RESPONSE-RATE INVARIANCE IN CONCURRENT SCHEDULES: EFFECTS OF DIFFERENT CHANGEOVER CONTINGENCIES[1]

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In a two-key chamber, one key (the food key) was either red or green with different variable-interval schedules operating concurrently in each color and a second key (the changeover key) served to change the food-key color. Three pigeons were trained with either a 2-sec changeover delay or a 0-sec changeover delay and three birds with a fixed-ratio 2 on the changeover key instead of a changeover delay. The proportion of time spent in red approximated the proportion of reinforcers delivered in red for all birds. When the procedure was changed so that reinforcers were signalled in the green schedule, rates of reinforcement were unaltered, but the pigeons spent virtually the whole session in red. Changeovers to green were allowed only when a reinforcer was assigned by the schedule associated with green. For all pigeons with the fixed–ratio requirement on the changeover key or with a 0-sec changeover delay, the overall rate of red-key responses was higher during the signalling condition than during unsignalled, or baseline, condition. The present data question the generality of previous reports that the rate of one response is independent of the amount of time allocated to the alternative response.

Response rate varies directly with the rate of reinforcement for that response. Such a direct relation holds, for example, between the rate of key pecking and the rate of variable-interval reinforcement (Catania, 1963; Catania and Reynolds, 1968). Response rate also varies inversely with the rate of reinforcement for alternative responses. The rate of one response decreases as the rate of reinforcement for an alternative response increases (Catania, 1963; Herrnstein, 1970; Rachlin and Baum, 1972).

The reinforcement rate for an alternative response might affect the rate of a response through response competition. To illustrate, increasing reinforcement of the alternative response would allocate more of the session time to the alternative response (Baum and Rachlin, 1969; Brownstein and Pliskoff, 1968; Catania, 1966; Shull and Pliskoff, 1967; Todorov, 1971). To the extent that the alternative response is incompatible with the

designated response, the increased time devoted to the alternative response reduces the time available for the designated response, thereby lowering its rate.

An alternative possibility is that the rate of a response is influenced directly by the alternative reinforcers independently of the time devoted to alternative responding. That is, response rate may be a function simply of the rate of reinforcement for that response relative to the rate of reinforcement for all responses.

Catania (1963) performed an experiment with pigeons to distinguish these two accounts. Concurrent variable-interval schedules were arranged according to a changeover—key procedure (Findley, 1958). Reinforcers assigned by each schedule could be obtained only when that schedule's stimulus was projected on one of the keys, the food key. The other key, the changeover key, changed the stimulus and schedule in effect on the food key. Catania's study established performance on the *conc* VI VI schedules. The proportion of time in the two colors approximated the proportion of reinforcers received in the colors. The pigeons were then forced to spend most of their time in one color by allowing

changeovers to the alternative color only when a reinforcer was assigned by the alternative schedule: the changeover key was dark and inoperative except when a reinforcer was assigned by the alternative schedule. Despite the greater amount of time available for making the designated response, the rate of that response (per session time) was invariant between baseline (unsignalled) and signalling conditions.

Although those data suggested that the time available for responding was not an important determiner of response rates, the role of some procedural details should be examined before dismissing response compatibility factors. Catania (1963) used a changeover delay (COD), which specifies a minimum amount of time that must elapse between a changeover and reinforcement. Sometimes the COD produces high-rate response bursts on the food key after each changeover (Pliskoff, 1971; Silberberg and Fantino, 1970). Perhaps these COD bursts contributed to the response–rate invariance between baseline and signalling conditions. Response rate can be invariant between baseline and signalling conditions only if the response rate calculated with respect to time actually spent in that color (local response rate) is lower in the signalling than in the corresponding baseline condition. Otherwise, the increased time available for responding during the signalling condition would increase the rate of the designated response. The signalling procedure may reduce local response rates by virtually eliminating changeovers, and hence the frequency of COD bursts. If so, response–rate invariance should not occur when the COD does not produce the postchangeover response bursts, nor should it occur with changeover contingencies that do not produce such bursting. The possible importance for response–rate invariance of such "local factors" has been noted recently (Catania, 1972; Shimp and Hawkes, 1974).

EXPERIMENT I

Experiment I followed Catania's basic procedure of comparing response rates on concurrent schedules with and without restriction on changeovers. One study determined whether response–rate invariances occur when the changeover contingency is a small fixed

ratio on the changeover key (Stubbs and Pliskoff, 1969). The changeover ratio (COR) does not generate postchangeover response bursts. A second study used a COD procedure. Responding during and after the COD was measured separately to see if there was any relation between COD bursts and changes in local rates between baseline and signalling conditions.

