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CHOICE FOR CONDITIONED REINFORCERS IN THE SIGNALED ABSENCE OF PRIMARY REINFORCEMENT

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Pigeons responded in a multiple schedule in which concurrent schedules of brief-stimulus presentation alternated with a component in which food was available (concurrent-chains component). In the initial links of the concurrent-chains component subjects chose either of two stimuli each correlated with the terminal link of one chain. The terminal links involved either variable-interval 30-second or variable-interval 60-second schedules. In the brief-stimulus component subjects chose between 0.5-second presentations of the terminal-link stimuli from the concurrent-chains component. Responding was generally maintained in the brief-stimulus component in two subjects for more than 300 sessions, suggesting that brief stimuli were conditioned reinforcers. During the brief-stimulus component, in 17 of 21 cases for which a minimal number of responses occurred, choice proportions above 0.55 were obtained for the brief-stimulus presentations correlated with the higher rate of primary reinforcement in the concurrent-chains component. These results support the suggestion that choice in conventional concurrent-chains procedures is partially controlled by production of the terminal-link stimuli.

Key words: conditioned reinforcement, choice, brief-stimulus presentations, multiple schedules, concurrent-chains schedules, delay-reduction hypothesis, variable-interval schedules, key peck, pigeons

Chain schedules have long been a preferred technique for the study of conditioned reinforcement (e.g., Ferster & Skinner, 1957; see reviews by Fantino, 1977, 1981; Gollub, 1977; Kelleher & Gollub, 1962). In a typical two-link chain schedule, responding in the presence of one exteroceptive stimulus produces a second stimulus in the presence of which responding produces primary reinforcement. The stimulus paired with primary reinforcement acts as a conditioned reinforcer, controlling appropriate patterns and rates of responding in the initial link of the chain (e.g., Kelleher & Gollub, 1962; Marr, 1969). It is unclear, however, to what extent responding in the initial link is maintained by the production of the stimulus of the terminal link (the putative conditioned reinforcer) or by the delayed effects of primary reinforcement at the end of the terminal link. One study (Williams & Fantino, 1978) assessed the role of conditioned and primary reinforcement on responding in the initial links of chain schedules and is especially relevant to the present study. It used the concurrent-chains procedure developed by Autor (1960, 1969) and Herrnstein (1964) in which a two-link chain schedule is arranged on each of two keys. Typically, the initial links of each chain are available concurrently and are correlated with equal variable-interval (VI) schedules. A reinforced response on either of the VI schedules produces entry into the appropriate terminal link while the other key becomes dark and inoperative. Responding in the terminal links then produces reinforcement according to some schedule. The independent variable is usually some difference between the terminal-link schedules; the dependent variable is a measure of choice such as the number of pecks in one initial link divided by the sum of pecks in both initial links. In one set of conditions reported by Williams and Fantino (1978), the different terminal-link schedules were correlated with different keylight stimuli (their "cued conditions"), whereas in a second set of conditions, the different terminal-link schedules were correlated with identical stimuli (their "uncued conditions"). In neither

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set of conditions was position of the terminal link a relevant cue. Williams and Fantino reasoned that:

> When the terminal-link schedules are associated with different stimuli, differences in delayed primary reinforcement and immediate conditioned reinforcement both should play a role in determining choice. When the different terminal-link schedules are associated with the same stimulus, however, differences in the immediate conditioned reinforcement should be eliminated, and the consequences of the two choice responses would differ only with respect to the overall delay of reinforcement. (p. 78)

Williams and Fantino found preference in the uncued conditions, implicating overall delay of reinforcement, but they found larger preferences in the comparable cued conditions, implicating conditioned reinforcement. The present study includes a procedure in which there is no primary reinforcement but there is the potential for conditioned reinforcement. In such a procedure will responding be maintained?

