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Behavioral effects of changeover delays in a concurrent-chains schedule with different delays and magnitudes of reinforcement

Efeitos comportamentais de atraso para resposta de mudança em um esquema concorrente encadeado com atrasos e magnitudes de reforçamento diferentes

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Abstract

The present study examined the effects of a changeover delay (COD) on the choice between smaller, shorter delayed reinforcement and larger, longer delayed reinforcement in a complex concurrent-chains schedule. Four pigeons were exposed to three conditions in an ABA or BAB reversal design. A COD of 2 seconds was included in the initial links during condition B. The concurrent-chains schedule had identical variable-interval schedules in the initial links and different delays and magnitudes of reinforcement that were programmed according to a fixed-ratio 10 (FR10) schedule in the terminal links. Each experimental condition lasted for two long sessions and five short sessions. Changeover rates were lower, and preference for the larger, longer delayed reinforcer was more pronounced during conditions with the programmed 2-second COD. The analysis of initial pauses and running rates during the FR10 schedules of the terminal links revealed no systematic effects of the COD on behavior in the terminal links. The COD had similar effects on choice performance in this modified concurrent-chain procedure as on simple concurrent performance.

Keywords: Choice behavior, concurrent-chains, COD, self-control paradigm, pigeons.

Resumo

O presente experimento examinou os efeitos de contingência de atraso para resposta de mudança (COD) sobre o comportamento de escolha entre reforçamento menor mais imediato e maior mais atrasado em um esquema concorrente encadeado complexo. Quatro pombos foram expostos a três condições em um delineamento de reversão ABA ou BAB. Um COD de 2 s foi adicionado aos elos iniciais durante a Condição B. Os concorrentes encadeados programavam esquemas de intervalo variável idênticos no elo inicial e diferentes atrasos e magnitudes de reforçamento de acordo com esquemas FR 10 nos elos terminais. Cada condição experimental permaneceu em vigor por duas sessões longas e cinco sessões curtas. As taxas de resposta de mudança foram mais baixas e a preferência pelo reforço menor-mais imediato foi mais acentuada durante as condições com o COD programado. As análises das latências e taxas de corrida nos esquemas FR 10 não revelaram efeitos sistemáticos do COD no comportamento nos elos terminais. Os resultados confirmam efeitos do COD em concorrentes encadeados semelhantes aos relatados para esquemas concorrentes simples.

Palavras-chave: Comportamento de escolha, concorrentes encadeados, COD, paradigma de autocontrole, pombos.

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Behavior analysts have conducted much research on choice and preference using contingencies in which two or more independent schedules of reinforcement are programmed simultaneously and independently. Distinguishing such research on choice from other research on operant behavior is when the experimenter makes two or more measurable alternatives explicitly available to the subject (Fantino & Logan, 1979).

A widely used procedure to identify effects of different parameters of reinforcement, such as delay, magnitude, frequency, and other sources of control, on choice performance is termed the concurrent schedule. In such a procedure, subjects' responses on different operanda are reinforced according to simultaneous and independent schedules. With concurrent schedules, the relative response rate at which animals respond on one operandum approximately matches the relative frequency of reinforcement for that response (Herrnstein, 1961; for review, see de Villiers, 1977; Wearden & Burgess, 1982).

Studies of simple concurrent schedules usually incorporate a changeover delay (COD), as used by Herrnstein (1961). The COD specifies a minimum delay between a changeover from responding on one reinforcement schedule to responding on the other and the next possible reinforcement. Without a COD, reinforcement may strengthen not only responses that actually produce the reinforcer but also immediately preceding responses on the operandum that is associated with the other schedule, thereby reinforcing the act of switching back and forth (Fantino & Logan, 1979; Shahan & Lattal, 2000). The COD that was used by Herrnstein (1961) proved to be an important determinant of matching between the relative response rate on a given operandum and the relative reinforcement rate for that operandum. Without a programmed COD, choice behavior was less sensitive to reinforcement frequencies.