METHOD

Subjects

Four naive adult male Silver King pigeons and two adult male White King pigeons (Birds B3 and B4) with brief experimental histories on multiple variable-interval schedules were maintained at approximately 80% of their free-feeding weights.

Apparatus

The front wall of the standard pigeon chamber measured 36 cm by 36 cm and contained two 1.8-cm (diameter) translucent Gerbrands pigeon keys and an opening for a mixed-grain feeder (Lehigh Valley Electronics). The keys were spaced 8 cm apart, center to center, and were mounted 25.5 cm from the floor. The feeder was centered below the left key. The keys operated with a minimum force of 0.15 N. A relay mounted behind the panel provided a feedback click for effective pecks. A speaker in the ceiling provided white noise and a fan provided ventilation. During feeder operation the keylights were turned off and the feeder opening illuminated.

Procedure

Preliminary training. Key pecking was hand-shaped in the four naive birds and all birds were then given 14 daily sessions on a variable-interval 1-min schedule (VI 1-min). The key color was alternated between red and green daily. Next, the schedule was changed to *conc* VI 2-min VI 6-min and the right key, illuminated white, was introduced as the changeover key for nine sessions. Sessions, conducted daily with few exceptions, contained 60 reinforcements. The reinforcer was 3-sec operation of the feeder.

Basic design. Each *conc* VI VI schedule was followed by a corresponding *conc* VI VI in which reinforcers assigned by one schedule were signalled. During baseline, changeovers could occur at any time; during the signalling

condition, changeovers to one of the schedules could occur only when a reinforcer was assigned by that schedule.

The rate of reinforcement in one of the schedules remained constant (VI 2-min) while the rate of reinforcement in the other schedule was varied among VI 6-min, VI 2-min, and VI 0.67-min. The baseline-*versus*-signalling comparison was made with each pair of schedules. The constant schedule was always the unsignalled schedule during signalling procedures and was correlated with red illumination of the food key. The varied schedule was correlated with green illumination of the food key.

All birds were exposed to the same baseline-signalling sequences. Three of the birds were studied with a COD in effect throughout. The other three birds were studied with a small fixed-ratio requirement (COR) in effect on the changeover key.

Baseline (conc VI VI) schedule. Each VI schedule consisted of an arithmetic series of 13 intervals with the smallest interval approximately 5 sec and the longest twice the mean interreinforcement interval, arranged in an irregular order.

The food (left) key was either red or green. A different VI schedule was associated with each of the two colors of the food key. Both VI schedules continued to time regardless of the current color of the food key. When one of the schedules assigned a reinforcer, both timers stopped until the assigned reinforcer was collected (Stubbs and Pliskoff, 1969). Reinforcers could be collected only by a food-key peck in the color associated with the assigned reinforcer. The second key, the changeover key (CO key), was illuminated white. A single peck on the changeover key (two pecks for the COR: see below) changed the color of the food key. The CO key was darkened and disconnected from the circuit after every changeover until a food-key response was made. Thus, at least one food-key response was required between each changeover. The VI timers and recording timers operated during the time that the food key was illuminated, including the time that the changeover key was darkened after a changeover. (Changeovers did not darken the CO key in Catania's (1963) study.)

Signalling procedure. Both schedules operated concurrently but the food key was red and the changeover key was dark and inoperative except when a reinforcement was assigned by the other schedule (the green schedule). At that time, the changeover key was illuminated and pecks on it changed the schedule on the food key and the correlated key color. After the delivery of the reinforcer on the green schedule, the food key was again red and the changeover key dark and inoperative.

Changeover contingencies. Three birds (B1, B2, B3) were trained on the baseline and signalling conditions with a changeover delay (COD) in effect. The COD was 2 sec, timed from a peck on the changeover key. Pecks on the food key could not produce reinforcement during the COD. The COD was in effect on both VI schedules during both baseline and signalling conditions. The VI schedules and recording timers operated during the COD.

The other three birds (B4, B5, and B6) were studied with a fixed-ratio of two responses (COR-2) instead of a COD. Two pecks on the changeover key were required to produce each changeover: the first darkened the food key and the second illuminated the food key with the alternative color and darkened the changeover key. The next food-key peck relit the changeover key. In all changeover ratio (COR) conditions, both VI timers and recording timers were stopped during the time between the two pecks on the changeover key.

Each condition was studied at least twice. Table 1 lists the actual sequence of conditions and the number of sessions of each.

RESULTS

The mean rate of red-key responses was calculated by dividing the total red-key pecks by the combined red-key and green-key time. (For COR conditions the time between the first and second pecks on the changeover key was excluded because the food key was darkened during the changeover ratio.) A single mean response rate was obtained for each condition by averaging five-day means across replications.

