*INTERACTIONS IN MULTIPLE SCHEDULES:
THE ROLE OF THE STIMULUS-
REINFORCER CONTINGENCY¹*

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In Experiments I and II, pigeons were exposed to single-key multiple schedules of response-independent and -dependent food presentation. Components were correlated with different keylights. When the rate of food presentation in the first component exceeded that in the second component, the local rate of key pecking was relatively high at onset of the first component. Overall rate in that component varied inversely with component duration and the rate of food presentation in the second component. When responding was maintained in the second component, the local rate of key pecking was relatively low at onset of that component. Overall rate in the second component varied directly with component duration and the rate of food presentation in that component. In Experiment III, pigeons were exposed to a two-key multiple schedule. Pecks on a constantly illuminated key produced food. Components were correlated with the color of a second key on which pecks had no scheduled consequences. The effects of component duration and rate of food presentation under the single-key response-dependent schedule were synthesized by combining response rates on each concurrently available key under the two-key procedure. The results support an account of multiple-schedule interactions in terms of the joint influence on responding of stimulus-reinforcer and response-reinforcer contingencies.

Key words: multiple-schedule interactions, behavioral contrast, matching, stimulus-reinforcer contingencies, response-reinforcer contingencies, multiple schedules, key peck, pigeons

Brown and Jenkins (1968) exposed pigeons to a trial procedure in which response-independent presentations of food followed the brief illumination of a key. The pigeons reliably pecked the lighted key, even though key pecks had no scheduled consequences. Subsequent experiments concerned with this effect (labelled "autoshaping" by Brown and Jenkins) demonstrated that the contingency between keylight (stimulus) and food presentation (reinforcer) was primarily responsible for the acquisition and maintenance of key peck-

ing under trial procedures of response-independent and stimulus-contingent food presentation (see Hearst and Jenkins, 1974 review). Gamzu and Schwartz (1973) extended this finding to a situation which, in many respects, approximated that of a conventional schedule of reinforcement. In their study, pigeons were exposed to multiple schedules of response-independent food presentation. Components were correlated with different keylights. Key pecking rarely occurred when food was presented at equal rates in each component. When the rate of food presentation was reduced in one component, key pecking in the unchanged component developed and was well maintained. On the basis of these results, Gamzu and Schwartz speculated that under conventional multiple schedules of response-dependent food presentation, key pecking is maintained not only by the dependency of food presentation on responding, but also by the extant relation between keylight and food presentation. Specifically, they suggested that certain multiple-schedule interactions (*e.g.*, behavioral contrast), reliably found in pigeons, can be accounted for in terms of behavior engendered by the contingency between

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stimulus and reinforcer (see also Hearst and Jenkins, 1974; Rachlin, 1973). The following experiments were designed to examine this possibility.

EXPERIMENT I

Results similar to those of Gamzu and Schwartz have been reported consistently under multiple schedules of response-dependent food presentation. For instance, Reynolds (1961) found that when one component of a multiple variable-interval variable-interval (*mult VI VI*) schedule was changed to extinction (EXT), the rate of key pecking in the unchanged component increased. Reynolds called this "positive behavioral contrast". Others (*e.g.*, Arnett, 1974; Malone and Staddon, 1973; Nevin and Shettleworth, 1966) demonstrated that the local magnitude of contrast was usually highest during the initial portion of the unchanged component (but see Buck, Rothstein, and Williams, 1975). Malone and Staddon labelled this "local positive contrast" to distinguish it from the overall contrast described by Reynolds. Experiment I investigated whether effects analogous to local and overall positive contrast occur under multiple schedules of response-independent food presentation (Phase 1) and assessed the influence of component duration on responding maintained under these schedules (Phase 2).

METHOD

Subjects

Four adult male White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights and were experimentally naive at the beginning of the study.

