CONCURRENT SECOND-ORDER SCHEDULES OF REINFORCEMENT¹

STEVEN L. COHEN

BLOOMSBURG STATE COLLEGE

Responses on one key (the main key) of a two-key chamber produced food according to a second-order variable-interval schedule with fixed-interval schedule components. A response on a second key (the changeover key) alternated colors on the main key and provided a second independent second-order variable-interval schedule with fixed-interval components. The fixed-interval component on one variable-interval schedule was held constant at 8 sec, while the fixed interval on the other variable-interval schedule was varied from 0 to 32 sec. Under some conditions, a brief stimulus terminated each fixed interval and generated fixed-interval patterns; in other conditions, the brief stimulus was omitted. Relative response rate and relative time deviated substantially from scheduled relative reinforcement rate and, to a lesser extent, from obtained relative reinforcement rate under both brief-stimulus and no-stimulus conditions. Matching was observed with equal components on both schedules; with unequal components, increasingly greater proportions of time and responses than the matching relation would predict were spent on the variable-interval schedule containing the shorter component. Preference for the shorter fixed interval was typically more extreme under brief-stimulus than under no-stimulus schedules. The results limit the extension of the matching relation typically observed under simple concurrent variable-interval schedules to concurrent second-order variable-interval schedules.

Key words: concurrent schedules, second-order schedule, brief-stimulus schedule, changeover delay, fixed interval, variable interval, key peck, pigeons

Much of the research devoted to concurrent schedules of reinforcement has been aimed at examining performance under concurrent variable-interval (*conc* VI VI) schedules. Several studies have examined the relationship between preference and reinforcement parameters. One common relationship frequently observed has been, for example, the matching relationship, which states that relative response rate and time on a schedule equal the relative reinforcement rate on that schedule (*e.g.*, Herrnstein, 1970). Other studies have examined changeover response performance

(*e.g.*, Shull and Pliskoff, 1967), local response rate (*e.g.*, Stubbs and Pliskoff, 1969), response interactions (*e.g.*, Catania, 1963), different operants (*e.g.*, McSweeney, 1975) and different schedules (*e.g.*, LaBounty and Reynolds, 1973; White and Davison, 1973).

The present study extended this analysis by examining concurrent second-order schedules of reinforcement. In a second-order schedule, behavior controlled by a schedule of reinforcement is treated as a unitary response and is reinforced according to a schedule of reinforcement (Kelleher, 1966). For example, food may be presented after 10 fixed-interval (FI) schedules, *i.e.*, the first response after a fixed time period completes a component, and 10 components are needed for each food presentation. Here, behavior generated by an FI schedule is said to be reinforced under a fixed-ratio (FR) 10 schedule. A brief stimulus (*e.g.*, 0.5-sec feeder light) presented at the end of each component has been shown to generate patterns of responding within components similar to patterns engendered by primary reinforcement. For instance, with FI components, behavior is characterized by a pause after each brief stim-

¹This paper is based on a thesis submitted to the Graduate School of the University of Maine in partial fulfillment of the requirement for a Ph.D. degree. This research was supported while the author was a National Institute of Mental Health Predoctoral Research Fellow under the United States Public Health Service Grant MH54656-01. The author is greatly indebted to D. Alan Stubbs for his support during the experiment and for reviewing an earlier version of this manuscript. I also wish to thank Stanley S. Pliskoff and Joan E. Hughes for their help and advice while conducting this research. Reprints may be obtained from Steven L. Cohen, Department of Psychology, Bloomsburg State College, Bloomsburg, Pennsylvania 17815.

ulus followed by positively accelerated responding. When brief-stimulus presentations are omitted, component patterning is eliminated (Stubbs, 1971).

Some research has suggested that performance under simple schedules of reinforcement and the overall performance engendered by second-order schedules resemble one another (*e.g.*, Kelleher, 1966; Shull, Guilkey, and Witty, 1972). Kelleher, for example, showed that when a pigeon completed 30 FI 120-sec schedules for food, the response rate across 30 consecutive fixed intervals yielded an interresponse-time distribution similar to one that might be generated under a simple FR 30 schedule. The present experiment questioned whether performance under concurrent second-order variable-interval schedules resembles performance typically reported under simple concurrent variable-interval schedules; will, for example, the matching relationship be preserved?