Figure 1 shows the mean rate of red-key responses plotted over the rate of reinforcement provided by the alternative schedule (green) for both the baseline and signalling conditions. The top panel shows the response-rate functions for the three birds trained with

Table 1

Order of conditions, schedule in green, procedure, and number of sessions of each condition with each bird. The schedule in red was always VI 2-min. During baseline procedures, reinforcements in both schedules were unsignalled. During signalling procedures, reinforcement assignments by the green schedule were signalled.

			Number of Sessions					
			COD 2 sec			COR 2		
Condition	Schedule in Green	Procedure	B-1	B-2	B-3	B-4	B-5	B-6
1	VI 6-min	Baseline	14	14	14	16	16	16
2		Signalling	16	16	16	16	16	16
3	VI 2-min	Baseline	20	20	20	20	20	20
4		Signalling	20	20	20	20	20	20
5		Baseline	15	15	15	15	15	15
6		Signalling	15	15	15	15	15	15
7	VI 0.67-min	Baseline	25	25	26	25	25	25
8		Signalling	20	20	19	20	20	25
9		Baseline	20	15	15	21	26	21
10		Signalling	15	20	20	19	15	20
11	VI 6-min	Baseline	35	35	35	35	36	46
12		Signalling	25	25	25	25	35	49
13		Baseline	—	—	—	70	60	37
14		Signalling	—	—	—	16	30	36
15		Baseline	—	—	—	26	20	11
16	VI 2-min	Baseline	—	—	—	40	40	40
17		Signalling	—	—	—	20	20	20
18		Baseline	—	—	—	7	7	7
19		Signalling	—	—	—	15	15	15

the COD; the bottom panel shows the response-rate functions for the birds trained with the COR. While there are some inversions, the response rate decreased as the alternative rate of reinforcement increased for both the baseline and signalling procedures.

Whether the rate of a response is affected by the time allocated to competing activities can be determined by comparing the response–rate functions for the baseline and signalling conditions. During baseline, the proportion of time in the alternative schedule approximately matched the schedule's proportion of reinforcers. During signalling, virtually the whole session was spent in the red color. (Actual proportions are listed in Table 2 for each bird.) If the rate of red-key responses depended on the concurrent rates of reinforcement, but not on the time allocated to the alternative schedule, the two curves would have been congruent for each subject. It is clear, however, that the curves are not congruent for any bird. For the birds trained with the COR, the rates of the red-key response were higher during signalling than during the corresponding baseline: for a given concurrent reinforcement rate, more responses to the red key occurred when virtually the whole session was spent in red than when time was allocated to the green schedule in proportion to green-key reinforcements.

The picture is more complex for the birds trained with the COD. For two birds (Birds B1 and B2), the red-key response rates were higher during signalling conditions than during corresponding baselines, as was the case with COR birds. For Bird B3, response rates were lower during signalling than during corresponding baseline.