The present procedure extends to the study of choice a procedure developed by Zimmerman (1963) and Zimmerman and Hanford (1967) in which responding was maintained by brief-stimulus presentations in the signaled absence of primary reinforcement so long as the brief stimulus was paired with food at other times. Thomas (1969), for example, found that the brief stimuli (hopper light and magazine noise) paired with food in one component of a multiple schedule could maintain responding in another component in which food was never presented. (In a multiple schedule two or more independent schedules are presented in alternation, and each schedule is correlated with a discriminable exteroceptive stimulus). In Thomas's study one schedule was a schedule of food reinforcement and the other was a schedule of brief-stimulus presentations only. Even though the absence of primary reinforcement was signaled explicitly, responding was maintained by the brief stimuli with rates and patterns appropriate to the various schedules employed. We extended this procedure so that it involved choice between two putative conditioned reinforcers. If responding is maintained by these stimuli, will choice reflect their assumed strength? Specifically this procedure allows the independent assessment of the relative strength of the two conditioned reinforcers by providing another measure of preference for the stimulus besides relative response rates in the initial links of the chain schedules. In this procedure the relationships between the stimuli and primary reinforcement are maintained in concurrent-chains schedules, but within the same procedure subjects can choose between brief presentations of the two terminal-link stimuli which are no longer followed by food. If the stimuli are conditioned reinforcers, will they maintain responding in such a situation? More specifically, if the relative strengths of these stimuli help determine choice in concurrent-chains schedules, we would expect to obtain the same qualitative preferences for the brief-stimulus presentations. Finally, if the procedure produces orderly data, it would offer promise for the study of variables contributing to conditioned reinforcement.

METHOD

Subjects

Three adult White Carneaux pigeons and one adult homing pigeon served as subjects. Throughout the course of the experiments they were maintained at approximately 80% of their free-feeding weights. Two of the White Carneaux pigeons (P2375 and P3757) had previous experience with the concurrent-chains procedure. One White Carneaux pigeon (P4527) and the one homing pigeon (Y86) were naive at the beginning of the experiment.

Apparatus

The standard experimental chamber was a Plexiglas enclosure measuring 33 by 33 by 18 cm. The front wall of the chamber, which was aluminum, contained two translucent response keys mounted 20 cm from the floor of the chamber and 9 cm apart. Industrial Electronics Engineers projectors were used to illuminate the keys from behind with various colors, and the chamber was illuminated by two 6-W miniature lamps. Every response on an illuminated key produced audible feedback from a DC relay. A minimum force of approximately 0.15 N was required to operate either key. A solenoid-operated hopper made grain available through a front wall opening that was 5.7 cm above the floor of the chamber. White noise masked extraneous sounds. Standard relay control and recording equipment was located in a separate room.

Procedure

The procedure involved a complex multiple schedule. In one component, concurrent-chain schedules were arranged with different terminal-link stimuli correlated with two different schedules of primary reinforcement. In the other component, brief presentations of these terminal-link stimuli were contingent on responding (see Figure 1). In the concurrent-chains component, two blue keylights signaled the initial links in which identical but independent VI 60-s schedules were operating concurrently. The subject could respond on either key. When access to the terminal link correlated with a given key was obtained, the other key became dark and inoperative. The terminal-link schedules were VI 30-s and VI 60-s. The terminal link on the left key was always accompanied by a green keylight, while the terminal link on the right key was accompanied by a red keylight. Primary reinforcement was 3-s access to grain. After food was obtained in either terminal link, the keylights became blue and the initial links were again in effect. This component of the multiple schedule was in effect for 5 min, unless the 5-min period elapsed while the subject was responding in a terminal link. In that case, the component was terminated immediately after food was obtained in that terminal link.

In the second component, a simple concurrent schedule was in effect, in which responding produced brief presentations of the chain terminal-link stimuli but no food. Identical but independent VI 60-s schedules, signaled by two white keylights, were available concurrently. Responding on one key produced a 0.5-s presentation of the red keylight and responding on the other key produced a 0.5-s presentation of the green keylight. Food was never available in this component, which was also in effect for 5 min. The two components were alternated, with a 30-s timeout (TO) occurring after each component in order to prevent the superstitious maintenance of responding in the brief-stimulus component by the contiguity of such responding with the onset of the concurrent-chains component. During the TO the chamber was completely darkened.

