 (16) | 18 (16) |
| 3 | VI 30 | VI 60 | — | — | — | — | 15 (3) | 15 (3) | 16 (3) | 16 (1) |
| | VI 60 | VI 30 | — | — | — | — | 15 (4) | 22 (4) | 15 (4) | 15 (2) |
| 4 | VI 30 | VI 60 | VI 60 | VI 60 | VI 30 | — | 18 (1) | 17 (1) | 25 (1) | 21 (7) |
| | VI 60 | VI 30 | VI 60 | VI 30 | VI 60 | — | 15 (2) | 22 (2) | 20 (2) | 15 (8) |
| 5 | VI 120 | VI 240 | — | — | — | — | 15 (7) | 16 (7) | 23 (7) | 15 (3) |
| | VI 240 | VI 120 | — | — | — | — | 20 (8) | 15 (8) | 17 (8) | 15 (4) |
| 6 | VI 120 | VI 240 | VI 60 | VI 60 | VI 30 | — | 17 (5) | 25 (5) | 27 (5) | 17 (5) |
| | VI 240 | VI 120 | VI 60 | VI 30 | VI 60 | — | 28 (6) | 15 (6) | 36 (6) | 28 (6) |
| 7 | VI 180 | VI 360 | — | — | — | 16 (4) | — | 16 (11) | 18 (11) | 15 (9) |
| | VI 360 | VI 180 | — | — | — | 19 (5) | — | 15 (12) | 20 (12) | 16 (10) |
| 8 | VI 180 | VI 360 | VI 60 | VI 60 | VI 30 | 23 (6) | — | 27 (9) | 25 (11) | 29 (11) |
| | VI 360 | VI 180 | VI 60 | VI 30 | VI 60 | 18 (7) | — | 19 (10) | 15 (12) | 15 (12) |

for each subject. Each condition included a key-position reversal; that is, the schedules previously arranged on one key were now arranged on the other key. A change in condition or a key-position reversal occurred only after behavior was considered stable according to the following criteria: After 15 sessions (and every session thereafter until stability was reached), the choice proportions of the last nine sessions were divided into three successive blocks of three sessions. Performance was considered stable when the means of the three-session blocks did not differ from each other by more than .07 and did not exhibit an upward or downward trend.

Conditions 1, 3, 5, and 7 were baseline conditions during which concurrent schedules of primary reinforcement were in effect alone. These VI schedules were identical to the VI schedules that had superimposed concurrent-chain initial links in the next conditions. All VI schedules were constructed according to Fleshler and Hoffman's (1962) progression.

In Conditions 2 and 4, transitions from a higher average rate of reinforcement in the initial link to a lower average rate of reinforcement in the terminal link were studied. The average rate of reinforcement in the terminal link was always one reinforcement every 45 s. The average rate of reinforcement in the initial link was one reinforcement every 10 s in Condition 2 and one every 20 s in Condition 4. In Conditions 6 and 8, transitions from a lower average rate of reinforcement in the initial links to a higher average rate of reinforcement in the terminal links were investigated. In Condition 6, the average rate of reinforcement in the initial link was one reinforcement every 80 s, and in Condition 8 it was one reinforcement every 120 s. Sessions were conducted daily, at approximately the same time of the day, 5 to 7 days per week.

## RESULTS

All data shown represent means computed over the last five sessions of each condition, averaged over initial and reversal determinations of preference, unless otherwise stated.

Figure 1 (left) shows preference for the VI with the higher reinforcement rate of the concurrent pair in the initial links (HIVI), for each subject, and the average of all subjects.

