CONTRAST EFFECTS IN MULTIPLE FIXED-INTERVAL REINFORCEMENT SCHEDULES

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Pigeons were exposed to a multiple fixed-interval one-minute fixed-interval three-minute schedule of reinforcement following training on either a multiple fixed-interval one-minute fixed-interval one-minute schedule or a multiple fixed-interval three-minute fixed-interval three-minute schedule. For all birds, large negative local contrast effects developed during the first of four three-minute intervals in a component; response rate was depressed and postreinforcement pause lengthened in this interval. Positive local contrast effects were evident during the first of 12 one-minute intervals in a component for five of six birds; at asymptote, the pause was very short and response rate slightly elevated during this interval. Overall positive contrast was generally transient and varied considerably across subjects, while overall negative contrast effects, if they occurred, appeared only after a large number of sessions.

Key words: schedule interactions, local contrast effects, fixed intervals, key peck, pigeons

If changing reinforcement rate in one component of a multiple schedule results in a change in performance in the other component, the effect is called an *interaction* (Reynolds, 1961a,b). Two types of interactions are possible—induction and contrast effects. *Induction* (generalization) refers to the case where changes in performance during both components are in the same direction; *contrast* describes the situation when changes in behavior are in the opposite direction. It is still not at all clear why behavioral contrast occurs, although a large body of data has been amassed and a number of theories have been proposed to account for the phenomenon (see Mackintosh, 1974; Rachlin, 1973; Schwartz and Gamzu, 1977, for reviews of the literature).

Contrast effects may be *positive* or *negative*, involving, respectively, an increase or decrease in responding in the unchanged component. These *overall* contrast effects are usually assessed with reference to performance on an ini-

tial baseline schedule, in which reinforcement rate is equal in both components. The most convincing studies also include a third phase, during which baseline performance is recovered. Within-session positive and negative contrast effects have been observed during the initial portions of the positive and negative components of multiple schedules (Nevin and Shettleworth, 1966; Staddon, 1969). These *local* contrast effects (Malone and Staddon, 1973) are frequently assessed with reference only to the response rate during the time remaining in the same component or to the average response rate in that component. Others assess them with respect to performance in the adjacent schedule (Schwartz and Gamzu, 1977).

Most studies of overall contrast have used variable-interval (VI) schedules in at least one, and usually both, schedule components, and have looked at the effect of changing one of these equal-valued schedules to extinction, although occasionally reinforcement rate has merely been reduced. This procedure generally produces positive behavioral contrast. Two researchers (Schwartz, 1975; Terrace, 1968) have studied negative contrast effects by increasing reinforcement rate in one of two VI schedule components. The three birds in the Schwartz study all showed reliable overall negative contrast, but only one of Terrace's birds did so. While positive overall contrast is more likely to be observed than negative, the op-

posite is true for local contrast effects. In this case, negative effects are both larger and more reliable than the positive effects.

Both overall and local contrast effects may be either *sustained* or *transient*. Hearst (1971) reported sustained overall positive contrast that lasted for 64 sessions; Terrace (1968) found a transient increase in overall response rate that disappeared after a few days. The local contrast effects reported by Nevin and Shettleworth (1966) were transient; those reported by Staddon (1969) were sustained.

Few studies (*e.g.*, Arnett, 1973) have looked at both local and overall contrast in the same situation. An understanding of the relationship between these two contrast effects may help us determine the mechanisms underlying behavioral contrast. The *mult* FI 1-min FI 3-min schedule used by Staddon (1969) produced large local contrast effects. Staddon, however, did not run a baseline condition and so was unable to assess overall contrast. In the present study, birds received training on either a *mult* FI 1-min FI 1-min or a *mult* FI 3-min FI 3-min schedule before being exposed to the *mult* FI 1-min FI 3-min schedule, thus providing the opportunity to study both positive and negative local and overall contrast effects.

METHOD

Subjects

Six, adult White Carneaux pigeons were used. Birds 77 and 96 had experience with interval reinforcement schedules; the other birds were experimentally naive. All birds were maintained at about 80% of free-feeding weights throughout the experiment.