Apparatus

A two-key chamber, measuring 32.0 cm high by 33.5 cm long by 30.0 cm wide, was used. One key was always dark and inoperative. The other key (Gerbrands), centered 25.5 cm above the floor on the front panel, could be transilluminated by a red or green jewel lamp (2 W, 28 V dc), and operated by a minimum force of 15 g (0.15 N). Keylights were shielded in an enclosure behind the front panel to prevent stray light from illuminating the feeder opening or other features of the chamber. The

feeder opening was centered 17.5 cm below the operative key. Three white jewel lamps (2 W, 28 V dc) were mounted at 7.5-cm intervals along the top of the front panel and provided continuous overall illumination. Except for the front panel, the inside of the chamber was painted flat black to reduce reflections. An exhaust fan provided ventilation and its noise helped mask extraneous sounds. Wide-angle lenses, mounted in each side wall of the chamber, allowed two observers to have an unobstructed view of the front panel and most of the chamber. Relay scheduling and recording equipment was located in an adjacent room.

Procedure

The pigeons were first trained to eat from the feeder within 3 sec of its presentation. Each pigeon was then exposed to the response-independent multiple variable-time variable-time (*mult VT VT*) and *mult VT EXT* schedules shown in Table 1. The VT schedules consisted of arithmetic distributions of 13 intervals arranged in irregular order. Food presentations (access to mixed grain) lasted 3 sec, during which the feeder was lighted and the key was dark. Components strictly alternated and were correlated with red or green keylights. Component changes scheduled while the feeder was operated were delayed until the end of food presentation. In this and subsequent experiments, sessions lasted approximately 30 min and, with some exceptions, were conducted six days per week. Conditions of each experiment remained in effect for at least 20 sessions and until performance was judged stable according to the statistical criteria described by Spealman and Gollub (1974). Systematic observations were conducted throughout the three sessions after responding stabilized under each condition in Phase 1. During each of these three sessions, two independent observers separately counted pecks directed to an area within 2.5 cm of the key (key-directed pecks) and pecks directed to other locations (nonkey-directed pecks) in each component. Pecks during food presentation were not counted. The reliability of observations was assessed by calculating a correlation coefficient (r) between the estimated rates of key-directed pecking for each pair of observers. The mean r was +0.973 (range: +0.864 to +0.997). All were significant ($p < 0.05$).

Table 1
Summary of Conditions (Experiment I)

Pigeon	Phase 1				Phase 2			
	Schedule		Component Duration (sec)	Sessions	Schedule		Component Duration (sec)	Sessions
	Red	Green			Red	Green		
254	EXT	VT 30-sec	30	24	VT 30-sec	EXT	10, 3, 100, 6, 300, 3	24, 22, 20,
	VT 30-sec	VT 30-sec		38				21, 26, 20
	VT 30-sec	EXT		27				
285	EXT	VT 30-sec	30	28	VT 120-sec	VT 30-sec	30, 6, 100, 10, 3, 300, 3	33, 30, 27,
	VT 30-sec	VT 30-sec		41				31, 22, 20,
	EXT	VT 30-sec		24				20
263	VT 30-sec	VT 30-sec	30	40	VT 30-sec	VT 120-sec	30, 10, 3, 6, 100, 300, 3	26, 24, 20,
	VT 30-sec	EXT		31				23, 21, 22, 22
287	VT 30-sec	VT 30-sec	30	40	EXT	VT 30-sec	100, 6, 10, 3, 300, 3	22, 25, 30,
	EXT	VT 30-sec		34				20, 21, 21

RESULTS AND DISCUSSION

Phase 1. Figure 1 shows the rate of key-directed pecking averaged across all observers (unfilled bars) and the rate of automatically recorded key pecking (filled bars) in each component of the *mult* VT VT and *mult* VT EXT schedules. Data are based on the mean of the last three sessions of each condition in Phase 1, during which the pigeons were continuously observed. The rate of observed key-directed pecking was usually much higher than the rate of key pecking. However, a relatively high rate of both pecking measures was maintained in the VT component of the *mult* VT EXT schedule, while a zero or near-zero

rate occurred in the EXT component and in both components of the *mult* VT VT schedule. Observed pecking motions were virtually always key-directed. No more than 28 nonkey-directed pecks were counted by any observer during a session. Key-directed pecks frequently fell short of striking the key and occasionally struck the front panel next to the key. These findings obviate the possibility (*cf.* Gamzu and Schwartz, 1973) that pecking, without regard to its locus, was maintained under both multiple schedules but became directed to the key only under the *mult* VT EXT schedule. In addition to overall rate, the local rate of key pecking during the first 3 sec (hereafter called initial rate) was measured in each com-

Fig. 1. Initial and overall rate of key pecking and overall rate of key-directed pecking in each component. Component schedules are shown below each set of three bars.

ponent. This rate, averaged over the last three sessions of each condition in Phase 1, is represented by the striped bars in Figure 1. In all cases, the initial rate exceeded the overall rate in the VT component of the *mult* VT EXT schedule. These results are similar to those of Wasserman (1973) under a trial procedure.