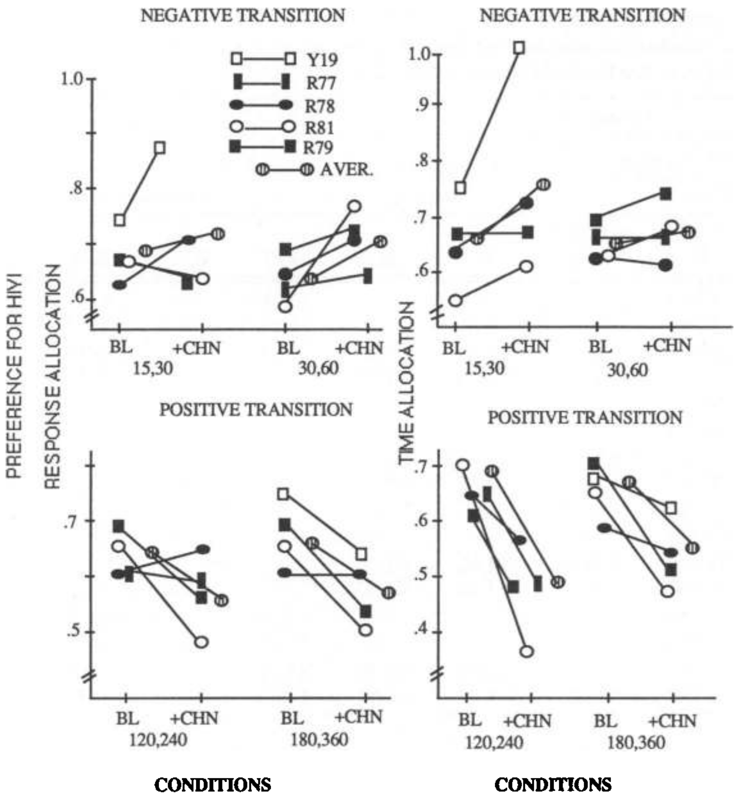

Fig. 1. Preference for the higher frequency VI food schedule in the initial links (HIVI), in every condition during baseline (BL, when a standard concurrent VI VI schedule was in effect), and during the experimental phase (+CHN, when the same concurrent food schedule was embedded within the initial links of a concurrent-chains procedure). Each pair of connected points represents conditions in which an identical concurrent VI VI schedule was in effect. The individual and average data shown represent the average of the last five sessions of each condition averaged over initial and reversal determinations of preference. Left: response allocation. Right: time allocation.

When the terminal links had a lower reinforcement density than the initial links (negative transition), the level of preference for the HIVI was higher than the preference shown for the same VI during baseline in six of eight cases. This change in preference was statistically significant ($t = 2.48$, $F(7)$, $p < .05$). On the other hand, when the transition was positive (i.e., when the terminal links had a higher reinforcement density than the initial links) preference for the HIVI decreased relative to the preference shown for the same VI during baseline in six of eight cases. This difference also was statistically significant ($t = 3.16$, $F(7)$, $p < .05$).

The time-allocation data (Figure 1, right) confirm and extend the relative response-rate data. They display the same basic pattern as the response-allocation data. The change in preference was significant ($t = 4.85$, $F(7)$, $p < .05$) in the conditions of positive transition, but nonsignificant in the conditions of negative transition ($t = 1.63$, $F(7)$, $p > .05$).

Figure 2 shows the relationship between proportion of responses (filled circles) directed to and proportion of reinforcers obtained (open circles) under the HIVI during baseline (BL) and experimental conditions (+CHN). The data points represent the averages for all subjects. In the experimental conditions, in the two cases of positive transition there was a clear tendency for the proportion of responses to undermatch the proportion of reinforcements. In one of the cases of negative transition (15,30 +CHN condition), the proportion of responses was below that of reinforcement, and in the other case of negative transition (30,60 +CHN condition), it was above the proportion of reinforcements.

Table 2 shows the absolute rate of responding on each of the initial-link food schedules and the proportion of terminal-link entries on the HIVI key. In the cases of negative transition, with one exception, the rate of responding on the HIVI increased relative to the baseline rate. The rate of responding on the LOVI, on the other hand, usually decreased relative to the baseline rates. In most cases of positive transition, there was an increase in the LO-VI rate and a decrease in the HIVI rate. Approximately equal frequencies of short and long terminal-link VIs were obtained by the animals, with the exception of Subject Y19 in the 15,30 +CHN condition.

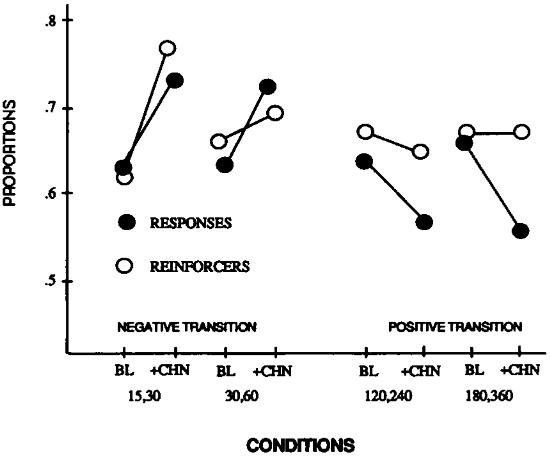

Fig. 2. Average data showing proportion of responses (filled circles) and reinforcers (unfilled circles) for the HIVI during baseline (BL) and experimental conditions (+CHN). The same pair of concurrent VI VI schedules in effect during baseline was embedded within the initial links of concurrent chains in the experimental conditions. Data represent averages of the last five sessions of each condition averaged over initial and reversal determinations of preference and over subjects.