Shull and Pliskoff (1967) performed a more extensive investigation of the effects of CODs with rats as subjects and brain stimulation as reinforcement. They used CODs that ranged up to 20 seconds with concurrent variable-interval variable-interval (VI-VI) schedules. The changeover rate decreased when the duration of the COD increased. They also reported an increasing function that related relative response rate for the richer alternative and COD duration when VI schedules of the concurrent pair were different. Relative response rates were unaffected by the COD duration when equal VI schedules were used. Similar results were reported by Pliskoff (1971) and Leigland (1987) with pigeons as subjects and food as the reinforcer, by Brownstein & Pliskoff (1968) with response-independent schedules, by Bourland & Miller (1978) with parallel schedules, and by others (for review, see Stubbs, Pliskoff, & Reid, 1977). Furthermore, Todorov, Acuña-Santaella, & Falcon-Sanguinetti (1982) showed that with a three-operanda procedure, a COD is unnecessary for determining matching between the relative response rate and relative rate of reinforcement. With a procedure whereby each schedule is associated with a different operandum and changeovers are topographically different from concurrent operanda, relative behavioral measures were sensitive to the relative reinforcement rate without a COD.

When two very discrepant schedules or two different reinforcers are utilized in concurrent schedules, the measure of choice is confounded by the rate of responding that is produced by the schedules themselves because schedules of reinforcement tend to control distinct rates and patterns of responding. Partly to avoid such confusion of choice with response rates that are generated by different schedules, Autor (1969) developed the concurrent-chain procedure. This procedure has been used extensively in studies of both choice and conditioned reinforcement. It measures choice by the rate of responding that is emitted during a choice phase that generally consists of two equal, concurrent VI schedules (i.e., initial links), each leading to a different schedule outcome (i.e., terminal links).

Despite the similarities between concurrent and concurrent-chain schedules and the general effects of CODs on concurrent performance, CODs are not normally used with concurrent chains (e.g., Davison & Temple, 1973; Dunn & Fantino, 1982; Fantino & Royalty, 1987; Grace, 1995; Grace, Bedell, & Nevin, 2002; Green & Snyderman, 1980; Marshall & Kirkpatrick, 2016; Squires & Fantino, 1971; Snyderman, 1983; Wardlaw & Davison, 1974; White & Pipe, 1987; Williams & Fantino, 1978), perhaps because (a) orderly results within experiments have been obtained without CODs (Horney & Fantino, 1984), and (b) the distribution of responses and the time spent on the operanda were found to be unaffected by the COD in concurrent schedules with equal VI schedules (i.e., the contingency that is normally used in the choice phase of concurrent-chain schedules; Shull & Pliskoff, 1967). Davison and McCarthy (1988) suggested, "The feeling has been, perhaps, that because reinforcers do not immediately follow initial-link responses in concurrent-chains schedules, a COD to eliminate concurrent superstitions is not necessary" (p. 192). Furthermore, a COD in initial links would be an additional feature of the already complex concurrent-chain procedure that may produce further difficulties in interpreting the results.

Another suggestion, however, is that the absence of a COD in concurrent-chain procedures is a factor that produces discrepant results. Poniewaz (1984) sought to interpret his results, which were different from Moore (1979), by suggesting that discrepancies between experimental reports on concurrent-chain performance in the literature might be attributable to the use or lack of use of CODs in initial links. Horney & Fantino (1984) were primarily interested in the effects of conditioned reinforcers on choice, but they reported that choice preference was amplified in concurrent-chains schedule with a COD. However, they used complex multiple schedules with concurrent and concurrent-chain schedules as its components. Davison (1983) argued that the COD eliminates some terminal- to initial-link interactions that can make quantitative predictions of concurrent-chain performance difficult. However, all conditions that were used in his study included a 3-second COD, and the assumption was based on comparisons between studies.

In a study that investigated effects of the segmentation of interreinforcement intervals, Leung and Winton (1985) found similar effects of a COD on concurrent-chain schedules to effects on concurrent schedules. Equal VI 60-second schedules in the initial links and VI or fixed-interval schedules in the terminal link were used. A chain schedule was always programmed as one of the terminal links and either a corresponding tandem or a simple schedule as the other terminal link. A COD of 2 seconds was used in a number of conditions. Inclusion of the COD generally changed relative rates of responding in the initial links and thus increased preference and lowered changeover rates.