The results support and extend those reported by Gamzu and Schwartz (1973; see also Redford and Perkins, 1974). In each study, key pecking was maintained in the VT component under a *mult* VT EXT schedule but not under an equal-valued *mult* VT VT schedule, an effect analogous to overall positive contrast. An effect analogous to local positive contrast was also observed in that the rate of key pecking was relatively high following onset of the VT component under the former schedule. These findings call into question accounts of key pecking under multiple schedules of response-independent food presentation based primarily on the notion of adventitious reinforcement (*cf.* Herrnstein, 1966). It is unclear why an accidental response-reinforcer contingency would not maintain key pecking under a *mult* VT VT schedule if it were playing a major role in the maintenance of responding under the *mult* VT EXT schedule. It is equally unclear why such a contingency would maintain the local pattern of key pecking observed here.

Phase 2. Figure 2 shows the initial (triangles) and overall (circles) rate of key pecking in each component as a function of component duration. Filled symbols represent rates in the VT 30-sec component and unfilled symbols, rates in the EXT or VT 120-sec component. Data are means of the last 10 sessions under each condition. The mean of the last 10 sessions of Phase 1 (30-sec component duration) is included for Pigeons 254 and 287. In all cases, key pecking was maintained in the VT 30-sec component but not in the EXT or VT 120-sec component. Moreover, the overall rate of key pecking in the VT 30-sec component decreased as a function of component duration, although nonmonotonically for Pigeons 263 and 285. As in Phase 1, the initial rate of key pecking always exceeded the overall rate in the VT 30-sec component. Changes in the initial rate were not systematically related to component duration, except for Pigeon 263.

The effects of component duration are simi-

lar to those under conventional response-dependent multiple schedules. In three studies (Killeen, 1972; Shimp and Wheatley, 1971; Todorov, 1972), pigeons were exposed to unequal-valued *mult* VI VI schedules in which the relative rate of food presentation in the first component was approximately 0.72, 0.80, or 0.75, respectively. As component duration was reduced, the relative rate of key pecking in the first component increased so as to match approximately the relative rate of food presentation in that component. Examination of absolute response rates (Killeen, Table 3; Shimp and Wheatley, Table 2; Todorov, Table 1) shows how this approximate matching came about. As component duration decreased, the overall rate of key pecking in the first component increased, while that in the second component decreased. Thus, under both response-dependent and -independent multiple schedules, the overall rate of key pecking in the component correlated with the higher food-presentation rate decreased as a function of component duration.

By combining data from Phases 1 and 2, another relation can be described for Pigeons 263 and 285. These pigeons were exposed to multiple schedules in which components lasted 30 sec. One component was always correlated with a VT 30-sec schedule (2.0 food presentations per minute). The other component schedule was EXT, VT 120-sec, or VT 30-sec (0, 0.5, or 2.0 food presentations per minute, respectively). Figure 3 shows the initial (triangles) and overall (circles) rate of key pecking in unchanged (filled symbols) and the changed component (unfilled symbols) as a function of the food-presentation rate in the changed component. Data are means over the last 10 sessions under each condition in Phase 1 and the first condition of Phase 2. For both pigeons, the rate of key pecking in the unchanged component decreased monotonically as a function of the food-presentation rate in the changed component. The rate of key pecking in the changed component was minimal under all conditions. These findings are analogous to those of Reynolds (1963) and Lander and Irwin (1968) under conventional response-dependent multiple schedules. Under both types of multiple schedule, the rate of key pecking in the unchanged component varied inversely with the rate of food presentation in the changed component.