Figure 1 shows the rates of the red-key response calculated with respect to the session time. *Local* response rates were computed by dividing the responses to each schedule by the time actually spent in that schedule, *i.e.,* when that schedule's color was projected on the food key. Local response rates are listed in Table 2. For the COR and two of the COD birds, the signalling procedure did not reduce the local response rate enough to balance the increased amount of time spent in red. Thus, response rate (per session time) increased from baseline to the signalling condition, instead of remaining invariant. For Bird B3, in
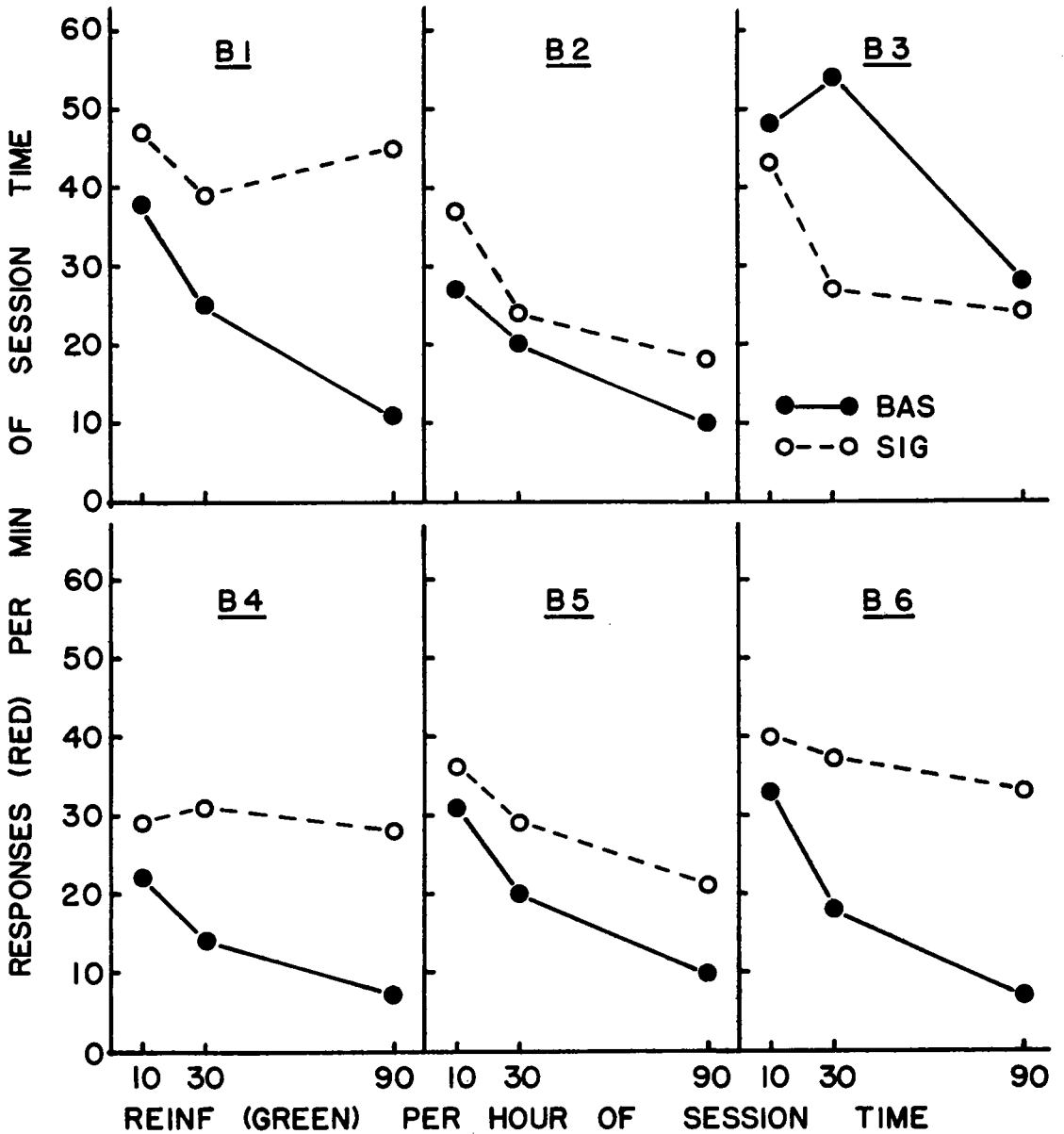
Fig. 1. Rate of the designated response (responses in red per minute of session time) plotted over the rate of reinforcement for the alternative response (green). The open points indicate the rates from the signalling conditions; the closed points from the baseline conditions. The top row shows the data from the three birds trained with the COD; the bottom row shows the data from the three birds trained with the COR. Each point represents the mean of the last five sessions averaged across replications.

contrast, signalling reduced the local response rate, more than balancing the increased time in red.

Local rates of the red-key response were partitioned into local response rates during and after the COD. The "COD rate" was calculated by dividing the number of red-key responses made during the COD by the ac-

cumulated COD time in red (the COD was always 2 sec timed from a peck on the changeover key.) The "post-COD rate" was calculated by dividing the number of red-key responses made after the COD by the accumulated time in red after the COD timed out. Figure 2 shows the COD and post-COD response rates during the baseline plotted over

Table 2

Relative responses and relative-time measures calculated with respect to red and the local response rate in red (responses in red/time in red) for each bird for each experimental condition. Each number is the mean of the last five sessions of a condition averaged across the two or more replications. The schedule associated with green is at the left; the schedule associated with red was always VI 2-min. Birds B1, B2, and B3 were studied with a 2-sec COD; Birds B3, B4, and B5 were studied with a COR 2.