Apparatus

A standard aluminum and Plexiglas one-key operant conditioning chamber was housed in a large wooden box, covered with Styrofoam to reduce sound transmission. The response key could be transilluminated with red or green light from an in-line stimulus projector mounted behind the key. A recorded response, requiring a minimum force of 0.15 N, produced a distinct click from a dc feedback relay. During reinforcement (3.2-sec access to mixed grain), the keylight was extinguished and the key became inoperative. A 10-W houselight remained on throughout the session. White noise and the noise of the ventilating fan helped mask extraneous sounds. Scheduling and recording equipment was in a different room. Data were recorded on digital and printing counters and a cumulative recorder.

Procedure

Before the experiment, Birds 105, 106, 107, and 108 were hand shaped to peck the response key. They then received one session during which 72, 20-sec fixed intervals were scheduled. The keylight changed from green to red, *etc.* after every twelfth food presentation.

Table 1 outlines the experimental conditions and number of sessions, under each condition, experienced by each bird. The birds were not all studied at the same time; Birds 77 and 96 had completed the experiment before the other birds were studied.

In Condition 1, the birds were exposed to alternating components, during which the key

Table 1

The multiple schedule in effect and the number of sessions received by each bird during the four conditions of the experiment. For conditions in which the *mult* FI 1-min FI 3-min schedule was in effect, the key color [(R) = red, (G) = green] associated with each schedule is indicated below the schedule designation.

Condi-tion	Birds											
	77		96		108		106		105		107	
	Sched.	Sess.	Sched.	Sess.	Sched.	Sess.	Sched.	Sess.	Sched.	Sess.	Sched.	Sess.
1	FI 1 FI 1	30	FI 1 FI 1	38	FI 1 FI 1	33	FI 1 FI 1	35	FI 3 FI 3	34	FI 3 FI 3	33
2	FI 1 FI 3	33	FI 1 FI 3	33	FI 1 FI 3	34	FI 1 FI 3	35	FI 1 FI 3	35	FI 1 FI 3	35
	(R) (G)		(G) (R)		(R) (G)		(G) (R)		(R) (G)		(G) (R)	
3	FI 1 FI 1	11	FI 1 FI 1	8	FI 1 FI 1	43	FI 3 FI 3	43	FI 1 FI 1	43	FI 3 FI 3	45
4	FI 1 FI 3	15	FI 1 FI 3	15	FI 1 FI 3	8	FI 1 FI 3	8	FI 1 FI 3	8	FI 1 FI 3	8
	(G) (R)		(R) (G)		(R) (G)		(G) (R)		(R) (G)		(G) (R)	

was lighted with green, and then with red. Each component lasted approximately 12 min and each pair of components is referred to as a cycle. Birds 77 and 96 received four such cycles per session; the other four birds received three cycles per session. Food was available on a fixed-interval 1-min (FI 1-min) schedule during both stimulus components for Birds 77, 96, 106, and 108. The stimulus change occurred following the twelfth food presentation in each component (*mult* FI 1-min FI 1-min schedule). For Birds 105 and 107, a fixed-interval 3-min (FI 3-min) schedule was in effect, and the stimulus changed following the fourth food presentation in each component (*mult* FI 3-min FI 3-min schedule).

During Condition 2, all birds were exposed to a *mult* FI 1-min FI 3-min schedule, with 12, 1-min intervals scheduled during the first component and four 3-min intervals during the second component of a cycle; again the stimulus changed after the last food presentation in a component. For half the birds, the stimulus during the FI 1-min component was a green keylight and the stimulus during the FI 3-min component, a red keylight; for the other birds, the significance of the stimuli was reversed (see Table 1).