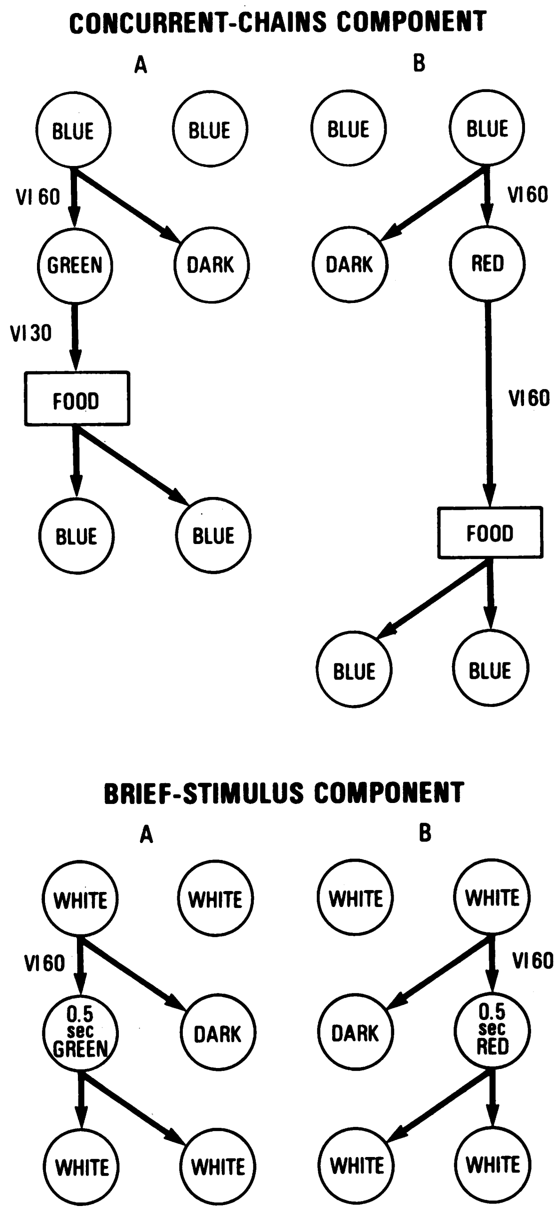

Fig. 1. Diagram of the two components of the multiple schedule. Top: For the concurrent-chains component, Part A shows the sequence of events leading to food reinforcement on the left key; Part B shows the sequence of events leading to food reinforcement on the right key. Immediately after food presentation on either key, the initial links were again in effect. Bottom: For the brief-stimulus component, Part A shows the sequence leading to a brief-stimulus presentation on the left key; Part B shows the sequence leading to a brief-stimulus presentation on the right key. Both keys were again lit white immediately after a brief-stimulus presentation on either key.

The alternation continued until each component had been presented 10 times. In both schedules a 1-s changeover delay (COD) was in effect. This requirement fixed a minimum delay of 1 s between the first response on a key (after responding on the other key) and reinforcement on that key (or entry into the terminal link, in the case of concurrent-chains). Herrnstein (1961) showed that without a COD in concurrent schedules, the relative rate of responding tended toward 0.50 due to a high frequency of alternating between the two keys. A COD is not usually used with concurrent-chains schedules because orderly results have been obtained without it. However, in this study it was used in order to make the procedures in the two components as similar as possible.

The sequence of conditions for each subject and the number of sessions in each condition are presented in Table 1. In the first condition and in each succeeding condition in which there was a manipulation in the concurrent-chains component, sessions were conducted until a stability criterion was met by the choice proportions in the concurrent-chains component. At least 15 sessions were conducted. After 15 sessions and for each subsequent session, the most recent nine sessions were partitioned into groups of three; the stability criterion was met when the average choice proportions from each group of three (m_1, m_2, and m_3) differed from each other by not more than 3% and when these proportions showed no increasing or decreasing trend ($m_1 < m_2 < m_3$ or $m_1 > m_2 > m_3$). For conditions in which a manipulation occurred in the brief-stimulus component, 20 sessions were conducted after the manipulation was introduced. Sessions were conducted daily.