| Schedule Green | Procedure | B-1 | | | B-2 | | | B-3 | | |
		Rel Rsp	Rel Time	Local Rate Red	Rel Rsp	Rel Time	Local Rate Red	Rel Rsp	Rel Time	Local Rate Red
VI 6.0-min	Baseline	0.65	0.73	52.5	0.74	0.70	38.3	0.67	0.76	62.7
	Signalling	—	—	48.4	—	—	36.9	—	—	44.2
VI 2.0-min	Baseline	0.42	0.53	47.4	0.60	0.57	35.4	0.48	0.49	110.7
	Signalling	—	—	39.8	—	—	24.7	—	—	27.2
VI 0.67-min	Baseline	0.21	0.30	36.7	0.26	0.34	28.8	0.41	0.30	95.8
	Signalling	—	—	47.9	—	—	19.0	—	—	25.2

| Schedule Green | Procedure | B-4 | | | B-5 | | | B-6 | | |
		Rel Rsp	Rel Time	Local Rate Red	Rel Rsp	Rel Time	Local Rate Red	Rel Rsp	Rel Time	Local Rate Red
VI 6.0-min	Baseline	0.77	0.76	25.5	0.75	0.73	42.5	0.80	0.76	43.7
	Signalling	—	—	28.8	—	—	36.0	—	—	39.7
VI 2.0-min	Baseline	0.55	0.53	26.0	0.52	0.47	42.1	0.56	0.51	35.1
	Signalling	—	—	31.4	—	—	29.1	—	—	37.6
VI 0.67-min	Baseline	0.20	0.26	27.8	0.25	0.28	36.7	0.16	0.24	30.4
	Signalling	—	—	29.9	—	—	22.0	—	—	33.4

the rate of reinforcement provided by the alternative schedule. (Plotted points are average values as described for Figure 1). The COD did not engender response bursts for Birds B1 and B2: the local response rates were about the same during as after the COD. For Bird B3, however, the COD did engender response bursts: local response rates were considerably higher during the COD than after. Because the signalling procedure reduced local response rate only for Bird B3, there appears to be a correlation between response bursts engendered by the COD and decreases in the local response rates from baseline to signalling procedures.

DISCUSSION

Some aspects of the present results are consistent with the data reported by Catania (1963) and some are not. Probably the most important consistency is the inverse relation between the rate of one response (per session time) and the rate of reinforcement for the alternative response. The present results extend the generality of that relation to the use

of a fixed–ratio changeover contingency. Because this inverse relation has now been observed in a variety of concurrent situations (for reviews see: Baum, 1973; Catania, 1973; Herrnstein, 1970; Lander and Irwin, 1968; Rachlin, 1973; Rachlin and Baum, 1972), it appears to be quite general.

Probably the most important inconsistency was the failure to observe invariance in the rate of the red-key response between baseline and corresponding signalling conditions. Procedural differences are no doubt responsible for this discrepancy between the present results and Catania's. Perhaps response-rate invariance is not obtained with a changeover ratio. Data reported by Pliskoff and Green (1972) support this possibility. In their study, there was no COD (or a 0-sec COD); a single peck on the changeover key was required for a schedule change (COR-1). Calculations based on their data (their Table 1) revealed that the rate of the designated response was highest during the signalling procedures, as was the case with the birds in the present study trained with the COR. Thus, in two
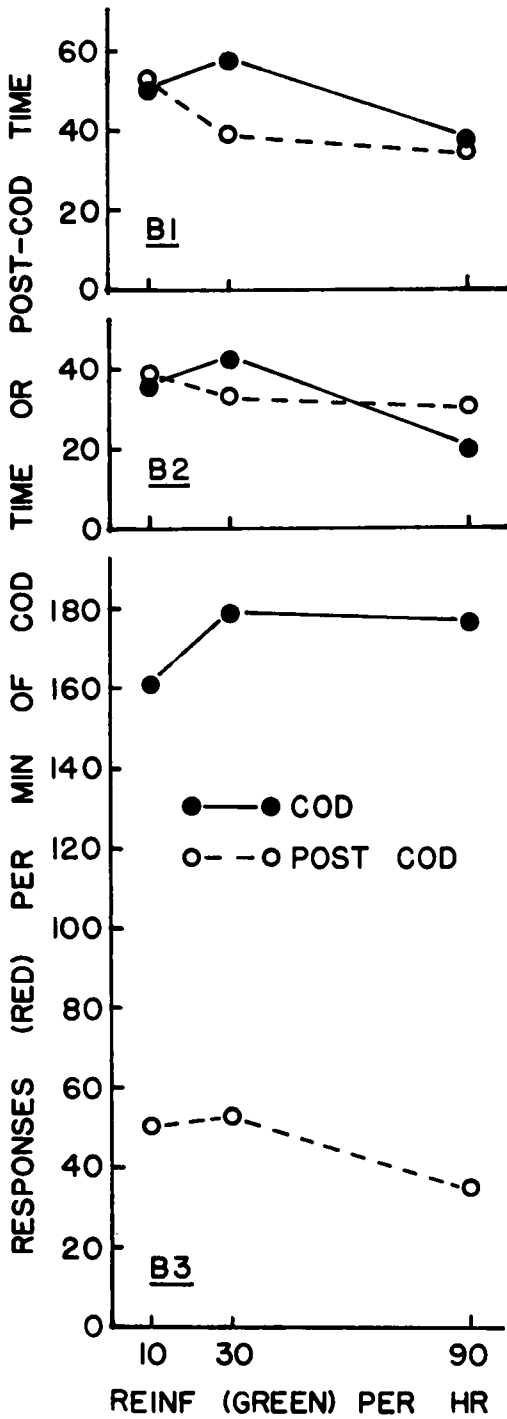
Fig. 2. Local response rates during the COD (closed points) and local response rates after the COD (open points) plotted over the rate of reinforcement for the alternative response. The rates are for the designated response (red) and are from the baseline conditions only. Each point represents the mean of the last five sessions averaged across replications.