In studies of choice with differing delays and magnitudes of the reinforcer (i.e., the so-called self-control paradigm; Rachlin, 1974; Rachlin & Green, 1972), either continuous reinforcement or identical VI schedules were programmed in the initial links. The majority of these studies involved discrete-trial procedures; therefore, no COD was programmed in the continuous reinforcement initial links. Studies that used VI schedules usually programmed a COD in the initial link (Chavarro & Logue, 1988; Ito & Nakamura, 1998; King & Logue, 1987; Logue & Chavarro, 1987; Logue, Rodriguez, Peña-Correal, & Mauro, 1984, Experiment 2; Logue, Peña-Correal, Rodriguez, & Kabela, 1986, Experiment 2; Navarick & Fantino, 1976; but see Green & Snyderman, 1980; Snyderman, 1983).

King & Logue (1987) showed that a programmed COD is important in self-control experiments. They investigated the effects of different COD durations on choice performance in simple concurrent schedules with alternatives with smaller-sooner reinforcement (SSR) and larger-later reinforcement (LLR). The results showed that with the 1-second COD, human subjects distributed their responses equally. When 15-second and 30-second COD durations were used, virtually exclusive preference for the large, more delayed reinforcer developed.

Although COD effects appear to be a general phenomenon, the complexity of initial links and terminal links and their possible variations in concurrent-chain schedules should elicit caution in generalizing the results. The present study examined the effects of a COD on the choice between SSR and LLR in a complex concurrent-chain schedule. A reversal design was employed to assess the effects of a COD on initial- and terminal-link behavior in concurrent-chain schedules with identical VI schedules in the initial links and different delays and magnitudes of reinforcement that were programmed according to FR10 schedules in the terminal links.

Method

Subjects

Four white pigeons were maintained at 80% of their free-feeding body weight by additional feeding, when necessary, after the conclusion of each experimental session. All of the subjects were previously exposed to concurrent-chain and multiple schedules.

Apparatus

Four experimental operant conditioning chambers for pigeons were used, each housed in a sound-attenuating box. An exhaust fan in the sound-attenuating box provided masking noise. The experiment was controlled and the data were recorded in an adjacent room by a BBC-Master computer programmed in SPIDER. Experimental sessions could be monitored through a video screen that showed each subject's recorded behavior and the number of reinforcers that were obtained.

Procedure

The experiment used a concurrent-chain schedule (Autor, 1960) with two equal independent VI 60-second schedules in the initial links and FR10 schedules in the terminal links (Figure 1). During the initial links, both lateral keys were illuminated white. Two independent timers were used to program the intervals for the VI schedules in the initial links. Changeover responses were defined as the first peck on the right (or left) key that was preceded by a peck on the left (or right) key. When the terminal link became available to a peck on one side, the VI timer that was associated with that side stopped while the alternate timer continued to operate. Entry into a terminal link stopped the alternate VI timer and produced stimulus conditions that were appropriate to the terminal-link schedule: blackout on both lateral keys and red or green illumination on the middle key. The house light remained on. Only the middle key was operative during the terminal link.

If the transition to a terminal link followed a peck on the left key, then the 10th response on the red middle key (FR10) was followed by 4-second delay throughout the experiment. During the delay period, only the house light remained on. At the end of the 4-second delay, a 2-second reinforcement period began, during which the house light was extinguished and the light above the grain hopper was lit. After reinforcement, the house light was again lit, initiating the 19-second postreinforcement interval.