## DISCUSSION

When a successive-reinforcement context was made contingent on responding in concurrent schedules, preference was affected. The successive-reinforcement context consisted of terminal links produced according to two independent VI schedules (access-controlling initial links). In all conditions, the higher frequency VI of the concurrent pair continued to be preferred, but the degree of preference changed depending on the relative increase or decrease in reinforcement density represented by the terminal links (Figure 1). When the terminal links represented a decrease in reinforcement density, preference for the HIVI increased. When the terminal links represented an increase in reinforcement density, preference for the HIVI decreased.

The increased preferences, relative to baseline, for the HIVI in the negative-transition conditions occurred despite the fact that responding on the HIVI key now led to a VI 60-s schedule outcome whereas responding on the LOVI key now led to a VI 30-s schedule outcome. In other words, in terms of the contingency added in these conditions, preference for the HIVI should have decreased relative to baseline. Instead, an increase occurred (Figures 1 and 2). Apparently, any differential reinforcing effects of transitions to the terminal links were overridden by an effect resembling positive behavioral contrast; that is, the HIVI schedule alternated on the same key with a VI schedule that provided the lowest rate of reinforcement in the condition (VI 60 s). Analogously, when the LOVI schedule was VI 30 s it alternated with a schedule providing the same reinforcement density, and when the LOVI schedule was VI 60 s it alternated with a schedule that provided twice the reinforcement density (VI 30 s). In the former of these two conditions the rate of responding in the LOVI decreased for 2 subjects; in the latter condition, decreases occurred for all 4 subjects (negative behavioral contrast).

Davison and Smith (1986), in a similar procedure in which terminal-link entries produced additional food reinforcers, also found that adding food reinforcers to initial-link responses decreased the sensitivity of initial-link responding to the reinforcer rates in the terminal-link periods.

The increased preferences, relative to baseline, for the HIVI in the negative-transition conditions are also reminiscent of the effects of punishment on responding maintained by concurrent VI VI schedules of reinforcement (de Villiers, 1980; Farley, 1980). These studies showed that preference for the richer VI schedule was enhanced when punishment was applied equally to responding on both appetitive VI schedules. If the transition to lower rates of reinforcement may be viewed as punishing (Michael, 1979), then the present results may be viewed in a similar light; namely, punishment of choice enhanced preference for the richer alternative.

Although results from the negative-transi-

Table 2

Absolute rate of responding (R rate) on each initial-link food schedule, and proportion of terminal-link entries (TL entries) on the HIVI key for all experimental (+CHN) and baseline (BL) conditions in Experiment 1. (HIVI refers to the higher frequency VI schedule and LOVI refers to the lower frequency VI schedule.)

| | | Subjects | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | R78 | | R79 | | R81 | | R77 | | Y19 | |
| | | R rate | TL entries | R rate | TL entries | R rate | TL entries | R rate | TL entries | R rate | TL entries |
| Conditions of negative transition | | | | | | | | | | | |
| Concurrent VI 15, VI 30 | | | | | | | | | | | |
| BL | HIVI | 36 | — | 77 | — | 34 | — | — | — | 61 | — |
| | LOVI | 22 | — | 41 | — | 17 | — | — | — | 19 | — |
| +CHN | HIVI | 43 | .58 | 86 | .53 | 61 | .51 | — | — | 66 | .75 |
| | LOVI | 17 | .42 | 45 | .47 | 32 | .49 | — | — | 12 | .25 |
| Concurrent VI 30, VI 60 | | | | | | | | | | | |
| BL | HIVI | 39 | — | 68 | — | 26 | — | 59 | — | — | — |
| | LOVI | 22 | — | 32 | — | 18 | — | 37 | — | — | — |
| +CHN | HIVI | 47 | .51 | 87 | .50 | 41 | .52 | 56 | .54 | — | — |
| | LOVI | 20 | .49 | 34 | .50 | 13 | .48 | 32 | .46 | — | — |
| Conditions of positive transition | | | | | | | | | | | |
| Concurrent VI 120, VI 240 | | | | | | | | | | | |
| BL | HIVI | 26 | — | 74 | — | 19 | — | 20 | — | — | — |
| | LOVI | 17 | — | 37 | — | 11 | — | 13 | — | — | — |
| +CHN | HIVI | 39 | .52 | 41 | .50 | 13 | .53 | 30 | .50 | — | — |
| | LOVI | 22 | .48 | 34 | .50 | 15 | .47 | 22 | .50 | — | — |
| Concurrent VI 180, VI 360 | | | | | | | | | | | |
| BL | HIVI | 47 | — | 81 | — | 19 | — | — | — | 48 | — |
| | LOVI | 29 | — | 40 | — | 11 | — | — | — | 20 | — |
| +CHN | HIVI | 39 | .50 | 52 | .51 | 17 | .53 | — | — | 49 | .46 |
| | LOVI | 29 | .50 | 47 | .49 | 18 | .47 | — | — | 27 | .54 |