Concurrent variable-interval schedules differ from concurrent second-order variable-interval schedules in certain respects. First, in simple concurrent schedules, the interreinforcement intervals conform fairly closely to the intervals precisely arranged by the separate VI schedules, assuming a moderately constant response rate as well as frequent changeover responses. With concurrent second-order schedules, however, there is a complex interaction between the intervals arranged by the VI schedules and components of the second-order schedules. Since under second-order schedules a component must be completed before reinforcement, intervals between successive reinforcers are determined by both the intervals on the VI schedule and the time required to complete the component. Therefore, with large-valued components, small intervals of the VI schedules are masked and larger intervals are increased. Second, the occurrence of brief-stimulus presentations at component completion of second-order schedules alters the pattern of responding within components from a constant response rate to one appropriate to the component schedule (*e.g.*, FI patterns). In addition, the presence of the brief stimulus and the accompanying patterns of responding may also affect preference under concurrent second-order schedules of reinforcement.

In the present experiment, pigeons' key pecks were reinforced according to concurrent

second-order variable-interval schedules with FI components. Pecks on a red key were controlled by an FI 8-sec component and reinforced under a VI schedule. In this case, the first FI 8-sec schedule completed after an interval of the VI schedule had elapsed produced food. Concurrently, pecks on a green key were controlled by an independent VI schedule with FI components. The values of the fixed interval on this key were varied from 0 to 32 sec. Under some conditions, a brief stimulus terminated fixed intervals and established the conditions for generating FI patterns of responding; in others, the brief stimulus was omitted.

METHOD

Subjects

Six adult female Silver King pigeons were maintained at 80% of their free-feeding body weights. All subjects had experimental histories involving visual discriminations.

Apparatus

Two keys (Ralph Gerbrands Co.) were mounted 23.5 cm above the floor, 6.3 cm between centers. A force of at least 0.15 N operated each key. A relay located behind the work panel provided a feedback click for responses to both keys. The left key could be transilluminated by white light, and the right key by red, green, blue, or yellow light. A Lehigh Valley Electronics pigeon feeder presented mixed grain. White masking noise was continuously present. Standard electromechanical relay and timing circuitry, located in an adjacent room, controlled experimental sessions.

Procedure

Daily experimental sessions terminated after 44 food presentations. Each food presentation consisted of 4-sec access to mixed grain while the food hopper was illuminated with white light and both response keys were darkened.

Key pecks were reinforced according to concurrent variable-interval second-order schedules using a changeover-key procedure (Findley, 1958). The VI schedules operated simultaneously and independently assigned food presentations for right- (main) key responses. A response on the left key (changeover key) alternated the color (red and green) and its associated schedule on the main key.

The changeover key was white. Changeover-key responses were ineffective during food presentations and for 0.5 sec after each FI schedule requirement (*e.g.*, brief-stimulus presentations) was completed.

For Subjects 58, 59, and 60, red-key responses were reinforced according to a second-order schedule where behavior controlled by an FI schedule was reinforced with food according to a VI 480-sec schedule. This meant that after a variable period of time, the first completed FI schedule was followed by food. The 15 intervals comprising the VI 480-sec schedule were derived from Catania and Reynolds (1968, pp. 380-381). Responding when the key was green was reinforced according to a second-order VI 160-sec schedule with FI components. The 22 intervals of the VI 160-sec schedule were derived from Catania and Reynolds.

For Subjects 61, 62, and 63, responses were reinforced according to concurrent second-order VI 240-sec schedules with FI components. The VI schedules contained 16 intervals (also from Catania and Reynolds, 1968).

Two variables were manipulated: (1) the values of the FI schedules, and (2) the presence or absence of a brief stimulus after each fixed interval was completed. Table 1 summarizes the order of presentation and number of sessions under each condition.

A control condition determined the effects of a brief stimulus following each response. The two VI schedules reinforced key pecking controlled by FI 0-sec schedules, *i.e.*, it was a

simple VI schedule. Each green-key response produced a 0.5-sec change in key color from green to yellow. Each red-key response produced a 0.5-sec blue stimulus. When the VI schedule requirement was met on either key, the next response produced the brief stimulus followed immediately by food. A 1.5-sec changeover delay, timed from each response on the changeover key, followed each changeover response and guaranteed at least a 1.5-sec interval between a changeover response and food presentations. In all conditions, responses to the right key produced an auditory feedback click except during the brief stimulus.