Fig. 2. Initial and overall rate of key pecking in each component as a function of component duration. Points representing the rate at the 3-sec component duration are averages of both determinations. Vertical lines show the range of these determinations except where contained within the symbol. Note the logarithmic x-axis.

EXPERIMENT II

Interactions similar to those under conventional multiple schedules were found under a response-independent multiple schedule in Experiment I. In that experiment, the rate of food presentation exceeded the rate usually

arranged under conventional multiple schedules, constraining a direct comparison between responding under the two procedures. Experiment II assessed the effects of component duration (Phase 1) and rate of food presentation in the changed component (Phase 2) on key pecking under a conventional multiple schedule

Fig. 3. Initial and overall rate of key pecking in each component as a function of the rate of food presentation in the changed component. For Pigeon 285, points representing the rate under the *mult* VT 30-sec EXT schedule are averages of both determinations. Vertical lines show the range of these determinations except where contained within the symbol.

which, except for the dependency of food presentation on responding, was comparable to that used in Experiment I.

METHOD

Subjects and Apparatus

Six adult male White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. Pigeons 254 and 263 served in Experiment I. Pigeons 329, 19, 22, and 24 were experimentally naive at the beginning of the study. The apparatus was the same as in Experiment I.

Procedure

Pigeons 329, 19, 22, and 24 were first trained to eat from the feeder within 3 sec of its pre-

sensation. Next, for all pigeons, food was presented contingent on successively closer approximations to key pecking in the presence of the red keylight. Each of the first 30 key pecks produced food. The key was then lighted green and each of the next 30 key pecks again produced food. After preliminary training, the pigeons were exposed to the *mult* VI VI and *mult* VI EXT schedules shown in Table 2. These schedules were identical to those described in Experiment I, except that food presentations were now response-produced. Scheduled food presentations not produced by a key peck were cancelled following component change. Cancellation of food presentation rarely occurred except when components were 3 sec long. Over the last 10 sessions of this condition, the obtained food-presentation rate

Table 2
Summary of Conditions (Experiment II)

Pigeon	Phase	Schedule		Component Duration (sec)	Sessions
		Red	Green		
254	1	VI 30-sec	EXT	30, 3, 300	20, 21, 21
	2	VI 30-sec	EXT, VI 30-sec, VI 120-sec	30	21, 22, 23
329	1	VI 30-sec	EXT	30, 300, 3	22, 20, 20
	2	VI 30-sec	EXT, VI 30-sec, VI 120-sec	30	21, 20, 20
19	1	EXT	VI 30-sec	30, 3, 300	24, 21, 22
	2	EXT, VI 30-sec, VI-120-sec	VI 30-sec	30	21, 24, 21
263	1	VI 30-sec	VI 120-sec	30, 300, 3	21, 20, 21
	2	VI 30-sec	VI 120-sec, VI 30-sec, EXT	30	21, 20, 23
22	1	VI 30-sec	VI 120-sec	30, 3, 300	25, 23, 20
	2	VI 30-sec	VI 120-sec, VI 30-sec, EXT	30	20, 22, 20
24	1	VI 120-sec	VI 30-sec	30, 300, 3	24, 21, 20
	2	VI 120-sec, VI 30-sec, EXT	VI 30-sec	30	22, 21, 21

averaged 8% (range: 4% to 11%) less than the scheduled rate.

RESULTS

Phase 1. Figure 4 shows the initial (triangles) and overall (circles) rate of key pecking in each component as a function of component duration. Filled symbols represent the rate in the VI 30-sec component and unfilled symbols, the rate in the EXT or VI 120-sec component. Data are means over the last 10 sessions under each condition. Except for Pigeon 22, overall rate in the VI 30-sec component decreased monotonically as a function of component duration. In all comparisons, the initial rate exceeded the overall rate in that component. Unlike overall rate, the initial rate did not vary systematically as a function of component duration. These results are similar to those under the comparable response-independent multiple schedules in Experiment I. When responding in the VI 120-sec or EXT component was maintained (Pigeons 263, 22, 24, and 329), the overall but not initial rate increased as a function of component duration. With a single exception, the initial rate was lower than the overall rate in the VI 120-sec or EXT component.