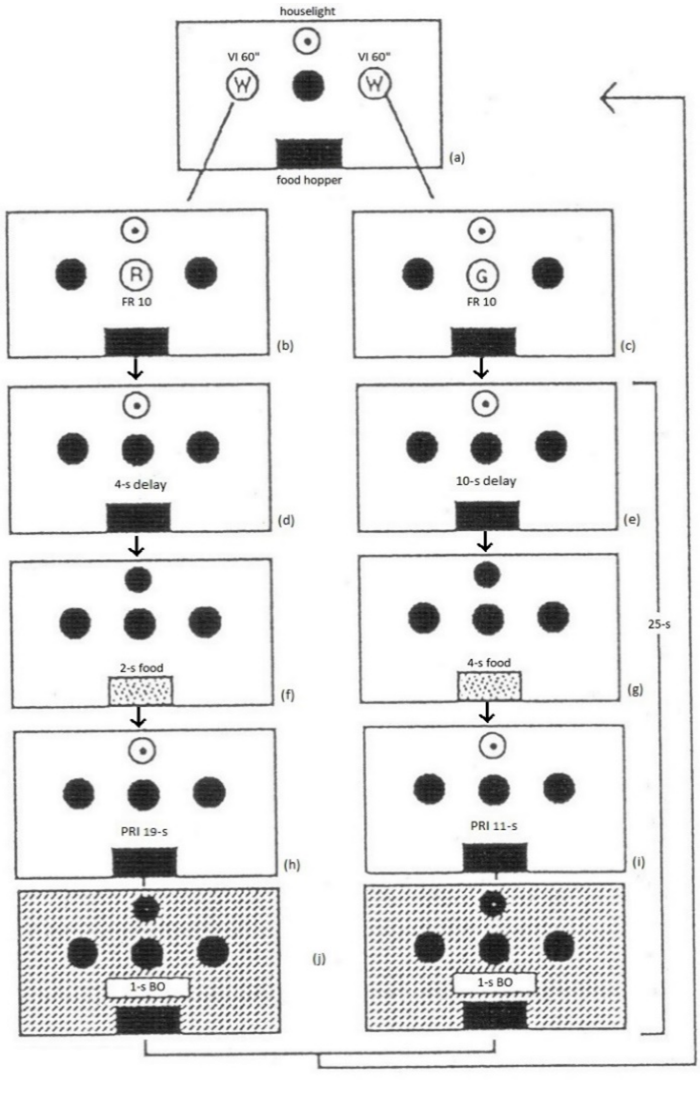

Figure 1. Concurrent-chain schedule that was used in all of the experimental conditions, showing initial links with independent VI 60-second—VI 60-second concurrent schedules (a), terminal-link entries with red or green center key and FR10 (b, c), 4-second (red entry) and 10-second (green entry) reinforcement delay (d, e), 2-second (red) and 4-second (green) access to food (f, g), 19-second (red) and 11-second (green) postreinforcement interval (h, i), and 1-second blackout (j).

If the transition to a terminal link followed a peck on the right key, then both lateral-key lights were extinguished, and the 10th response on the green middle key was followed by a 10-second delay. The delay period was followed by 4-second access to food and then an 11-second postreinforcement interval. Every terminal link ended with 1-second blackout. Following this blackout, the initial-link stimuli were reinstated, and another cycle began.

A COD of 2 seconds was included in the initial links during condition B of an ABA (pigeon no. 30 [P30] and P33) or BAB (P26 and P28) reversal design. Each experimental condition lasted for two long sessions (Todorov, Hanna, & Bittencourt de Sá, 1984; Hanna, Blackman, & Todorov, 1992) and five short sessions. Each long session was terminated after 4 hours or 240 reinforcements, whichever came first, followed by a non-test day. Short sessions were terminated after 60 reinforcements (approximately 1 hour) and were conducted on consecutive days.

Responses and the time spent in each schedule of the initial links, changeovers, the number of reinforcers, initial pauses, and running rates in the terminal links were recorded every 60 reinforcements.

Results and Discussion

In previous studies that used long session procedures with concurrent schedules (e.g., Todorov et al., 1984; Hanna et al., 1992), response rates decreased over hours of continuous training, but were still high during the fourth hour. In the present study with long sessions and delayed reinforcers in the terminal links of a concurrent-chain schedule, the pigeons often stopped responding after 3 hours of training. Therefore, the data from those long sessions included long pauses after the second hour. After this preliminary training, however, relative response rates in most cases showed small variability during the five short sessions. Thus, the following results were analyzed using only data from the short sessions of each experimental condition.

Figure 2 shows initial-link performance in each experimental condition for the five short sessions. Changeovers per minute (graphs on the left), relative responses (graphs in the center), and the relative frequency of entries in the SSR terminal link (graphs on the right) are presented for individual subjects. Changeover rates were lower during conditions with the programmed 2-second COD (filled symbol) for all subjects. Differences between conditions with and without CODs were significant (Wilcoxon signed-rank test for paired samples, $p \leq 0.05$; Table 1).