After behavior had stabilized on the *mult* FI 1-min FI 3-min schedule, Birds 77, 96, 108, and 107 were reexposed to the multiple schedule they had experienced during Condition 1. Bird 106, originally trained on the *mult* FI 1-min FI 1-min schedule, was exposed to the *mult* FI 3-min FI 3-min schedule in Condition 3, and Bird 105, first trained on *mult* FI 3-min FI 3-min, now experienced the *mult* FI 1-min FI 1-min schedule.

In a final condition, all birds were again exposed to a *mult* FI 1-min FI 3-min schedule. For Birds 105, 106, 107, and 108, Condition 4 was a replication of Condition 2; for Birds 77 and 96 the stimulus associated with each schedule was the reverse of that experienced during Condition 2.

RESULTS

On fixed-interval schedules of reinforcement, two measures of performance are of interest—response rate and postreinforcement pause (time to the first response in an interval). Response rate may be computed over the entire interval (overall rate) or for the time following the first response in an interval (running rate). Overall response-rate data are shown in Figure 1 for individual birds across the four conditions of the experiment. Postreinforcement pause data from the same sessions are shown in Figure 2. Each data point is the mean of two sessions. Occasionally, a session was omitted due to equipment failure; for conditions involving an odd number of sessions, data from the session at mid-condition were omitted. Performance during 1-min intervals is indicated by a solid line; during 3-min intervals by a dashed line. Intervals during which the keylight was red are marked by closed circles, those with a green light by open circles.

Overall Positive Contrast

Birds 77, 96, 106, and 108 were initially trained on the *mult* FI 1-min FI 1-min schedule before exposure to the *mult* FI 1-min FI 3-min schedule. By the end of Condition 1, all birds were performing in a similar way during both schedule components. For three birds, response rate stabilized at between 40 and 50 responses per minute; for Bird 106, response rate was much lower. Three birds tended to respond at a slightly higher rate on the green key. Except for Bird 106, pause durations were the same in both components; for Birds 77 and 96, the average pause was about 17 sec and for Birds 106 and 108, about 25 sec.

When the interreinforcement interval during one component of the schedule was changed from 1 to 3 min, all, except Bird 108, showed an initial increase in response rate during the FI 3-min component. As postreinforcement pause gradually increased across sessions, response rate decreased for all birds, so that by the end of the condition it had returned to the baseline level.