It is unlikely that the reduced rate of food presentation under the 3-sec component duration (see Procedure) had a marked effect on responding. Response rate during the first 3 sec following component change was comparable regardless of component duration. A similar local rate-constancy effect has been re-

ported by Green and Rachlin (1975) and Menlove (1975).

Phase 2. Figure 5 shows the initial (triangles) and overall (circles) rate of key pecking in the VI 30-sec (filled symbols) and changed component (unfilled symbols) as a function of the scheduled rate of food presentation in the changed component. Data are means over the last 10 sessions of each condition. The overall rate of key pecking in the unchanged component decreased monotonically as a function of the food-presentation rate in the changed component for all pigeons. Thus, the magnitude of overall positive contrast was inversely related to the rate of food presentation in the changed component. With one exception, the initial rate of key pecking in the unchanged component exceeded the overall rate under the *mult* VI 30-sec EXT and *mult* VI 30-sec VI 120-sec schedule. Local positive contrast was, therefore, usually observed. These positive contrast effects are analogous to the effects under the comparable response-independent multiple schedule in Experiment I. Local negative contrast was also observed. In nine of 12 cases, the initial rate of key pecking in the changed component was lower than the overall rate under the *mult* VI 30-sec EXT and *mult* VI 30-sec VI 120-sec schedule.

EXPERIMENT III

Experiments I and II are consistent with an account of interactions under conventional multiple schedules in terms of the joint main-

Fig. 4. Initial and overall rate of key pecking in each component as a function of component duration for individual pigeons and the averages. Note the logarithmic x-axis.

tenance of responding by the stimulus-reinforcer and response-reinforcer contingencies present under those schedules (*cf. e.g.*, Gamzu and Schwartz, 1973). The adequacy of this in-

Fig. 5. Initial and overall rate of key pecking in each component as a function of the rate of food presentation in the changed component for individual pigeons and the average.

terpretation can be evaluated by means of a procedure described by Keller (1974; see also Schwartz, 1974; Schwartz, Hamilton, and Silberberg, 1975). Under Keller's procedure, pigeons were exposed to response-dependent multiple schedules that differed from those commonly studied in that two keys were il-

luminated at all times. One key (constant key) was always lighted with a constant stimulus. Pecks on this key produced food according to the component schedules. The other key (stimulus key) was illuminated with a different stimulus during each component. Pecks on this key had no scheduled consequences. The results of Keller's experiment generally confirmed that key pecking maintained by the contingency between response and reinforcer was directed to the constant key, while that maintained by the stimulus-reinforcer contingency was directed to the stimulus key. Key pecks maintained by each contingency were, therefore, "topographically tagged" (*cf.* Catania, 1973). Experiment III investigated the effects of component duration (Phase 1) and food-presentation rate in the changed component (Phase 2) on key pecking under a multiple schedule of the type described by Keller.

METHOD

Subjects

Six adult male White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. Pigeons 287 and 285 served in Experiment I. Pigeons 25, 21, 257, and 72 were experimentally naive at the beginning of the study.

Apparatus

A two-key experimental chamber was constructed of clear Plexiglas and measured 33.5 cm high by 35.0 cm long by 35.0 cm wide. With the exception of the front panel, and a

6.5-cm by 6.0-cm portion of the right side wall, the inside of the chamber was painted flat black. Each key (Gerbrands) was located 25.5 cm above the floor and centered 3.0 cm to one side of the vertical midline of the front panel. A minimum force of 15 g (0.15N) was required to operate either key. The right (constant) key could be transilluminated by a white light and the left (stimulus) key, by a red or green light. Each keylight (7 W, 115 V ac) was individually shielded behind the front panel. The feeder opening was centered 17.5 cm below the keys. A single white lamp (6 W, 115 V ac) was centered at the top of the front panel and provided continuous overall illumination. The chamber was housed inside a sound-attenuating wooden enclosure provided with an exhaust fan and white masking noise. A wide-angle lens was mounted in the enclosure in front of the unpainted portion of the chamber. Scheduling and recording equipment was located in an adjacent room.