In Conditions 2 to 5, the fixed interval on the red key was FI 8-sec. The first red-key response completing each FI 8-sec schedule produced a 0.5-sec blue key; when the variable interval timed out, completion of an FI 8-sec schedule resulted in a brief stimulus followed by food. The value of the FI schedule on the green key was varied from 0 to 32 sec as shown in Table 1. Each fixed interval ended with a 0.5-sec yellow stimulus, or the yellow stimulus followed by food when the VI requirement was met. The FI schedule on both keys began anew following all changeover-key responses. Since this procedure consistently maintained a minimum fixed period of time (the FI value) between a changeover and a brief stimulus and was used throughout the experiment, the 1.5-sec changeover delay of Condition 1 was abandoned. The fixed interval was reset after changeovers because this arrangement maintained the unity of the FI component and fa-

Table 1

Summary of conditions in order of presentation for all subjects. Schedules for Subjects 58, 59, and 60 were VI 480-sec (red key) and VI 160-sec (green key) and for Subjects 61, 62, and 63, VI 240-sec (red key) and VI 240-sec (green key).

Condition	Component Schedule		Brief Stimulus		Sessions					
	Red Key	Green Key	Red Key	Green Key	#58	#59	#60	#61	#62	#63
1	FI 0-sec	FI 0-sec	blue	yellow	39	39	39	35	35	35
2	FI 8-sec	FI 8-sec	blue	yellow	29	27	29	40	49	46
3	FI 8-sec	FI 0-sec	blue	yellow	23	16	18	18	14	12
4	FI 8-sec	FI 32-sec	blue	yellow	15	19	13	13	17	14
5	FI 8-sec	FI 16-sec	blue	yellow	12	14	11	15	14	19
6	FI 8-sec	FI 16-sec	none	none	19	21	24	31	20	23
7	FI 8-sec	FI 0-sec	none	none	23	22	23	21	28	20
8	FI 8-sec	FI 32-sec	none	none	32	26	25	31	33	24
9	FI 8-sec	FI 8-sec	none	none	31	23	23	18	16	19
10	FI 8-sec	FI 8-sec	none	yellow	15	15	16	16	15	15
11	FI 8-sec	FI 8-sec	blue	none	23	23	23	23	24	23
12	FI 8-sec	FI 16-sec	blue	yellow	26	27	26	26	26	26
13	FI 8-sec	FI 16-sec	none	none	15	15	20	15	20	23

cilitated FI patterning within components of the second-order schedules.

In Conditions 6 to 9, the brief stimulus terminating FI schedules was omitted. The main key remained red or green when FI schedules not producing food were completed. In order to maintain the same relationship between key pecks and reinforcement observed in previous conditions, a brief stimulus preceded each food presentation.

In Conditions 10 and 11, both the red and green key contained FI 8-sec schedules. However, in Condition 10, completion of an FI 8-sec schedule on the red key did not produce any brief stimulus except for those fixed intervals ending with food, while completion of each FI 8-sec schedule on the green key produced a brief stimulus. In Condition 11, these arrangements were reversed.

The experiment concluded with redeterminations of Conditions 5 and 6 (brief-stimulus

and no-stimulus schedules with FI 16-sec components on the green key).

Conditions were changed when no consistent increasing or decreasing trends in relative response rate and relative time were observed for at least five consecutive sessions.

RESULTS

Table 2 shows relative response rate, time, and reinforcement rate, changeover response rate, and local response rate (responses on a key divided by time spent on that key) across conditions.

Some of the data are recast in Figures 1 and 2, which show relative time and response rate as a function of the FI schedule on the green key. In each Figure, the top row shows relative time (time spent in the presence of the red key divided by time spent in the presence of both keys) and the bottom row shows relative re-

Table 2

Relative response rate, time, and reinforcement rate on the red key, total changeover (CO) response rate, and local response rate on both red and green keys for stimulus and no-stimulus conditions. The parentheses around the FI 16-sec condition represent redeterminations. The scheduled relative reinforcement rate was 0.25 for red-key responses for Subjects 58, 59, and 60, and 0.50 for Subjects 61, 62, and 63. Data are medians of the last five sessions of each condition.