The two experienced subjects, P3757 and P2375, were exposed to an identical series of thirteen conditions; the two naive subjects, Y86 and P4527, were added later and were exposed to only three and five conditions, respectively. In the first four conditions for P3757 and P2375, the brief stimuli were available on VI 60-s schedules, and a 1-s COD was in effect in both components of the multiple schedule. The positions of the concurrent-chains terminal links and of the brief stimuli were varied in these conditions. As a control for the possibility that any brief-stimulus presentations would maintain responding, neutral stimuli (which had never been paired with food) were substituted for the red and green brief stimuli in Conditions V and VI. Conditions VII through XIII were basically replications of the first four conditions. In Condition IX and the succeeding conditions, the brief stimuli were available on VI 30-s schedules instead of VI 60-s schedules; starting with Condition X the COD was removed from both components.

The sequence for Subject P4527 differed from the other three primarily in that it began with brief stimuli available in VI 30-s schedules. This procedural feature was maintained throughout all five conditions for this subject. A 1-s COD was in effect for this subject in the first two conditions, but was removed for the third and subsequent conditions.

Subject Y86 differed from the other three in that it began the experiment with comparable brief stimulus and terminal-link stimulus on opposite keys—that is, the green stimulus correlated with the VI 30-s schedule was on the left key in the concurrent-chains component but green brief-stimulus presentations were produced on the right key in the brief-stimulus component. In all three conditions for this subject the brief stimuli were available in VI 60-s schedules and the 1-s COD was in effect.

RESULTS AND DISCUSSION

A summary of the results is presented in Table 1, which presents data averaged over the last nine sessions of each condition. Choice proportions for both components are given (and are explained below). The response rates in the brief-stimulus component are also presented as are the numbers of brief-stimulus presentations obtained per session. Responses that occurred during the 0.5-s stimulus presentations were recorded, and the data are presented as the average number of responses per stimulus presentation. These response rates were fairly high but seemed to bear no systematic relationship to other results.

The presentation of brief stimuli in the signaled absence of food maintained responding in all four pigeons. The results for P3757 and P2375 confirm Zimmerman's (1963) and Thomas's (1969) findings that such responding could be maintained over very long periods of time. It is not apparent from the reports of the prior studies whether responding finally decreased to near zero rates or whether the experiments were simply terminated after the

Table 1

Choice proportions in each component, response rate (responses/min) in the initial links of the concurrent-chains component, number of brief-stimulus responses made and number of brief stimuli obtained per session, and the mean number of responses during each brief stimulus, all for each subject in each condition. The schedules on each key (in seconds) and the number of sessions per condition are also given. The upper portion presents data for the two subjects exposed to the identical series of thirteen conditions. Data from P4527 and Y86 are presented separately in the lower portions.