Interaction effects were observed in the unchanged FI 1-min component for all except Bird 108. These were most consistent in the postreinforcement pause measure; the birds showed a decrease in pause of at least 5 sec, which persisted for several sessions. Pause was reduced during all intervals of the component, as is more clearly shown in the center column of Figure 3, which presents within-session data and which is described more fully in the discussion of local contrast effects. This decrease in pause is a positive overall contrast effect—
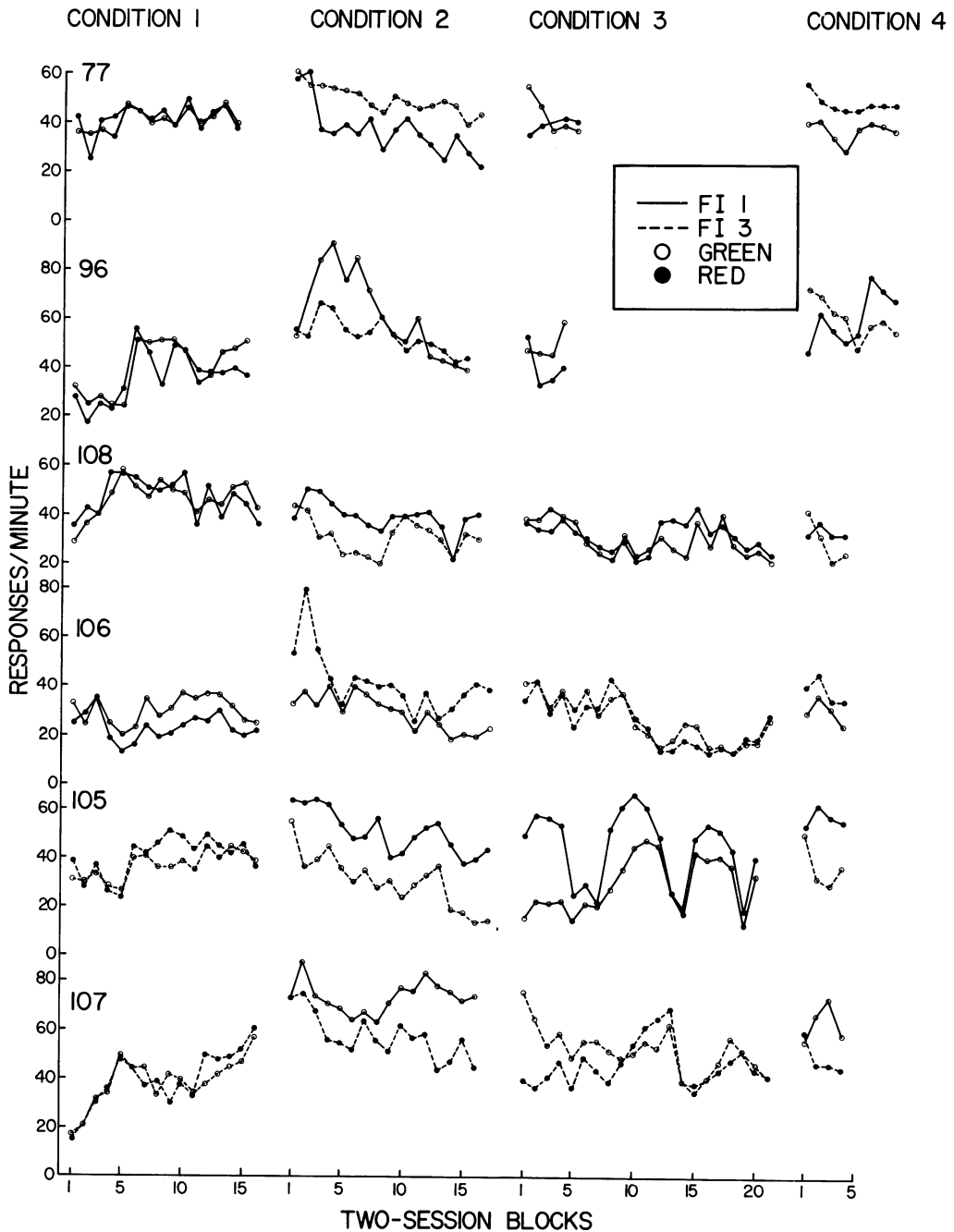
Fig. 1. Average response rate over blocks of two sessions for individual birds for the four experimental conditions. Performance during 1-min intervals is indicated by a solid line; during 3-min intervals, by a dashed line. Data from intervals during which the keylight was red are shown in closed circles, those with a green light in open circles.

pause in the unchanged component changed in the opposite direction to that in the changed component and it became shorter in comparison with pauses on the baseline FI 1-