tion conditions suggest no role for the differential reinforcing effects of the terminal links on preference measures (in the sense of transitions to the richer terminal link enhancing preference), results from the positive-transition conditions show that the pigeons could be sensitive to such effects. In these conditions, preference decreased relative to baseline in a manner consistent with the reinforcement densities (or reductions in time to reinforcement) correlated with the terminal links (Fantino, 1977, 1981). However, the effects on choice were insufficient to cause a preference reversal. Thus, as expected, the conditioned-reinforcement effect of terminal-link onset did not entirely offset control of preference by the concurrent food schedules (as in Nevin et al., 1981).

Finally, to the extent that this experiment is interpreted as investigating the effects of successive-reinforcement context on choice, its results are contrary to Lobb and Davison's (1977) statement that response allocation in concurrent schedules is unaffected by successive-reinforcement context.

## EXPERIMENT 2

In this study, the effect of context on choice (concurrent VI VI) was assessed under conditions in which, unlike Experiment 1, choice did not affect the context. Instead, in certain conditions, a third key (the contextual alternative) was present. A chain VI 30-s VI 45-s schedule was always operative on this key. Only the initial link of the chain, however, was ever available simultaneously with the concurrent VI VI. When the terminal link was entered, the concurrent keys became dark and inoperative. Across conditions, the rate of reinforcement arranged on the concurrent VI VI schedule decreased; thus, the relative value of the chain schedule increased.

In the first two conditions, the delay to food correlated with the chain schedule was longer than the average delay correlated with the concurrent VI VI schedules. Responding on the chain schedule resulted in a transition to a situation of lower reinforcement density—the schedule operating in the terminal link was longer than the average delay arranged by the concurrent VI VI schedules. Accordingly, it was expected that the chain schedule would not maintain much responding in the first two experimental conditions of this experiment. The result of interest was whether or not the mere availability of this third alternative would affect responding on the two alternatives of the concurrent VI VI schedule. In the last two conditions, the delay to reinforcement correlated with the terminal link of the chain schedule was shorter than the average delay correlated with the concurrent VI VI schedules. It was expected, therefore, that the chain schedule would maintain responding. Again, the question was whether or not preference for the concurrent schedules would differ when the third-key schedule was available from when it was not. Thus, these results would permit further assessment of the generality of the constant-ratio rule as it applies to types of concurrent choice (Davison, 1982; Davison & Hunter, 1976; Fantino & Dunn, 1983, Experiment 4).

## METHOD

### *Subjects*

Four White Carneau pigeons (Y28, Y29, B21, and R80), all with varied and extensive experimental histories, were kept at 80% of their ad-lib weights through restricted feeding. Water was available continuously in the home cages.

### *Apparatus*

Four identical, cylindrical, three-key experimental chambers for pigeons were used. The chambers were made of Plexiglas and were 36 cm high and 35 cm in diameter. The response keys were 2 cm in diameter, 24 cm above the grid floor, and equally spaced in a horizontal line, 7 cm apart. The hopper opening was 10 cm below the center key, and when activated, provided 4-s access to mixed grain. The response keys could be transilluminated with various colors. A minimum force of approximately 0.15 N was required for key operation. A houselight mounted above the keys provided general chamber illumination except during operation of the hopper. White noise was present continuously.

Scheduling of experimental events and data recording were accomplished with a PDP-8e® computer under the control of a program running under Systol® software developed in our laboratory.

### *Procedure*

The birds were trained with concurrent VI schedules (their values are shown in Table 3) on the side keys for 20 sessions. Then, a reversal of contingencies was in effect for the next 20 sessions, in which the VI schedules were arranged on the keys opposite to those of the first 20 sessions. Five sessions followed, during which a chain schedule was in effect on the center key and the side keys were dark and inoperative. Finally a three-key procedure was instituted: The same concurrent VI VI schedule was in effect on the side keys and the same chain schedule was in effect concurrently on the center key. During the choice phase, the side keys were white and the center key was green. Responses on the side keys were reinforced according to the concurrent VI VI schedules. Responses to the center key ended the choice phase according to a VI 30-s schedule, initiating the terminal link, during which the side keys remained dark and inoperative and the center key was transilluminated with a red light. In the terminal link, responses on the center key were reinforced according to a VI 45-s schedule. After reinforcement, the choice phase was reinstated.