Procedure

Pigeons 25, 21, 257, and 72 were first trained to eat from the feeder within 3 sec of its presentation. The right key was illuminated with a white light and food was presented contingent on successively closer approximations to pecking this key for each pigeon. Each of the first 60 key pecks produced food. Following preliminary training, the pigeons were exposed to the two-key *mult* VI VI and *mult* VI EXT schedules shown in Table 3. These schedules were identical to those of Experiment II, ex-

Table 3
Summary of Conditions (Experiment III)

Pigeon	Phase	Schedule (Constant Key)		Component Duration (sec)	Sessions
		Red Key	Green Key		
287	1	EXT	VI 30-sec	30, 3, 300	23, 21, 20
	2	EXT, VI 30-sec, VI-120-sec	VI 30-sec	30	22, 28, 21
25	1	EXT	VI 30-sec	30, 300, 3	24, 20, 21
	2	EXT, VI 30-sec, VI-120-sec	VI 30-sec	30	20, 20, 22
21	1	VI 30-sec	EXT	30, 3, 300	22, 20, 20
	2	VI 30-sec	EXT, VI 30-sec, VI 120-sec	30	21, 24, 22
285	1	VI 120-sec	VI 30-sec	30, 300, 3	24, 20, 21
	2	VI 120-sec, VI 30-sec, EXT	VI 30-sec	30	20, 23, 24
257	1	VI 120-sec	VI 30-sec	30, 3, 300	25, 22, 22
	2	VI 120-sec, VI 30-sec, EXT	VI 30-sec	30	20, 27, 20
72	1	VI 30-sec	VI 120-sec	30, 300, 3	23, 23, 20
	2	VI 30-sec	VI 120-sec, VI 30-sec, EXT	30	22, 27, 20

cept that the component keylights (red or green) were displayed on the stimulus key while the constant key was always lighted white. Pecks on the stimulus key had no scheduled consequences. Pecks on the constant key produced food according to the component schedules. Because of the reinforcement cancellation procedure (see Procedure, Experiment II), the obtained rate of food presentation averaged 11% (range: 3% to 16%) less than the scheduled rate over the last 10 sessions under the 3-sec component duration. Reinforcement cancellation rarely occurred under other component durations. Following Phase 2, 10 additional sessions were conducted in which each stimulus-key peck initiated a changeover delay (COD). The COD ensured that a constant-key peck never produced food if it followed a stimulus-key peck by less than 1 sec. Under this condition, the schedule of food presentation was otherwise identical to that in the last condition of Phase 2.

RESULTS AND DISCUSSION

Phase 1. Figure 6 shows the initial (triangles) and overall (circles) rate of pecking each key in each component as a function of component duration. Filled symbols represent the rate in the VI 30-sec component and open circles, the rate in the EXT or VI 120-sec component. Data are means over the last 10 sessions of each condition. With the possible exception of Pigeon 257, the overall rate of stimulus-key pecking in the VI 30-sec component varied inversely with component duration. In all cases, the initial rate of stimulus-key pecking exceeded the overall rate in that component. However, changes in the initial rate were not systematically related to component duration. These effects are, in all important respects, similar to those under the comparable response-independent multiple schedule (Experiment I). This finding suggests that the effects of component duration on responding maintained by the contingency between stimulus and reinforcer (stimulus-key pecking) were not greatly influenced by the extant contingency between pecking the constant key and food presentation in the present study.

Unlike stimulus-key pecking, the overall rate of constant-key pecking in the VI 30-sec component was affected unsystematically by changes in component duration. Furthermore,

the initial rate of constant-key pecking in that component exceeded the overall rate in only two of 12 possible comparisons. The effects of component duration on responding in the EXT or VI 120-sec component were similar to those under the conventional one-key multiple schedule (Experiment II). Cancellation of scheduled reinforcement, which occurred when components were 3 sec long, did not markedly affect responding. The rate of constant-key pecking under the 3-sec component duration was usually no lower than the rate during the first 3 sec under the 30- or 300-sec component durations.