studies using a changeover ratio with no COD, the response rates increased instead of remaining invariant when the signalling conditions were imposed. It is unclear what procedural differences are responsible for the failure to observe response-rate invariance with the three birds trained with the COD.

The rate of one concurrent response (per session time) will be invariant only if the signalling procedure produces a substantial decrease in the local rate of that response. In the present study, local response rate decreased substantially in the signalling conditions only for the bird showing high-rate bursts during the COD (Bird B3). Although the data are correlational, changes in the frequency of COD bursts were probably responsible for the local response-rate changes for Bird B3. During baseline, changeovers occurred frequently. As a result, as much as 80% of the session was spent in the COD, with responding at high rates. During signalling, changeovers were limited to one per reinforcement in the alternative schedule and so the COD occurred infrequently. Thus, the reduction in the amount of COD responding during signalling resulted in a lower local response rate in red. Because the COD did not engender reliable bursts for the other two COD birds (B1 and B2), there were no bursts for the signalling procedure to eliminate—so the local rate during signalling did not drop appreciably for those birds. Similarly, the COR did not engender any obvious post-changeover bursts and the local response rates did not decrease during signalling for these birds. In sum, the local response rate may drop when the signalling condition is imposed only when the local response rate has been inflated by postchangeover bursts during baseline.

EXPERIMENT II

Experiment II was undertaken to achieve stronger experimental control over post-changeover response bursts. In the first phase, the COD procedure was modified in an attempt to engender COD bursts for Birds B1 and B2 during baseline. In the second phase, the COD was eliminated (0-sec COD) to determine whether eliminating the COD during the baseline would eliminate postchangeover

bursts (especially for B3) and the reduction in the local response rate during signalling.

METHOD

Procedure

Birds B1, B2, and B3, which had been studied with the COD in Experiment I, served. The apparatus and basic procedure were the same as in Experiment I. The birds were first exposed to a baseline concurrent schedule, then to a corresponding signalling condition, then to baseline again. Throughout Experiment II, the schedule was *conc* VI 2-min (red) VI 0.67-min (green). What differed between Experiments I and II was the changeover contingency. In Phase I of Experiment II, a different type of COD was used; in Phase 2 of Experiment II, there was no COD. The baseline-signalling-baseline sequence was studied in each phase.

In Experiment I, the COD had been timed from the response on the changeover key. With that procedure, the first response on the food key after a changeover could have been reinforced if the bird paused for at least 2 sec between a changeover and the first food-key response. This possibility for differentially reinforcing pausing might have operated against any tendency for the COD to engender bursts of food-key responses (for B1 and B2 in particular). In Phase 1 of Experiment II, this possibility of differential reinforcement for postchangeover pausing was eliminated by having the first food-key response following each changeover initiate the COD. Thus, the 2-sec COD did not begin until a postchangeover food-key response was made, and so the first food-key response after a changeover could never be reinforced.

The COD was eliminated in Phase 2 of Experiment II. A changeover required merely a single peck on the changeover key. This procedure can be designated as a 0-sec COD or as a COR-1.