During the choice phase, a changeover delay (COD) was in effect for the side keys, preventing responses from being followed by primary reinforcement within 2 s of a changeover. No COD was programmed on the center key because only the initial link of the chain schedule was in effect on that key during the choice phase, and consequently no primary reinforcement could occur within 2 s of a changeover to that key.

Table 3 lists the sequence of experimental conditions, the number of sessions per condition, the number of reinforcers per session, the mean interreinforcement intervals for each schedule in each condition, and the relative rate of responses emitted in each condition. On two occasions, side position reversals were not

Table 3

Conditions, numbers of sessions, numbers of reinforcements per session (Rfct), order (within parentheses) in which each determination of preference was conducted, and choice proportions (preference for the VI with the higher reinforcement rate of the concurrent pair) for every subject in Experiment 2.

| | | Sessions | Subjects | | | | |
|---|---|---|---|---|---|---|---|
| | Conditions | (order) | Y28 | Y29 | B21 | R80 | Rfct |
| 1 | Conc VI 15, VI 30 | 20 (5) | .73 | .63 | .57 | .80 | 50 |
| | Conc VI 30, VI 15 | 20 (6) | .60 | .58 | .60 | .49 | 50 |
| | Conc VI 15, VI 30 +CHN[a] | 20 (7) | .66 | .62 | .69 | .54 | 45 |
| | Conc VI 30, VI 15 +CHN | 20 (8) | .60 | .72 | .62 | .77 | 45 |
| 2 | Conc VI 30, VI 60 | 20 (1) | .64 | .67 | .67 | — | 50 |
| | Conc VI 60, VI 30 | 20 (2) | .70 | .58 | .58 | .63 | 50 |
| | Conc VI 30, VI 60 +CHN | 20 (3) | .63 | .64 | .55 | .78 | 45 |
| | Conc VI 60, VI 30 +CHN | 20 (4) | .68 | .57 | .69 | .50 | 45 |
| 3 | Conc VI 120, VI 240 | 20 (9) | .69 | .56 | .78 | .46 | 45[b] 38[c] |
| | Conc VI 240, VI 120 | 20 (10) | — | .56 | .52 | .73 | |
| | Conc VI 120, VI 240 +CHN | 20 (11) | .71 | .69 | .60 | .56 | 35 |
| | Conc VI 240, VI 120 +CHN | 20 (12) | .54 | .38 | .60 | .71 | 35 |
| 4 | Conc VI 180, VI 360 | 20 (13) | .59 | .59 | .59 | .68 | 30[b] 23[c] |
| | Conc VI 360, VI 180 | 20 (14) | .51 | .52 | .60 | .42 | |
| | Conc VI 180, VI 360 +CHN | 20 (15) | .62 | .42 | .73 | .50 | 30 |
| | Conc VI 360, VI 180 +CHN | 20 (16) | .44 | .69 | .50 | .72 | 30 |

[a] The chain schedule, in effect on the center key, had the same values (VI 30, initial link and VI 45, terminal link) in all conditions.

[b] Scheduled.

[c] Obtained (averaged over initial determination and reversal of preference, and over subjects).

conducted: Subject R80 was added after the experiment had already started for the other 2 subjects; Subject Y28 became ill and was removed from the experiment temporarily until it recovered.

Sessions were conducted 5 to 7 days per week at approximately the same time of day. Sessions were terminated after a predetermined number of reinforcements (see Table 3). This number was chosen to limit the session duration to approximately 1 hr, to keep the duration of the sessions with the added center key as similar as possible to the duration of the baseline sessions, and to avoid temporary satiation when the richer schedules of reinforcement were in effect. Any session terminated after 55 min if the designated total number of reinforcers had not been obtained.

## RESULTS

All data shown represent means from the last five sessions of each condition. Relative rates of responding on the VI schedule with the higher reinforcement rate of the concurrent pair (HIVI), number of sessions per condition, and number of reinforcements per session are presented for each subject in Table 3. Figure 3 (top panel) shows the same data averaged over initial and reversal determinations of preference in each condition. As can be seen in Figure 3, there was no consistent change in choice proportions when the chain schedule was added as a context for choice relative to the choice proportions obtained during baseline.