Pigeon	Component (FI sec)	Rel. Resp.	Rel. Time	Rel. Rein.	CO/hr	Local Resp./Min	
						Red	Green
58	Stim.						
	0	0.31	0.18	0.25	210.6	111.0	55.3
	8	0.27	0.25	0.25	138.6	84.7	80.5
	16	0.50	0.63	0.27	151.2	48.9	82.2
	(16)	0.47	0.32	0.25	122.4	38.9	77.9
	32	0.68	0.78	0.36	84.6	51.6	87.4
	No Stim.						
	0	0.41	0.22	0.25	201.0	106.8	43.0
	8	0.28	0.31	0.25	121.8	59.5	61.6
	16	0.30	0.37	0.27	135.6	57.4	77.6
	(16)	0.22	0.25	0.25	93.0	62.1	63.4
	32	0.28	0.38	0.27	112.8	56.8	92.8
59	Stim.						
	0	0.19	0.16	0.23	180.6	65.9	58.3
	8	0.25	0.23	0.23	111.6	65.9	64.4
	16	0.27	0.34	0.25	96.6	49.9	65.3
	(16)	0.38	0.30	0.27	102.0	46.6	63.3
	32	0.34	0.47	0.30	81.0	33.2	56.8
	No Stim.						
	0	0.26	0.35	0.20	541.8	42.5	62.8
	8	0.16	0.27	0.25	108.0	46.2	90.2
	16	0.22	0.30	0.25	72.0	57.1	84.4
	(16)	0.15	0.23	0.25	85.8	50.9	84.7
	32	0.18	0.27	0.27	69.0	53.0	91.1

Table 2 continued

Pigeon	Component (FI sec)	Rel. Resp.	Rel. Time	Rel. Rein.	CO/hr	Local Resp./Min	
						Red	Green
60	Stim.						
	0	0.36	0.23	0.25	297.0	64.1	36.9
	8	0.30	0.28	0.25	134.4	55.7	45.3
	16	0.38	0.53	0.30	135.6	51.3	91.6
	(16)	0.33	0.28	0.25	89.4	26.3	34.9
	32	0.66	0.78	0.41	91.2	46.0	92.7
	No Stim.						
	0	0.35	0.26	0.25	229.8	36.7	27.9
	8	0.23	0.36	0.25	140.4	26.4	49.8
	16	0.29	0.39	0.27	94.8	28.7	43.8
	(16)	0.29	0.28	0.25	113.4	36.6	37.6
	32	0.40	0.46	0.32	78.0	29.0	39.0
61	Stim.						
	0	0.43	0.31	0.48	402.6	74.6	45.2
	8	0.56	0.59	0.50	155.4	95.5	105.2
	16	0.68	0.75	0.57	61.2	65.8	92.9
	(16)	0.65	0.65	0.52	88.2	54.2	69.2
	32	0.77	0.83	0.68	44.4	71.7	103.2
	No Stim.						
	0	0.65	0.48	0.48	631.2	65.8	31.1
	8	0.64	0.56	0.52	134.4	62.1	45.8
	16	0.58	0.72	0.55	70.2	44.3	74.8
	(16)	0.53	0.55	0.50	149.4	53.1	66.8
	32	0.71	0.78	0.64	58.2	47.5	74.4
62	Stim.						
	0	0.15	0.12	0.39	196.2	39.2	39.2
	8	0.63	0.62	0.52	76.8	44.2	40.0
	16	0.82	0.80	0.59	41.4	46.3	42.1
	(16)	0.77	0.77	0.59	42.0	48.0	44.3
	32	0.95	0.90	0.80	19.8	58.0	31.2
	No Stim.						
	0	0.34	0.30	0.45	229.8	38.7	33.4
	8	0.47	0.52	0.50	123.0	40.7	51.0
	16	0.66	0.70	0.55	73.8	34.5	40.1
	(16)	0.57	0.65	0.55	77.4	41.1	52.8
	32	0.85	0.87	0.68	28.8	33.4	40.2
63	Stim.						
	0	0.24	0.38	0.48	299.3	30.6	61.0
	8	0.45	0.44	0.48	121.2	61.0	60.0
	16	0.70	0.83	0.59	42.7	36.3	77.5
	(16)	0.76	0.74	0.55	66.0	29.0	31.5
	32	0.92	0.96	0.89	15.0	43.5	89.9
	No Stim.						
	0	0.28	0.54	0.48	485.4	12.6	41.7
	8	0.45	0.53	0.45	165.6	34.4	47.1
	16	0.39	0.54	0.52	181.2	40.1	78.6
	(16)	0.52	0.50	0.52	155.4	35.5	35.8
	32	0.71	0.80	0.68	49.8	27.3	47.8