Order of Conditions	Number of Sessions		Multiple Component: Concurrent Chains Left (Green)	Concurrent Chains Right (Red)	Brief Stimulus Left	Brief Stimulus Right	Choice Proportion: Concurrent Chains		Choice Proportion: Brief Stimulus		Response Rate (Responses/Min) in Initial Links, Concurrent-Chains		Response Rate (Responses/Min) in Brief-Stimulus Component		Number of Brief Stimuli Obtained Per Session		Mean Number of Responses in Presence of Brief Stimulus	
	P3757	P2375					P3757	P2375	P3757	P2375	P3757	P2375	P3757	P2375	P3757	P2375	P3757	P2375
I	75	80	VI 30	VI 60	Green	Red	0.73	0.72	0.81	0.79	84	99	14.2	8.7	53	42	0.59	2.01
II	20	20	VI 30	VI 60	Red	Green	0.81	0.79	0.04	0.17	74	87	1.9	3.2	14	39	0.21	0.32
III	40	52	VI 60	VI 30	Red	Green	0.95	0.81	0.85	0.90	62	62	0.5	3.0	93	23	0.12	0.35
IV	20	20	VI 60	VI 30	Green	Red	0.87	0.92	0.56	0.70	64	53	5.7	3.2	44	22	0.54	0.58
V	20	20	VI 60	VI 30	Orange	Orange	0.74	0.85	0.73	0.50	65	56	0.5	1.9	8	22	0.04	0.59
VI	20	20	VI 60	VI 30	Yellow	Yellow	0.91	0.95	0.56	0.76	54	56	0.1	0.1	16	14	0.07	0.00
VII	20	20	VI 60	VI 30	Green	Red	0.98	0.96	0.93	0.67	57	52	0.3	1.8	7	20	0.82	0.85
VIII	60	43	VI 30	VI 60	Green	Red	0.93	0.89	0.74	0.81	35	61	0.7	1.3	6	7	0.30	1.41
IX	20	20	VI 30	VI 60	Red	Green	0.76	0.97	0.14	0.10	42	65	0.04	0.7	1	6	0.71	0.66
X	26	38	VI 60	VI 30	Green	Red	0.68	0.68	0.85	0.58	54	49	2.4	0.5	26	10	0.85	0.29
XI	20	20	VI 60	VI 30	Red	Green	0.91	0.74	0.44	0.76	55	47	0.2	0.04	2	2	0.35	1.64
XII	42	24	VI 30	VI 60	Red	Green	0.80	0.68	0.04	0.14	48	44	0.1	0.1	2	3	0.38	0.45
XIII	20	20	VI 30	VI 60	Green	Red	0.86	0.77	0.88	0.89	48	51	0.02	0.1	1	3	0.78	1.20
	P4527																	
I	64		VI 30	VI 60	Green	Red	0.99		1.00		46		0.38		8		0.62	
II	20		VI 30	VI 60	Red	Green	0.98		0.35		53		0.04		1		0.44	
III	30		VI 60	VI 30	Green	Red	0.86		0.91		45		0.9		22		0.17	
IV	20		VI 60	VI 30	Red	Green	0.96		0.39		50		0.1		3		0.15	
V	40		VI 30	VI 60	Red	Green	0.77		0.72		50		2.1		30		0.44	
	Y86																	
I	68		VI 30	VI 60	Red	Green	0.96		0.85		71		0.3		3		1.10	
II	20		VI 30	VI 60	Green	Red	0.94		0.28		79		0.3		4		0.97	
III	20		VI 30	VI 60	Red	Green	0.99		0.56		68		0.5		4		1.74	

noted time period. In the present study, responding for two subjects declined over approximately 400 sessions until there was little or no responding in the brief-stimulus components during the last conditions.

The present results should be qualified in at least two ways. In the first place, it can be argued that the brief-stimulus components resemble the concurrent-chains components in an important way. In each case the subject responded in the presence of a stimulus never paired with food (blue lights in the concurrent-chains component; white lights in the brief-stimulus component) and produced stimuli that were sometimes paired with food (red and green lights). Looked at in this way, the subject was responding on what amounts to a conditional discrimination (because food always followed red and green in the concurrent-chains component but never followed the 0.5-s presentation of red and green in the brief-stimulus component). If so, responding in the brief-stimulus component may reflect the subjects' failure to make this discrimination perfectly and may not indicate conditioned reinforcement. Although this argument cannot be refuted by the present data, there is ample evidence that each subject responded differentially in the presence of the blue and white lights. In the first, as well as in the subsequent conditions, for example, rates of responding were substantially higher in the initial links of the concurrent-chains component (the ratio of response rates in this component divided by response rates in the brief-stimulus component ranged from about 6:1 for P3757 to over 100:1 for P4527 and Y86 in the first condition for each subject). Moreover, it may well be that for *any* conditioned reinforcer a new situation may be found that is sufficiently different from that in which the stimulus acquired reinforcing strength that the stimulus will maintain no behavior in this new situation. In any event, such was not the case in the present experiment.

The second qualification concerns the very low response rate typically maintained by the brief stimuli. For example, in 22 of 30 experimental conditions these rates were below two per minute. Moreover, the rates were particularly low in the first condition for the two experimentally naive subjects (although one, P4527, increased its rate in the final condition). Although it is impossible to draw definitive conclusions about acquisition with only two naive and two experienced subjects, these data raise the possibility that the brief stimuli can better sustain responding already occurring at higher rates. In any event, the response rates in the brief-stimulus component were substantially lower than those reported by Thomas (1969). Onset of his brief stimuli (hopper lights and noises) were closely contiguous with food, whereas onset of the terminal-link stimuli in the present concurrent-chains component preceded food by an average of 45 s. In terms of one view of conditioned reinforcement, the delay-reduction hypothesis (Fantino, 1969; Fantino & Davison, 1983; Fantino & Dunn, 1983), the brief stimuli of the present study were correlated with much less reduction in time to primary reinforcement than were those used by Thomas (1969). This account could be assessed by manipulating the VI schedules in either link of the concurrent-chains component.