Phase 1 showed that the effects of component duration under the conventional single-key multiple schedule (Experiment II) could be synthesized by combining the rates of pecking each of the two keys. This synthesis is shown in Figure 7. The initial and overall rates of stimulus-key *plus* constant-key pecking are plotted as a function of component duration. The data are taken from Figure 7 and are averaged across the three pigeons exposed to the *mult* VI 30-sec EXT schedule (left panel) and the three pigeons exposed to the *mult* VI 30-sec VI 120-sec schedule (right panel). Symbols are the same as in Figure 6. Comparison with Figure 4 (single-key procedure) shows that the relations between response output and component duration were highly similar under the one- and two-key multiple schedules.

Phase 2. Figure 8 shows the initial (triangles) and overall (circles) rate of stimulus-key and constant-key pecking in each component as a function of the food-presentation rate in the changed component. Filled symbols represent the rate of key pecking in the VI 30-sec component and open symbols, the rate in the changed component. Data are means of the last 10 sessions under each condition. The rate of stimulus-key pecking in the unchanged component was inversely related to the rate of food presentation in the changed component for all pigeons. With one exception, the initial rate of stimulus-key pecking in the unchanged component exceeded the overall rate under the *mult* VI 30-sec EXT and *mult* VI 30-sec VI 120-sec schedules. Stimulus-key pecking rarely occurred in the changed component under any condition. These effects are similar to those under the comparable response-independent multiple schedule in Experiment I.

Fig. 6. Initial and overall rate of stimulus-key and constant-key pecking in each component as a function of component duration for individual pigeons. Note the logarithmic x-axis.

With regard to constant-key pecking in the unchanged component, neither local nor overall positive contrast was reliably observed. Indeed, the rate of constant-key pecking in that component frequently increased as a function of the food-presentation rate in the changed component (induction). As expected,

the rate of constant-key pecking in the changed component increased as a function of the food-presentation rate in that component. In 10 of 12 comparisons, the initial rate of constant-key pecking was lower than the overall rate in that component under the *mult* VI 30-sec EXT and *mult* VI 30-sec VI 120-sec schedules.

Fig. 7. Average initial and overall rate of stimulus-key *plus* constant-key pecking in each component as a function of component duration. Note the logarithmic x-axis.

Thus, a local negative contrast effect was usually observed with respect to pecking the constant key.

Phase 2 showed that the positive contrast effects under the conventional single-key multiple schedule (Experiment II) could be synthesized by combining the rates of concurrent stimulus-key and constant-key responding. Figure 9 shows the initial and overall rate of stimulus-key *plus* constant-key pecking in each component as a function of the food-presentation rate in the changed component. Data are from Figure 8, averaged across all pigeons. Symbols are the same as in that figure. Comparison of Figure 9 with Figure 5 (single-key procedure) shows that the relations between response output and rate of food presentation in the changed component were similar under the one- and two-key multiple schedules. Notice, however, that response output in the VI 30-sec component under the two-key procedure is attenuated relative to that under the single-key procedure. A similar attenuation can be seen by comparing Figure 7 (two-key procedure) with Figure 4 (single-key procedure) where component duration, rather than rate of food presentation was manipulated. While it is likely that topographical differences in the two chambers were, in part, responsible for the rate difference, it is probable that confounding variables introduced under the two-key procedure contributed to this difference.

For instance, changeover responses might have reduced key-peck output. It is also possible that rates of pecking the two concurrently available keys were not mutually independent. While either possibility appears compatible with the present data, neither has withstood experimental scrutiny in other concurrent situations (*cf.* Catania, 1963, 1973).

Within these limits, Experiment III supports the contention that two classes of pecking, one engendered by the stimulus-reinforcer contingency and the other by the response-reinforcer contingency, can be dissociated by arranging these contingencies on spatially separated keys. That an adventitious response-reinforcer contingency (*cf.* Herrnstein, 1966) contributed to the maintenance of stimulus-key pecking is untenable, since a constant-key peck necessarily intervened between a stimulus-key peck and food presentation. However, it remains possible that an adventitiously reinforced chain (*cf.* Herrnstein, 1961) of stimulus-key and constant-key pecking was responsible for the maintenance of stimulus-key pecking. This possibility is unlikely. The addition of the 1-sec COD during the last 10 sessions of the experiment did not have a deleterious effect on responding. Table 4 shows that, although the rate of stimulus-key pecking decreased in five of six cases, pecking this key continued for all pigeons. This was true even though the COD prevented an immediate temporal relation between a stimulus-key peck and a constant-key peck that produced food.