min schedule. This effect was transient, however, and by the end of Condition 2 the average pause during this component had returned almost to baseline.
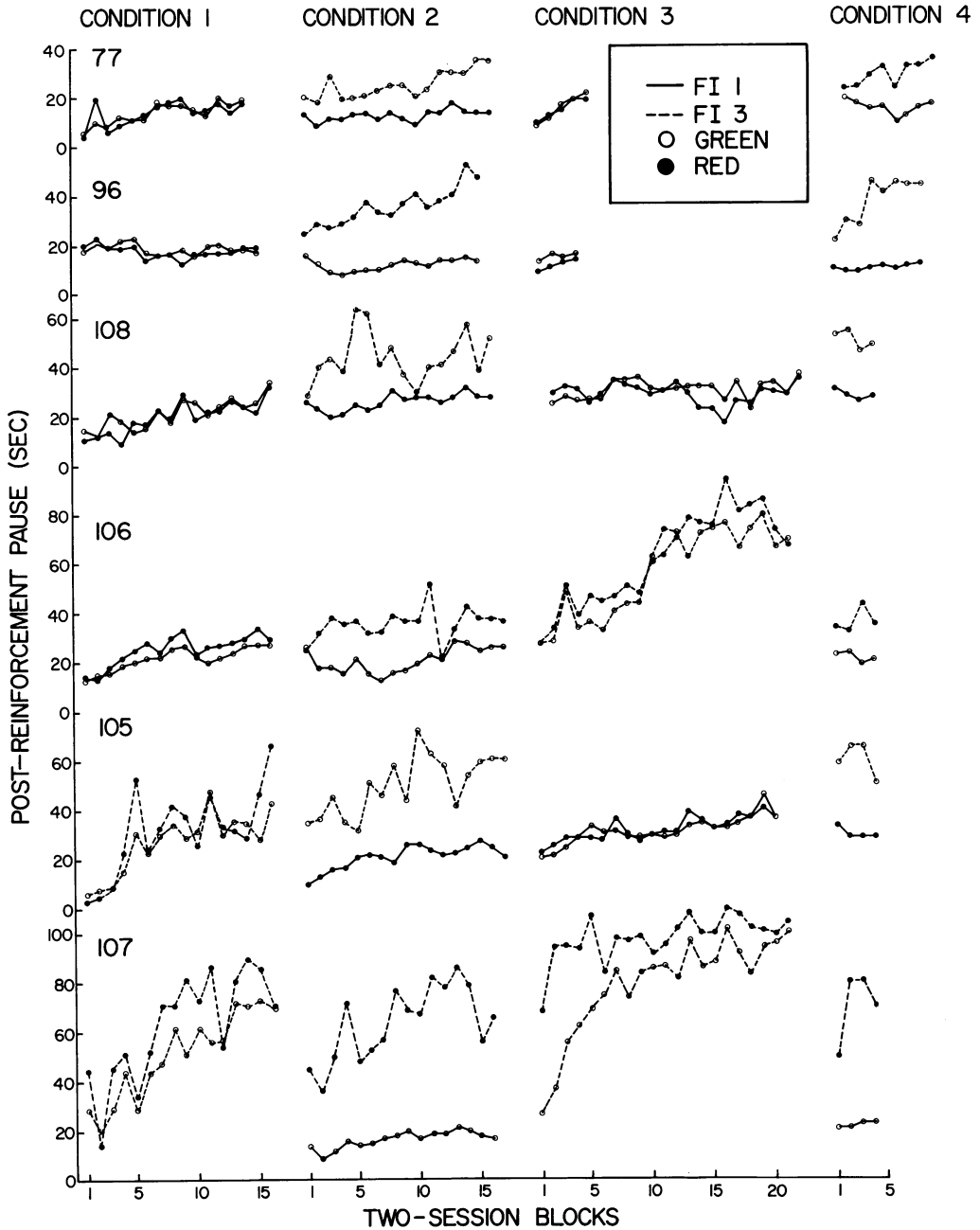
Fig. 2. Average postreinforcement pause over blocks of two sessions for individual subjects for the four experimental conditions. See Figure 1 for other details.

Birds 77 and 96 both showed a substantial elevation in response rate during FI 1-min intervals for a few sessions early in Condition 2, after which the rate declined. Birds 106 and 108 did not show the initial increase, but did show a similar slow decline in rate throughout the condition. The initial increase in response rate shown by Birds 77 and 96 could, perhaps, be labelled a transient positive-contrast effect. Although this change in performance was in the same direction as that observed in the FI 3-min component, it did involve an increase in responding over the baseline rate.

Overall Negative Contrast

Birds 105 and 107 were initially trained on the *mult* FI 3-min FI 3-min schedule before being exposed to *mult* FI 1-min FI 3-min. During Condition 1, pause stabilized at about 40 sec for Bird 105 and between 70 and 80 sec for Bird 107, while response rates were around 40 and 55 responses per minute, respectively. The change from 3-min to 1-min intervals during one component of the schedule in Condition 2 resulted in an immediate and substantial decrease in postreinforcement pause to about 10 sec during these intervals. By the end of the condition, pauses during all but the first interval of each cycle had increased to about 20 sec. Response rate increased considerably during this component, remaining at high levels for Bird 107 and gradually falling off for Bird 105.