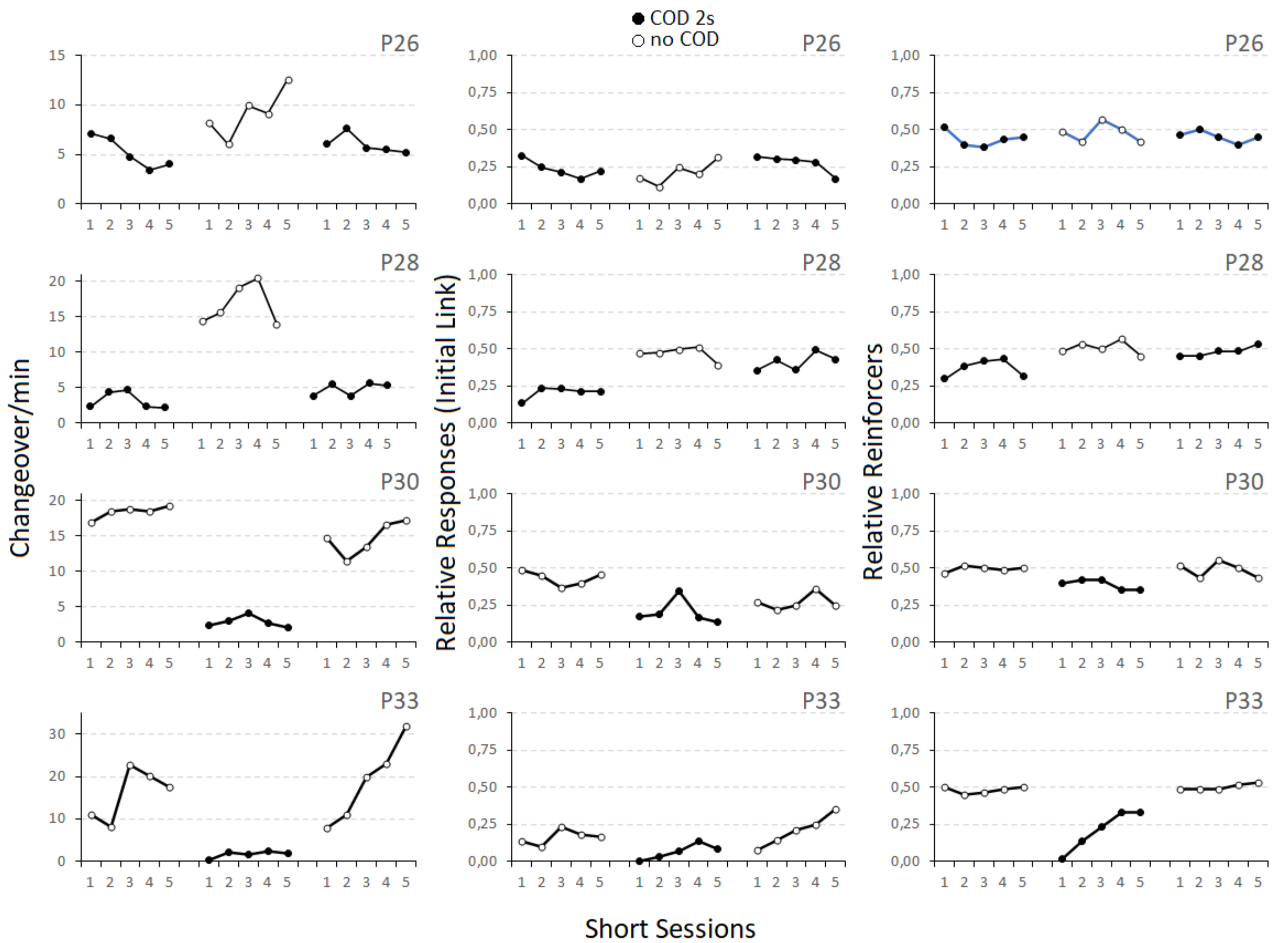

Figure 2. Changeover responses per minute, relative response rates on the left key (SSR), and the relative frequency of entries in the SSR terminal link in the concurrent-chain schedule with 0-second and 2-second CODs that were programmed in the initial links for the five short sessions for each subject.