The fundamental data from this study are the choice proportions presented in Figure 2 and in Table 1. Choice proportions in the concurrent-chains portion of the schedule represent initial-link responses on one key (the VI 30-s terminal link) divided by the total number of initial-link responses on both keys. A brief-stimulus choice proportion represents responses on the key on which the stimulus correlated with the VI 30-s schedule is presented, divided by the total responses on both keys. The data represent the means of the last nine sessions of each condition. The two control conditions are not included in the figure (Conditions V and VI for P3757 and P2375) but are discussed below. Conditions in which response rates in the brief-stimulus component were below a criterion level are not presented. The criterion for minimal rates of responding was set arbitrarily at 100 responses over the last nine sessions. Inspection of Table 1 reveals that the results would not at all be affected if the criterion were set at 135 (corresponding to 15 responses per session) and would not be affected in any important sense if set even higher (e.g., to 300, although in this case the data of Y86 would be excluded).

All subjects preferred the terminal link with the VI 30-s schedule over that with the VI 60-s schedule in all conditions (Table 1). According to the Squires-Fantino formulation, choice proportions should have approximated .80

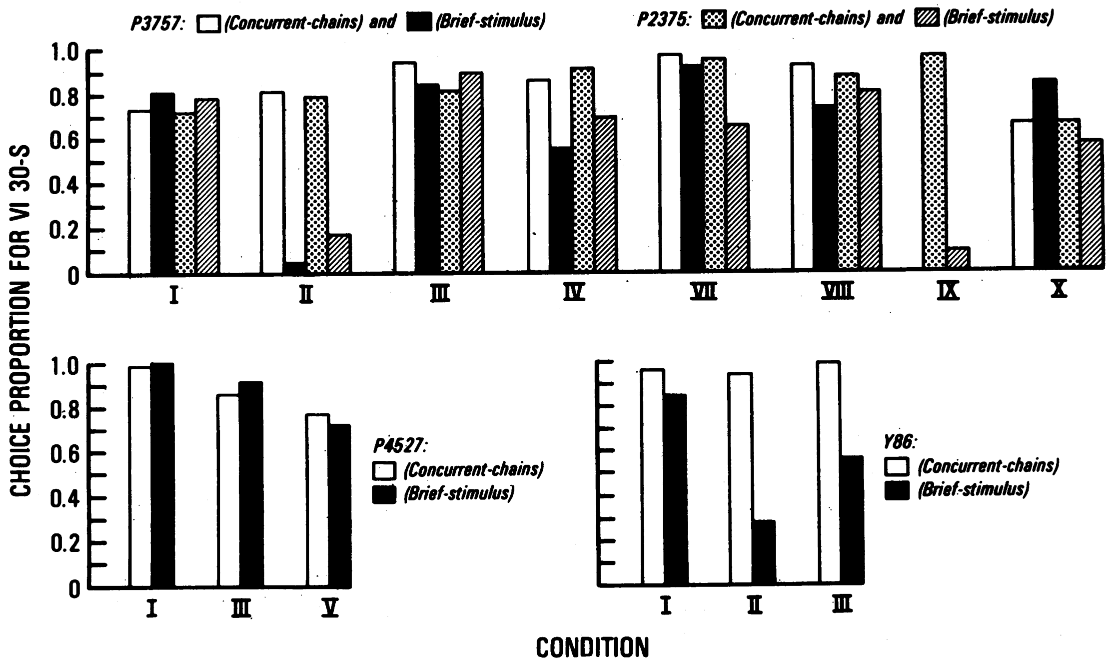

Fig. 2. Choice proportions in concurrent-chains and brief-stimulus components for each subject in each experimental condition in which the subject made at least 100 responses in the brief-stimulus component over the last nine sessions. Data are averaged over the final nine sessions. Because subjects P3757 and P2375 were exposed to identical series of conditions, their data are shown together in the top panel. Roman numerals refer to condition numbers and correspond to those described in Table 1. Conditions V and VI for these Subjects were control conditions and are not presented here (see Table 1 and text). Data for the concurrent-chains component represent choice proportions for the VI 30-s schedule and data for the brief-stimulus component represent choice proportions for the stimulus associated with the VI 30-s schedule. Note that in each of 21 conditions in the concurrent-chains component and in 17 of 21 conditions in the brief-stimulus component, choice proportions exceeded .55.

(Squires & Fantino, 1971). Averaged over all 13 conditions, Subjects P3757 and P2375 produced mean choice proportions of .84 and .83, respectively. For both pigeons, however, there was a tendency towards higher choice proportions when a COD was used (mean choice proportions of .85 and .87 with COD and .81 and .72 without COD for P3757 and P2375, respectively). Subject P4527 had a mean choice proportion of .98 in two conditions with a COD and .86 in three conditions without a COD. Finally, Pigeon Y86, studied with a COD throughout, had a mean choice proportion of .96. Although the present experiment was not designed to assess the effects of COD on choice, the high choice proportions obtained for all subjects with a COD and the within-subjects comparisons from Subjects P3757, P2375, and P4527 suggest that use of the COD amplifies choice in the concurrent-chains procedure.