sponse rate (responses emitted on the red key divided by responses on both keys). Points falling along the dashed horizontal lines indicate that relative measures matched scheduled relative rate of reinforcement. Under Condition 1,

responding tended to conform to the matching relation; when a brief stimulus terminated all responses, and a 1.5-sec changeover delay was in effect, relative time and responses approximately equalled the relative reinforcement fre-

Fig. 1. Relative time and relative response rate across the fixed-interval components on the green key for Subjects 58, 59, and 60. The C on the horizontal axis refers to the control condition (Condition 1). The isolated points under the FI 16-sec condition are redeterminations. Calculations were made with respect to the red key. Data are medians and ranges of the last five sessions of each condition. No-stimulus conditions are displaced slightly to the left of stimulus conditions.

quency on the red key (reinforcers on the red key divided by total reinforcers).

Under brief-stimulus conditions, subjects showed a preference for the schedule containing the shorter fixed interval. Relative time and responses approximated matching when both components were FI 8-sec. The proportion of responses and time on the red key decreased when the schedule on the green key was FI 0-sec (with the exception of relative response rate for Subjects 58 and 60) and increased as the schedule increased to FI 16-sec. Relative response rate and time with respect to the red key increased further as the green-key component increased to FI 32-sec.

In general, no-stimulus conditions generated behavior similar to that observed under brief-stimulus conditions. However, curves generated by these conditions were more shallow than curves generated by brief-stimulus schedules. That is, relative measures were usually higher under no-stimulus compared to stimulus conditions at FI 8-sec *versus* FI 0-sec, but

lower at FI 8-sec *versus* FI 16-sec and FI 8-sec *versus* FI 32-sec. These stimulus no-stimulus differences were confirmed during redeterminations. In most cases, redeterminations were lower than initial determinations; however, with one exception (Subject 60) relative measures remained higher under brief-stimulus than under no-stimulus conditions. Considerable individual differences were evident across subjects; for example, while the no-stimulus curves tended to increase across conditions for Subjects 58 and 60, they were relatively constant for Subject 59. However, the forms of the curves were quite similar across subjects and conditions, and stimulus no-stimulus differences were quite consistent, although variable in magnitude. Relatively little overlap in the ranges was observed between stimulus and no-stimulus conditions.

Figures 1 and 2 show that in most conditions with unequal components, relative time and response rate failed to match scheduled relative reinforcement rate. Although these devia-

Fig. 2. Relative time and relative response rate across the fixed-interval components on the green key for Subjects 61, 62, and 63. The C on the horizontal axis refers to the control condition (Condition 1). The isolated points under the FI 16-sec conditions are redeterminations. Calculations were made with respect to the red key. Data are medians and ranges of the last five sessions of each condition. No-stimulus conditions are displaced slightly to the left of stimulus conditions.

tions were generally large under brief-stimulus conditions, they were also evident (to a lesser extent) under no-stimulus conditions. Table 2 shows that scheduled and obtained relative reinforcement rates differed, and that deviations from matching obtained relative reinforcement rate were less extreme than matching deviations depicted in Figures 1 and 2. However, deviations from matching obtained relative reinforcement rate were still evident under many conditions for both stimulus and no-stimulus schedules. Differences from obtained reinforcement rates were large in many instances but relatively small in others. Typically, the differences were larger under stimulus than under no-stimulus conditions. There was little variability in relative reinforcement rate within subjects. Examination of the maximum percentage deviations from the medians for the last five sessions of each condition re-

vealed that in 59 of 60 cases (six birds and 10 conditions per bird) maximum deviations were within 20% of the medians, and all were within 30%.