RESULTS

Figure 3 shows for each bird the rates of the red-key response for baseline sessions, for signalling sessions, and for recovery of baseline. The COD engendered response bursts for Birds B2 and B3, but not for Bird B1, as indicated in Figure 3 by the fact that local response rates in red (open points) are higher than the mean post-COD local response rate

(dashed line). During the signalling procedure, virtually the whole session was spent in red and there were very few changeovers. Thus, the denominator for all three response-rate calculations is virtually the same, and all three response-rate calculations give the same number. That number is shown by the solid points during the signalling condition in Figure 3. A primary concern was whether the imposition of the signalling condition would produce a decrease in the local rate of the red-key response only if the COD had engendered bursts during baseline. Signalling reduced the local response rate for Birds B2 and B3, but not for Bird B1. The COD engendered COD response bursts for B2 and B3 but not for B1, and so these data provide additional evidence that postchangeover re-
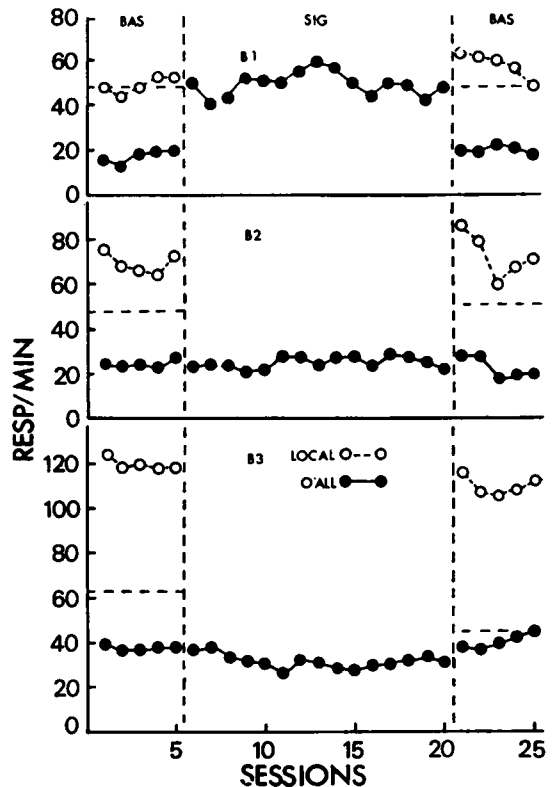

Fig. 3. Overall response rate (responses in red per mintue of session time) and local response rate (responses in red per minute of time in red) for the three birds plotted over consecutive sessions of the response-initiated COD condition. During the signalling condition the overall and local response rates were the same. The dashed horizontal lines indicate the mean post-COD local response rate for the baseline sessions shown. The schedule was *conc* VI 2-min (red) VI 0.67-min (green).

sponse bursts during baseline, such as may be generated by the COD, are important for the decrease in the local response rate during the signalling condition.

Given that the local response rate in red decreased for two birds, the next question is whether the decrease balanced the increased time in the designated schedule and thereby produced invariance in response rate (per session time). For B2 and B3, response rates (per session time) were roughly invariant between baseline and signalling. The results for these two birds thus support Catania's (1963) findings.

Figure 4 shows the local response rate and the response rate (per session time) for baseline sessions, for signalling sessions, and for recovery sessions with the no-COD (or 0-sec COD or COR-1) condition. For none of the birds in this condition did the signalling pro-

cedure decrease local response rate enough to balance the increased time in red. Thus, the signalling condition increased the rate (per session time) instead of producing invariance. The evidence from this manipulation is particularly compelling because the same two birds (B2 and B3) that showed response-rate invariance with the response-initiated COD showed response-rate increases without the COD.

GENERAL DISCUSSION

The inverse relation between the rate of one response and the rate (or amount) of reinforcement for a concurrently available alternative response is quite well established (Baum, 1973; Catania, 1963, 1973; Herrnstein, 1970; Rachlin and Baum, 1969, 1972). The present data provide additional support for the generality of this relation. The question addressed was whether this relation is independent of the time available for the response. One possibility is that concurrent reinforcement maintains a certain response rate (per session time) by determining the proportion of time allocated to the stimulus for each response. According to this view, if the time allocation were changed with the reinforcement context held constant, the responses per session time would change in a corresponding way. The second possibility is that a concurrent reinforcement supports a particular response rate in each schedule regardless of the time available for the response. According to this view, if the time allocation were changed with the concurrent reinforcement held constant, compensating adjustments in the local response rate should maintain a constant response rate calculated with respect to session time. The results of the original signalling study (Catania, 1963; see also Rachlin and Baum, 1972) appeared to support this second position. More recent data, however, have cast doubt on the generality of the response-rate invariance effect (Catania, 1972; Pliskoff and Green, 1972). Invariance between baseline and signalling occurred in the present study only under a restricted set of conditions (Experiment II, Phase 1), those in which the baseline schedule engendered postchangeover response bursts. More commonly, the response rate increased when signalling made more time available in the designated schedule.
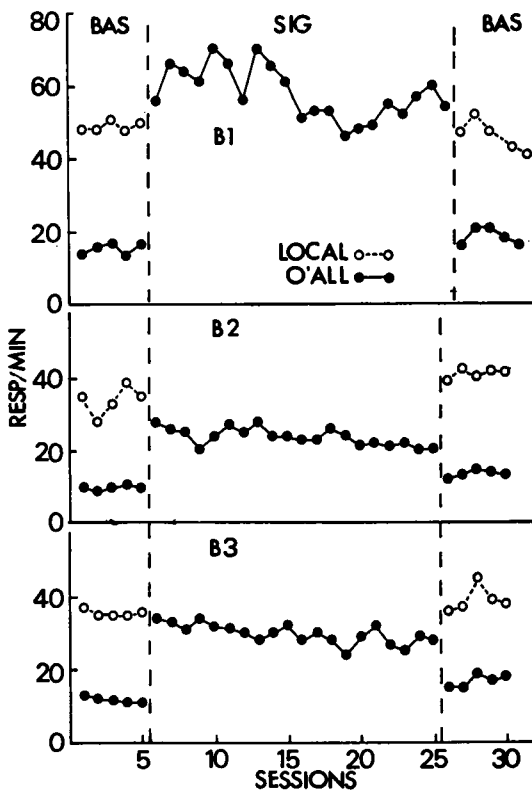