Figure 3 (bottom panel) also shows the relationship between the proportion of responses emitted and the proportion of reinforcers obtained during each condition. The data displayed are averages for all subjects. Undermatching was observed in all conditions, and the degree of undermatching was the same whether or not the third key (chain schedule) was available.

Figure 4 shows the proportion of responses emitted on (empty bars) and reinforcers obtained from (shaded bars) the HIVI (top panel); comparable data for the initial link of the chain schedule are shown in the bottom panel, for conditions in which the chain key was available. The response proportions were calculated using the total number of responses

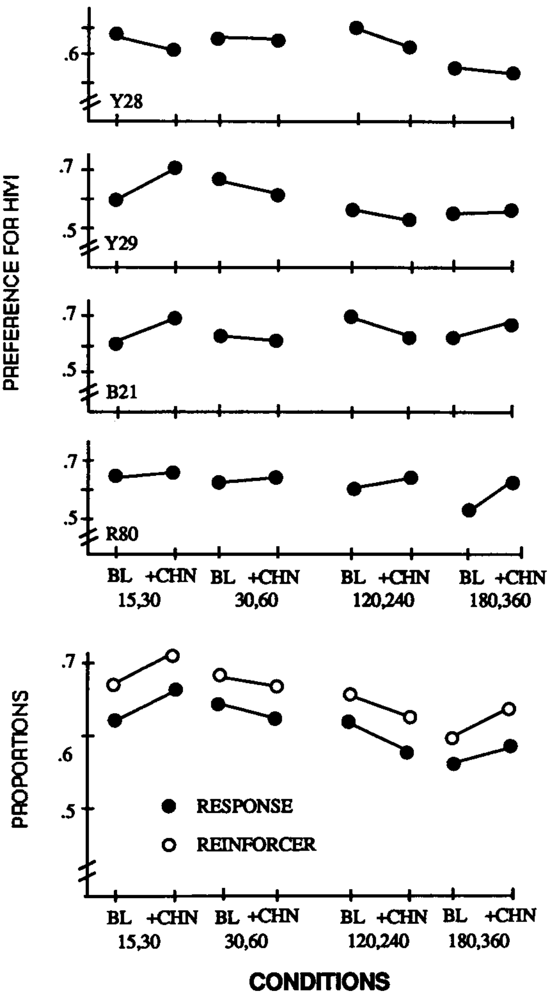

Fig. 3. Top panel: Preference for the HIVI in every condition during baseline (when a concurrent VI VI schedule was in effect) and experimental phase (when a chain schedule was available on the center key) for every subject. Preference was calculated as number of responses on the HIVI key divided by the total number of responses on the two VI schedules of the concurrent pair. Data represent means computed over the last five sessions of each condition. Bottom panel: Average data showing proportion of responses (filled circles) and reinforcers (unfilled circles) for the HIVI during baseline (BL) and experimental phase (+CHN) of each condition. Data represent means computed over the last five sessions of each condition, averaged over subjects.

emitted on the *three* keys during the choice phase. The broken line in the top graph represents the scheduled relative rate of reinforcement for the HIVI considering the three keys. The broken line in the bottom graph represents the scheduled relative rate of reinforcement for the chain schedule. The scheduled