Table 2 also reveals: (1) Local response rate on both red and green keys varied considerably across conditions both within and between pigeons. However, no systematic differences in local rates were observed between red- and green-key responding or between stimulus and no-stimulus conditions. In 55 of 60 cases, maximum deviations from the medians were within 20% and 59 of 60 were within 30% for red-key responding; 55 of 60 calculations were within 20% of the medians and 59 of 60 were within 30% for green-key responding. (2) Overall changeover response rate decreased as FI components increased. No differences were found between stimulus and no-stimulus conditions. Changeover response rates were more variable

Table 3

Relative time, relative response rate, and relative reinforcement rate on the red key for Conditions 10 (no stimulus on the red key) and 11 (brief stimulus on the red key). Also shown are the local response rates on both red and green keys. Data are medians of the last five sessions of each condition.

Subject	Condition Red Key	Rel. Time	Rel. Resp.	Rel. Rein.	Local Rate (Resp. per Min)	
					Red Key	Green Key
58	no stimulus	0.26	0.25	0.25	62.5	64.5
	stimulus	0.23	0.24	0.25	59.2	54.7
59	no stimulus	0.30	0.30	0.25	59.7	56.4
	stimulus	0.31	0.23	0.25	62.6	94.8
60	no stimulus	0.26	0.18	0.25	30.8	45.1
	stimulus	0.30	0.25	0.25	33.2	42.1
61	no stimulus	0.59	0.55	0.50	56.6	63.7
	stimulus	0.56	0.55	0.50	64.2	65.6
62	no stimulus	0.56	0.54	0.52	49.9	55.5
	stimulus	0.44	0.47	0.48	50.9	45.5
63	no stimulus	0.41	0.35	0.48	24.3	32.1
	stimulus	0.54	0.54	0.52	35.2	34.9

than local response rates. Maximum deviations from the medians were within 30% in 51 of 60 cases and within 50% in 56 of 60.

Table 3 describes Conditions 10 and 11 when one schedule contained brief-stimulus presentations but the other schedule did not. Brief-stimulus presentations had little effect on relative time, relative response rate, and local response rate. In other words, no systematic changes in performance resulted from brief-stimulus presentations on only one schedule. Little variability in performance was observed in Conditions 10 and 11. Maximum deviations from the medians were within 25% for all calculations (with the exception of relative response rate where the performance of one bird in Condition 11 was 32% from the median).

DISCUSSION

Under simple *conc* VI VI schedules, relative response rate and time match relative reinforcement rate (Herrnstein, 1970). Matching was observed in the present study with simple *conc* VI VI schedules (Condition 1) when a brief stimulus followed each response. However, matching was not observed across the concurrent second-order schedules examined. Table 2 showed deviations from both scheduled and obtained relative reinforcement rate, although deviations from obtained rates were not large in many cases. Deviations were evident under both stimulus and no-stimulus conditions but generally larger under stimulus conditions. These results agree with those of

Pliskoff (personal communication), who examined concurrent second-order variable-interval schedules with FR components. Every two responses on one VI schedule produced a brief stimulus or a brief stimulus plus food provided that the VI requirement was met, and every 10 responses on the other VI schedule produced a brief stimulus or a stimulus plus food. With the ratios on each key fixed at FR 2 and FR 10 respectively, the VI schedules were varied. Across conditions, relative response rate failed to match relative reinforcement rate.

Two factors may have accounted for these deviations. First, simple VI schedules differ from second-order VI schedules with respect to their interreinforcement intervals. Under simple VI schedules, time between successive reinforcers is determined primarily by the distribution of intervals on the VI schedule, but with second-order schedules it is determined by the interaction of these intervals and the time to complete the component schedule. With large-valued components, the effects of the small intervals on the VI schedule would be masked by the greater time required to complete the component before food. For example, the present VI 160-sec schedule contained 7, 15, 23, 31, 40, 49, 59, 70, 81, 93, 106, 121, 137, 155, 175, 198, 225, 257, 297, 350, 430, and 590-sec intervals; with an FI 32-sec component, the four intervals shorter than 32 sec were not functional (*i.e.*, the shortest time between reinforcers was 32 sec), and the larger intervals were increased.