Changes in performance were also observed in the 3-min intervals of the unchanged component. Initially, Bird 107 showed a large reduction in postreinforcement pause, which then gradually increased across sessions. Although Bird 105 did not show an initial reduction, its pauses also increased throughout the condition. Both birds showed an early increase in response rate, which then slowly declined, until at the end of the condition it was lower than the rate in the 3-min intervals of the baseline condition. The interactions observed during the early sessions of Condition 2, especially for Bird 107 could be labelled induction effects, since the changes in performance were in the same direction during both components. The low rate observed at the end of the condition could, perhaps, qualify as a negative contrast effect, since rate had declined below baseline level.

In Condition 3, four of the six birds were returned to their original schedule. As Figures 1 and 2 show, baseline performance was generally recovered. There are two exceptions to this finding. Bird 107 showed somewhat longer postreinforcement pauses during Condition 3 than during Condition 1, although response rate returned to baseline. Bird 108 showed a slow but steady decline in response rate across Condition 3. However, rate for Bird 108 was declining at the end of Condition 1 and this bird did not really show any interaction effects during Condition 2, so recovery of baseline is irrelevant.

Re-instating the two-valued schedule during Condition 4 resulted in changes in performance similar to those observed in Condition 2. The greatest difference in performance between these two conditions was shown by Birds 77 and 96, for which the stimulus conditions were the reverse of those experienced during Condition 2.

Local Contrast Effects

When performance had stabilized in Condition 2, all birds were showing substantial local contrast effects during the initial interval of schedule components. Within-session data for the postreinforcement pause measure, the most stable of the two measures of overall performance, are shown in Figure 3. The average cycles presented for each bird are means across three cycles per session for the last five sessions of Condition 1 and the first and last five sessions of Condition 2. Data from the first cycle of each session are omitted for Birds 77 and 96 (which received four rather than three cycles each day). Data from the first interval of each session are omitted for the other four birds.

Local contrast is usually assessed with respect to ongoing performance during the rest of the component. Few differences in performance across the intervals of components were observed in Condition 1 when both components had equivalent rates of reinforcement; most birds showed similar pauses during all intervals. Exceptions to this were the very short pause shown by Bird 77 during the initial interval in the red stimulus and the elevated pauses shown by Bird 105 during the first interval of both components. Postreinforcement-pause behavior did not change dramatically in terms of local effects during the first five sessions of Condition 2 (center panel, Figure 3), although the initial short pause shown by Bird 77 during the red stimulus disappeared. The large overall decrease in pause, referred to earlier, for the birds that had previously experienced the *mult* FI 1-min FI 1-min schedule is quite apparent, however.