Relative response rates in the left initial link (SSR) were lower with the COD for P28, P30, and P33, but not for P26 (Figure 2). These differences were significant for the first two conditions for these three subjects ($z = 1.89$, $p = 0.03$) but not for the second or third condition ($z = 1.35$, $p = 0.06$) for P28 and P30 (Table 1). Relative time allocation in the SSR initial link in each experimental condition (not shown) was similar to relative responses. The results showed reversibility and within-subject replication for three pigeons. Therefore, there was some evidence that COD increased preference in concurrent chains with differing delays and magnitudes. The short duration of the COD that was used in this study may have produced such variability. King and Logue (1987) found little or no effect of a short COD (1 second) on performance in concurrent chains in a self-control paradigm. Longer CODs showed more systematic effects. Furthermore, the few sessions that were used in the present study may not be sufficient for all complex contingencies to establish control for all subjects. Although there was a clear change in changeover rate for P26, training was likely too short to produce changes in the response distribution.

The relative frequency of SSR terminal-link entries (Figure 2) also decreased with the 2-second COD (except for P26). Differences were significant ($z = 1.89$, $p = 0.03$) for subjects with the ABA order (P30 and P33) and for the first two conditions for P28 (Table 1). These results are consistent with the observed response distribution, in which relative entries were consequences of the choice performance of concurrent chains.

When the five short sessions for all subjects were considered, comparisons between the 2-second COD and no COD showed significant differences ($p \leq 0.05$) in all three measures (i.e., changeover rates, relative responses, and relative reinforcers; Table 1) when both the first and last conditions were compared. The effect sizes for the three behavioral measures were medium for group data (except for relative responses when the last two conditions were analyzed).

Table 1.

Results of the Wilcoxon signed-rank test for paired samples of changeover rates, relative responses (SSR), and relative reinforcers (entries in SSR terminal link) between conditions with no COD and a 2-second COD for individual and group data.

Subject	Condition	Changeover Rate				Relative Responses				Relative Reinforcers			
		Median	z	p	effect r	Median	z	p	effect r	Median	z	p	effect r
P26	COD1	4.77				0.22				0.43			
	no COD	9.11	1.62	*0.05*	*0.51*	0.20	0.27	0.39	0.09	0.48	0.54	0.29	0.17
	COD2	5.63	1.62	*0.05*	*0.51*	0.30	0.81	0.21	0.26	0.45	0.54	0.29	0.17
P28	COD1	2.34				0.21				0.38			
	no COD	15.68	1.89	*0.03*	*0.60*	0.47	1.89	*0.03*	*0.60*	0.50	1.89	*0.03*	*0.60*
	COD2	5.30	1.89	*0.03*	*0.60*	0.43	1.35	0.09	0.43	0.48	1.08	0.14	0.34
P30	no COD1	18.51				0.45				0.50			
	COD	2.74	1.89	*0.03*	*0.60*	0.17	1.89	*0.03*	*0.60*	0.40	1.89	*0.03*	*0.60*
	no COD2	14.74	1.89	*0.03*	*0.60*	0.25	1.35	0.09	0.43	0.50	1.89	*0.03*	*0.60*
P33	no COD1	17.46				0.17				0.48			
	COD	1.87	1.89	*0.03*	*0.60*	0.07	1.89	*0.03*	*0.60*	0.23	1.89	*0.03*	*0.60*
	no COD2	19.98	1.89	*0.03*	*0.60*	0.21	1.89	*0.03*	*0.60*	0.48	1.89	*0.03*	*0.60*
Group	COD	2.60				0.18				0.38			
1st x 2nd	no COD	16.28	3.86	*0.00*	0.61	0.34	3.23	*0.00*	0.51	0.49	3.72	*0.00*	0.59
2nd x 3rd	COD	3.82				0.23				0.42			
	no COD	14.21	3.86	*0.00*	0.61	0.25	1.81	*0.04*	0.29	0.49	3.14	*0.00*	0.50

The analysis of initial pauses and running rates during the FR10 schedules of the terminal links (not shown) revealed no systematic effects of the COD on behavior in terminal links of the concurrent chains.