In addition, there was asymmetry in "changeover delays" imposed by the present schedules. Since each changeover response reset the components, a type of changeover delay was imposed by this arrangement (*i.e.*, the component duration specified a fixed period of time between changeovers and reinforcer availability). The systematic decrease in overall change-over response rate with increasing component size indicates that the components acted like changeover delays in simple *conc VI VI* schedules (Shull and Pliskoff, 1967). Typically, matching has been reported under conditions with equal changeover delays in both directions, even with long changeover delays (*e.g.*, Shull and Pliskoff, 1967). However, asymmetrical delays have produced systematic deviations from matching (Pliskoff, 1971). Similar asymmetry may have operated in the present study.

With unequal components, pigeons showed a greater preference for the VI schedule containing the shorter fixed interval, undoubtedly because this schedule was also the one with briefer times between successive reinforcers and changeovers and reinforcer availability. The preference was more extreme, however, under brief-stimulus than under equivalent no-stimulus conditions. The differences between stimulus and no-stimulus conditions were generally quite consistent, although Figures 1 and 2 do show that the differences were small in some cases and large in others. The brief stimulus could have affected preference in two ways. First, brief-stimulus presentations generated different response patterns and preference may have been affected in part by these differences (see White and Davison, 1973). Secondly, the brief stimulus could have affected choice by virtue of its conditioned-reinforcing properties. Pigeons may have shown a greater preference for the smaller fixed interval under brief-stimulus conditions because it provided the greater brief-stimulus rate. Since the stimulus was intermittently paired with food, its possible conditioned-reinforcing properties could have accentuated preference for the smaller fixed interval under brief-stimulus compared to no-stimulus conditions. Some of the present data, however, do not support this conditioned-reinforcement interpretation. While previous research (*e.g.*, de Lorge, 1971) has shown that a brief stimulus paired with food may generate high response rates, no dif-

ferences in local response rate were found between stimulus and no-stimulus conditions, or between red- and green-key responding. The results of Conditions 10 and 11 also showed that choice was not affected when a brief stimulus was scheduled on only one key.

REFERENCES

- Catania, A. C. Concurrent performances: reinforcement interaction and response independence. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 253-263.
- Catania, A. C. and Reynolds, G. S. A quantitative analysis of the responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 327-383.
- de Lorge, J. The effects of brief stimuli presented under a multiple schedule of second-order schedules. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 19-25.
- Findley, J. D. Preference and switching under concurrent scheduling. *Journal of the Experimental Analysis of Behavior*, 1958, **1**, 123-144.
- Herrnstein, R. J. On the law of effect. *Journal of the Experimental Analysis of Behavior*, 1970, **13**, 243-266.
- Kelleher, R. T. Conditioned reinforcement in second-order schedules. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 475-485.
- LaBounty, C. E. and Reynolds, G. S. An analysis of response and time matching to reinforcement in concurrent ratio-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 155-166.
- McSweeney, F. K. Matching and contrast on several concurrent treadle-press schedules. *Journal of the Experimental Analysis of Behavior*, 1975, **23**, 193-198.
- Pliskoff, S. S. Effects of symmetrical and asymmetrical changeover delays on concurrent performances. *Journal of the Experimental Analysis of Behavior*, 1971, **16**, 249-256.
- Shull, R. L., Guilkey, M., and Witty, W. Changing the response unit from a single peck to a fixed number of pecks in fixed-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1972, **17**, 193-200.
- Shull, R. L. and Pliskoff, S. S. Changeover delay and concurrent schedules: some effects on relative performance measures. *Journal of the Experimental Analysis of Behavior*, 1967, **10**, 517-527.
- Stubbs, D. A. Second-order schedules and the problem of conditioned reinforcement. *Journal of the Experimental Analysis of Behavior*, 1971, **16**, 289-313.
- Stubbs, D. A. and Pliskoff, S. S. Concurrent responding with fixed relative rate of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 887-895.
- White, A. J. and Davison, M. C. Performance in concurrent fixed-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 147-153.

Received 7 November 1974.

(Final Acceptance 12 June 1975.)