Fig. 4. Overall response rate (responses in red per minute of session time) and local response rate (responses in red per minute of time in red) for the three birds plotted over consecutive sessions of the no-COD (COR 1) condition. During the signalling condition, the overall and local response rates were the same. The schedule was *conc* VI 2-min (red) VI 0.67-min (green).

REFERENCES

Baum, W. M. The correlation-based law of effect. *Journal of the Experimental Analysis of Behavior,* 1973, **20**, 137-153.

Baum, W. M. and Rachlin, H. C. Choice as time allocation. *Journal of the Experimental Analysis of Behavior,* 1969, **12**, 861-874.

Brownstein, A. J. and Pliskoff, S. S. Some effects of relative reinforcement rate and changeover delay in response-independent concurrent schedules of reinforcement. *Journal of the Experimental Analysis of Behavior,* 1968, **11**, 683-688.

Catania, A. C. Concurrent performances: reinforcement interaction and response independence. *Journal of the Experimental Analysis of Behavior,* 1963, **6**, 253-263.

Catania, A. C. Concurrent operants. In W. K. Honig (Ed.), *Operant behavior: areas of research and application.* New York: Appleton-Century-Crofts, 1966. Pp. 213-270.

Catania, A. C. Concurrent performances: synthesizing rate constancies for a single response. *Journal of the Experimental Analysis of Behavior,* 1972, **17**, 139-146.

Catania, A. C. Self-inhibiting effects of reinforcement. *Journal of the Experimental Analysis of Behavior,* 1973, **19**, 517-526.

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.

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.

Lander, D. G. and Irwin, R. J. Multiple schedules: effects of the distribution of responses between components. *Journal of the Experimental Analysis of Behavior,* 1968, **11**, 517-524.

Pliskoff, S. S. Effects of symmetrical and asymmetrical changeover delays on concurrent performances. *Journal of the Experimental Analysis of Behavior,* 1971, **16**, 249-256.

Pliskoff, S. S. and Green, D. Effects on concurrent performance of a stimulus correlated with reinforcer availability. *Journal of the Experimental Analysis of Behavior,* 1972, **17**, 221-227.

Rachlin, H. Contrast and matching. *Psychological Review,* 1973, **80**, 217-234.

Rachlin, H. and Baum, W. M. Response rate as a function of amount of reinforcement for a signalled concurrent response. *Journal of the Experimental Analysis of Behavior,* 1969, **12**, 11-16.

Rachlin, H. and Baum, W. M. Effects of alternative reinforcement: does the source matter? *Journal of the Experimental Analysis of Behavior,* 1972, **18**, 231-241.

Shimp, C. P. and Hawkes, L. Time-allocation, matching, and contrast. *Journal of the Experimental Analysis of Behavior,* 1974, **22**, 1-10.

Shull, R. L. and Pliskoff, S. S. Changeover delay and concurrent performances: some effects on relative performance measures. *Journal of the Experimental Analysis of Behavior,* 1967, **10**, 517-527.

Silberberg, A. and Fantino, E. Choice, rate of responding, and the changeover delay. *Journal of the Experimental Analysis of Behavior,* 1970, **13**, 187-197.

Stubbs, D. A. and Pliskoff, S. S. Concurrent responding with fixed relative rates of reinforcement. *Journal of the Experimental Analysis of Behavior,* 1969, **12**, 887-895.

Todorov, J. C. Concurrent performances: effects of punishment contingent on the switching response. *Journal of the Experimental Analysis of Behavior,* 1971, **16**, 51-65.