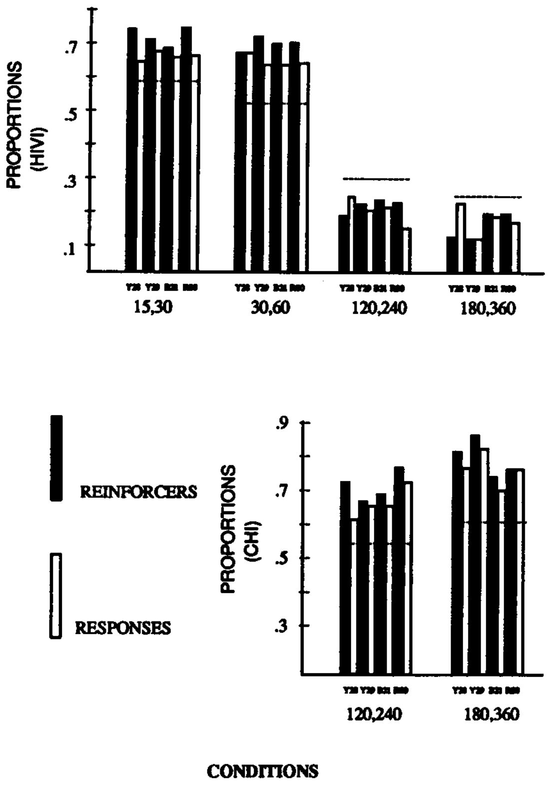

Fig. 4. Proportion of responses (empty bars) and reinforcers (shaded bars) for the HIVI and chain schedule (CHI) relative to the three-key total during experimental phases (when a chain schedule was in effect on the center key) for every subject. The upper graph shows the proportions for the HIVI; the broken line shows the predicted relative rate of reinforcement for the HIVI. The lower graph shows the proportions of responses for the initial link of the chain schedule and of reinforcers obtained from this schedule. The broken line in the bottom graph shows the predicted relative rate of reinforcement for the chain schedule, based on the average interreinforcement interval associated with that schedule. Data represent the average of the last five sessions of each condition, averaged over initial and reversal determinations of preference.

relative rate of reinforcement in both the HIVI and the chain schedule was calculated on the basis of the average interreinforcement interval in each schedule; that is, it represents the rate of reinforcers predicted if the subjects collected all the possible reinforcers in each schedule.

In the first two conditions, no responses were emitted on the chain key. Thus, a higher proportion of responses was directed to the HIVI, because responses continued to be allocated between just the two side keys, as during baseline. In the last two conditions, however, when

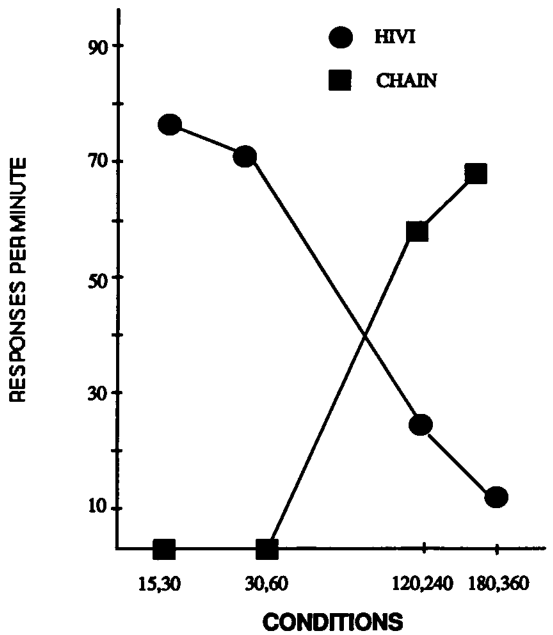

Fig. 5. Absolute rate of responding on the HIVI key (circles) and on the initial link of the chain schedule (squares) during the experimental phase of each condition (i.e., when the chain schedule was in effect on the center key). The time basis used for calculation of the response rates was the total time during which the three keys were lit. These data are means computed over the last five sessions of each phase and then averaged over initial and reversal determinations of preference and over subjects.

responding on the chain key occurred, the proportion of responses on the HIVI was lower than predicted on the basis of the matching equation extended to the three-key situation (broken line). For every subject, the proportion of responses on the chain key was higher than predicted.

Figure 5 shows the rate of responding on the HIVI schedule and during the initial link of the chain schedule in the conditions in which the chain key was available. The data shown are averaged over all subjects. The time basis used to calculate the response rates was the total time spent responding on the three keys during the choice phase. The rate of responding during the initial link of the chain schedule was an inverse function of the rate of reinforcement on the side keys: As the rate of reinforcement produced on the side keys decreased, the rate of responding on the constant chain schedule increased. Responding on the HIVI key was greatly reduced when the subjects started responding on the chain key (120,240 +CHN condition).

## DISCUSSION

In Experiment 2, when a type of successive-reinforcement context was provided for choice between a pair of concurrent VI schedules, preference was unaffected. This result is consistent with Lobb and Davison's (1977) conclusion that choice in concurrent VI VI schedules is unaffected by a successive-reinforcement context. These results are also consistent with the constant-ratio rule (Luce, 1959, 1977). The present findings extend the generality of Lobb and Davison's conclusion to a situation wherein the production of the successive-reinforcement context was under the subject's control (i.e., only by responding in the initial link of the chain was reinforcement provided on the contextual alternative). The present results also confirm predictions that the subject's allocation should shift away from the concurrent schedules to the chain schedules when the delay to food correlated with the chain schedule was shorter than that of the original alternatives (Figure 5).