The COD had similar effects on choice performance in this modified concurrent-chain procedure as on simple concurrent performance (i.e., it increased preference and lowered changeover rates). These results confirmed the effects of the COD on concurrent chains that were reported by Leung & Winton (1985) and King and Logue (1987) and extend to concurrent-chain schedules with terminal links that are programmed on the center key and different delays and magnitudes of reinforcers that are programmed according to FR10 schedules.

The presence or absence of a COD affected the distributions of responses and time in the identical VI schedules of initial links of the concurrent chains. In concurrent schedules, such an effect was not found when equal VIs were programmed as alternatives (Shull & Pliskoff, 1967). The effects of the COD, however, appear to depend on the subject's preference for one alternative, which in concurrent schedules is determined by reinforcer parameters (e.g., frequency and magnitude) of the single-link alternatives. In concurrent chains, preference is determined by a combination of initial- and terminal-link contingencies (Fantino, Squires, Delbruck, & Peterson, 1972; Grace, 1994).

When no COD was programmed in initial links of the concurrent-chain schedule, the relative rates of conditioned reinforcers (or terminal-link entries) were closer to the programmed rates (i.e., 0.50; Figure 2). In experiments on choice between SSR and LLR, the primary concern is to identify the effects of different combinations of delays and magnitudes of reinforcement on choice behavior. Equal reinforcement schedules are programmed in initial links to keep reinforcement rates in the alternatives as equal as possible. Thus, the relationship between choice behavior and reinforcement contingencies of terminal links (i.e., delays and magnitudes but not frequency) may be identified. However, with independent initial links and a programmed COD, as the preference for one alternative develops, the relative reinforcement frequency deviates from 0.50. Research in this area has attempted to control the number of entries in each terminal link using a modified independent concurrent procedure (Logue et al., 1984) or non-independent concurrent procedure (Stubbs & Pliskoff, 1969). In modified independent concurrent schedules, the two VI timers never stop. When the assigned intervals elapse, reinforcers accumulate in a counter and are held until the subjects obtain them. Even in studies that used this procedure, however, reinforcer rates were not equal to programmed reinforcer rates (Chavarro & Logue, 1988; Logue et al., 1984); instead, they varied in the alternatives similarly to when the standard independent schedules were used. Furthermore, local reinforcer rates also vary in this modified procedure because reinforcers accumulate on the non-preferred alternative. Whenever a pigeon spends a few seconds responding on that key, it is likely to receive reinforcers (Logue et al., 1984). In the non-independent procedure, only one VI timer programs the intervals for both alternatives. As each reinforcer becomes available, it is randomly assigned to one of the alternatives. Such reinforcer scheduling, however, has at least two problems. First, it violates the definition of the choice situation. Second, it reduces sensitivity to reinforcement delays and magnitudes (Chavarro & Logue, 1988). Therefore, none of the attempts to solve the problem have been entirely successful. One argument could be that because with no COD in the initial links the obtained reinforcement rates were usually equal to the programmed rates, a COD should not be arranged in concurrent-chain schedules. However, the substantial increase in changeover response rates with no COD that was found in the present study suggests that both responses followed by reinforcers and the act of switching back and forth were strengthened. Although initial-link responses in concurrent chains are not immediately followed by primary reinforcers, the conditioned reinforcers in concurrent chains and primary reinforcers in simple concurrent schedules appear to have similar functions with regard to COD effects on choice performance. These results suggest that, as in concurrent schedules, a programmed COD should be part of the standard concurrent-chain procedure.

Importantly, this experiment was not a parametric study. Therefore, the generality of the present results when different COD values and different delays and magnitudes are programmed awaits further empirical support. Studies of COD and other "penalties" for switching (e.g., changeover ratio) have recently become rare, perhaps because interest in the related phenomenon of matching has also decreased. However, some choices in natural settings also include changeover and self-control contingencies (e.g., exchange of investments) and may benefit from knowledge of their effects on behavior.

Declaração de conflito de interesses

The authors declare that there is no conflict of interest regarding the publication of this article.

Contribuição de cada autor

Both the authors are equally responsible for the article contents.

Direitos Autorais

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