The novel question raised in the present experiment is whether the stimulus correlated with the VI 30-s schedule was also preferred in the brief-stimulus component, during which food was never available. In order to answer this question several conditions were studied in which the schedule correlated with a given stimulus was varied, as was the key on which the stimulus appeared. The answer was affirmative in 17 of 21 cases (which gives a binomial probability of $p < .005$). In Conditions V and VI for Subjects P3757 and P2375, no preference for either side was expected because the same stimulus was presented on each key. Any preference in the brief-stimulus component (shown in Table 1 in terms of left key) here would be an indication of a key bias—that is, a tendency to respond more on the same key preferred in the concurrent-chains components. Neither subject showed consistent preferences during the brief-stimulus component in these conditions. If anything, fewer responses were made on the key associated with the preferred concurrent-chains schedule (e.g., Subject P3757 in Condition V had a choice proportion of .73 for the left key, whereas its preference in the concurrent-chains component was .74 for the right), further suggesting that responding in the brief-stimulus component did not simply reflect responding in the concurrent-chains component.

Having assessed the relative strengths of the terminal-link stimuli, in the absence of primary reinforcement, and having found that their relative strengths are affected by the correlated schedules of food reinforcement, it becomes more reasonable to assume that the stimuli play a role in determining choice in the initial links of concurrent-chains schedules. The results suggest that the stimuli have acquired conditioned reinforcing effectiveness. As the immediate consequences of responding in the initial links, they may well mediate preference in the concurrent-chains procedure. This suggestion is comparable to that made by Duncan and Fantino (1972), Fantino (1983), Williams and Fantino (1978), and others. The present study differs from the prior ones in that choice was assessed in a procedure in which responding might be attributed solely to conditioned reinforcement. Similar results were reported by Mandell and Nevin (1975) although they did not use a concurrent-chains procedure. They arranged stimulus-food pairings in one component of a multiple schedule, while the stimuli alone were contingent upon responding in the second component. They too found that the relative proportion of responses for one stimulus in the second component was positively related to the relative proportion of reinforcers arranged in the presence of that stimulus in the first component. Mandell and Nevin concluded that the distribution of choice responding is positively related to the distribution of conditioned reinforcers in a manner "qualitatively similar" to the relationship between choice responding and the distribution of unconditioned reinforcers and that this relationship is due, in part, to the stimulus-food pairings (when pairing was eliminated, the relationship deteriorated). The present results, although sometimes variable and not always robust, nonetheless support the same conclusion: Choice was controlled by conditioned reinforcement in the brief-stimulus components. More generally, the present results support the suggestion that choice is partially controlled by the terminal-link stimuli in concurrent-chains procedures.

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