When preference for the chain key is considered (Figure 4, bottom panel), the results of Experiment 2 differ from results obtained by Moore (1982) and by Fantino and Duncan (1972) in a similar procedure in which the initial link of a chain schedule in effect on one key was pitted against a VI schedule concurrently in effect on a second key. In both previous studies, the proportion of responses allocated to the initial link of the chain schedule undermatched the obtained relative rate of reinforcement on that schedule to a much larger extent than the undermatching obtained here. In Fantino and Duncan's study, the pigeons virtually ignored the initial-link key. In the present study, the proportion of responses allocated to that key only slightly undermatched the obtained relative rate of reinforcement for that key and overmatched the predicted relative reinforcement rate for all subjects (Figure 4, bottom panel). It is unclear which factor(s) can explain the differences in results between the present study and the previous ones.

The present results suggest that the value of the chain key may have been enhanced by the production of the conditioned reinforcer midway through the interreinforcement interval, relative to the other alternatives with no explicit conditioned-reinforcer production. This result is reminiscent of Gollub's (1958) finding with two-link chain schedules. Such a conditioned-reinforcement effect (see Royalty, Williams, & Fantino, 1987) may explain why the obtained preference for the chain key was more extreme than predicted. Because the chain key was always the center key, however, position bias could also explain the results. A third possibility involves the fact that the minimum interreinforcement intervals (IRIs) in the VIs comprising the chain schedule were shorter than those of either of the concurrent VIs (1 s in each schedule of the chain and 10 s in the VI 120-, 180-, 240-, and 360-s schedules). This factor may also help account for the larger preference for the chain schedule in the present study than in that of Fantino and Duncan (1972), in which the two chains and their IRIs were identical, and in that of Moore (1982) who did not report IRIs. There were, however, other procedural differences among the three studies.

The response-rate data (Figure 5) confirmed previous findings that the response rate on one key varies inversely with its contextual rate of reinforcement and directly with its contingent rate of reinforcement (e.g., Catania, 1963; Rachlin & Baum, 1972; Reynolds, 1961).

## GENERAL DISCUSSION

The present studies examined the effects of successive-reinforcement context on choice for two concurrent VI VI schedules. In one study, choice responses also led to successive reinforcement by producing entry into the terminal links of concurrent-chains schedules. In the second study, however, access to the contextual reinforcement (again the terminal link of a chain schedule) required a response on a third key. As might be expected, the effects of introducing these successive-reinforcement contexts differed in the two studies: When responses on the concurrent VI schedules were also effective in producing terminal-link outcomes, choice was affected by these outcomes; when responses on the concurrent VI schedules were independent of those producing terminal-link outcomes, choice measures were unaffected by the presence or absence of the contextual reinforcement. Thus, these latter results provide additional confirmation of the constant-ratio rule with concurrent schedules (reviewed by Fantino & Dunn, 1983).

With one exception (next paragraph), the present results suggest that the pigeons' behavior was sensitive to the differences in reinforcement density between the alternatives. Thus, in the first study, when the terminal-link outcomes provided a greater reinforcement density than the concurrent VI VI schedules, choice proportions on the concurrent schedules changed in the direction of greater preference for the terminal link that accompanied a reduction in time to reinforcement. At the same time, choice was more sensitive to the concurrent schedule of food reward than to the differences in reinforcement density between the terminal links. In other words, responding was more sensitive to food directly produced by that responding than to the production of terminal links. In the second study, when the terminal link of the chain schedule was accompanied by a lower reinforcement density than the concurrent VI VI schedule, responses were rarely emitted in the initial link of the chain. When the terminal link was correlated with a higher reinforcement density than the concurrent VI VI schedules, however, more responses were emitted in the initial links of the chain than in the two concurrent VIs combined.

The one exception involved conditions in the first study in which the terminal-link outcomes provided a lower reinforcement density than the concurrent VI VI schedules (negative-transition conditions). Here one might have expected that choice proportions on the concurrent schedules would have changed (relative to the no-context baseline) in the direction of greater preference for the terminal link that was accompanied by a lesser increase in time to reinforcement. Instead, choice proportions increased for the shorter concurrent VI or in the direction opposite to that predicted (because the shorter concurrent VI always led to the longer terminal link). As noted above, both Farley (1980) and de Villiers (1980) found that preference for the shorter of two concurrent VI VI schedules increased when punishment was arranged equally for responding on both VIs. If the negative transitions served as punishers (arranged equally for responding on both VIs by a VI 60-s schedule of access to the terminal links), an enhancement might have occurred in the present study as well. The results support this possibility and suggest that such punishment-produced enhancement overrode any effects of differential terminal-link outcomes.

The present results suggest that response allocation in concurrent schedules may be affected by successive-reinforcement context. More generally, they suggest that contextual reinforcement produces orderly effects on choice.

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