GENERAL DISCUSSION

The results support an account of interactions in conventional multiple schedules

Table 4

Effect of the added 1-sec COD on the rate of pecking each key in the unchanged component. Data are based on the mean of the last three sessions of the last two conditions of Experiment III.

Pigeon	$\frac{\text{resp/min (with COD)}}{\text{resp/min (without COD)}} \times 100$	
	Constant Key	Stimulus Key
287	113	91
25	97	113
21	90	79
285	93	75
257	121	88
72	119	49

Fig. 8. Initial and overall rate of stimulus-key and constant-key pecking in each component as a function of the rate of food presentation in the changed component for individual pigeons.

Fig. 9. Average initial and overall rate of stimulus-key plus constant-key pecking in each component as a function of the rate of food presentation in the changed component.

along the lines originally proposed by Gamzu and Schwartz (1973) and Rachlin (1973). By that account (labelled the "additivity theory" by Schwartz and Gamzu, *in press*), key pecking in a component correlated with a relatively high rate of food presentation is maintained not only by the contingency between responding and food presentation but also by the extant stimulus-reinforcer contingency. Experiments I and II demonstrated analogous local and overall contrast (or contrast-like) effects under comparable multiple schedules of response-dependent and -independent food presentation. Moreover, by topographically tagging key pecks maintained by the stimulus-reinforcer and response-reinforcer contingencies (Experiment III), these effects were observed with respect to former (stimulus-key) but not the latter (constant-key) contingency. These results are entirely consistent with an "additivity" account of positive behavioral contrast. The effects of component duration on responding under conventional multiple schedules can be interpreted in a similar fashion. The rate of key pecking in a component correlated with a relatively high rate of food presentation was inversely related to the dura-

tion of components. This was true under both the response-independent (Experiment I) and -dependent multiple schedules (Experiment II). An inverse relation was also obtained with respect to stimulus-key pecking, but not with respect to constant-key pecking under the two-key procedure (Experiment III). Thus, the inverse relation between response rate and component duration and, hence, its contribution to matching under short-component multiple schedules is readily compatible with an account based primarily in terms of key pecking maintained by the contingency between stimulus and reinforcer.

The above discussion placed emphasis on the positive interactions in the component associated with a relatively high rate of food presentation. Several individual results of Experiments II and III suggest that symmetrical but opposite (negative) interactions occurred in the alternate component. Indeed, local negative contrast as well as a direct, rather than inverse, relation between response rate and component duration was reliably found in that component. To account for data such as these, Rachlin (1973) proposed that behavior in a component correlated with a zero or relatively low rate of food presentation is influenced by the negative (inhibitory with respect to key pecking) stimulus-reinforcer contingency in that component. Although Rachlin left open the question of whether inhibition resulted from the maintenance of a response incompatible with key pecking, data relevant to this issue have been reported by Wasserman, Franklin, and Hearst (1974). In their study, pigeons approached and pecked keylights that were positively correlated with food presentation, withdrew from keylights that were negatively correlated with food presentation, and neither reliably approached nor withdrew from keylights that were uncorrelated with food presentation. These results implicate the negative contingency between stimulus and reinforcer as a critical determinant of withdrawal from the key. As Wasserman *et al.* pointed out, withdrawal would necessarily limit the ongoing rate of key pecking when both responses are concurrently maintained (perhaps as in a component correlated with a zero or relatively low rate of food presentation). Maintenance of withdrawal by the negative contingency between stimulus and reinforcer provides a plausible and, more im-

portant, testable account of the observed negative interaction effects. These considerations, along with the present findings, strongly suggest that the related phenomena of contrast and matching in multiple schedules might be reasonably ascribed to the combined influence on responding of stimulus-reinforcer and response-reinforcer contingencies, at least when food-correlated stimuli are localized on keys at which pigeons peck. Fruitful research may well lie in analyzing the contribution of these contingencies to a variety of effects generally regarded as by-products of stimulus control (e.g., peak shift and response summation with compound stimuli).

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