By the end of Condition 2, large local contrast effects, both positive and negative, were very obvious. Irrespective of their previous experience, all birds showed very similar performance across the intervals of a cycle. The negative contrast effects were the largest and were shown by all birds. Postreinforcement
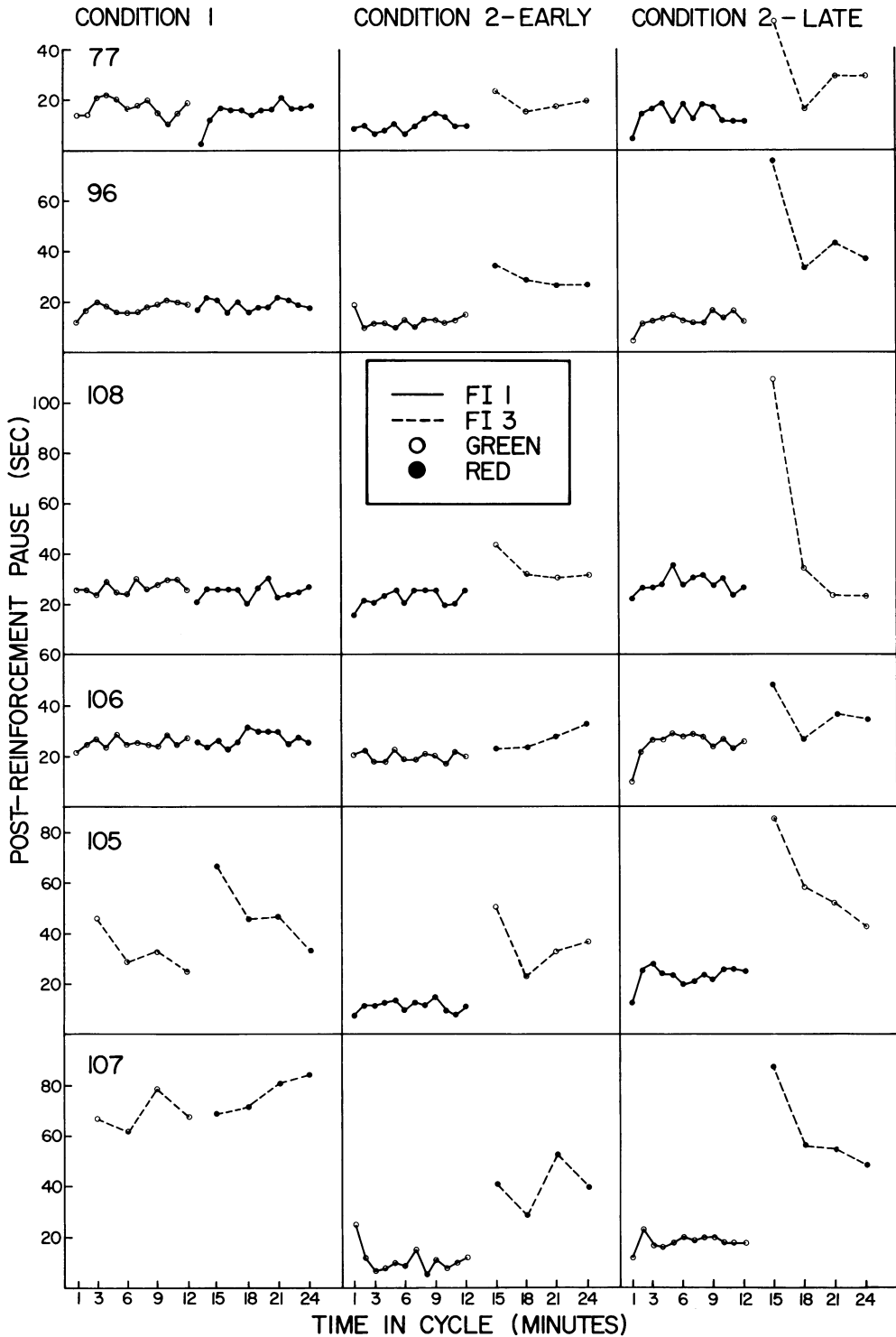
Fig. 3. Average cycles of postreinforcement pause for individual birds for the last five sessions of Condition 1 (left panel) and the first (center panel) and the last (right panel) five sessions of Condition 2. See text for other details.

pauses during the first of the four 3-min intervals were consistently longer than pauses in the other three intervals. The pauses during this interval shown by the two birds that had previously been studied on the schedule with 3-min intervals were also longer than pauses during this initial interval on the baseline schedule, so the local contrast effect holds when assessed against performance in the preceding condition as well.

Five of the six birds showed a positive local contrast effect during the first of the 12, 1-min intervals. Only Bird 108 did not show this effect, which involved a reduced pause during this interval. The positive contrast effect was not as large as the negative effect, but it was consistent. For the birds previously exposed to 1-min intervals, an assessment of local contrast in terms of performance during the initial interval of the same component in Condition 1 clearly indicates contrast for Birds 96 and 106. The performance of Bird 77 was similar during both conditions.

Comparable local contrast effects, not presented here, were observed in the response-rate measure. All six birds showed local negative contrast during the first of the four 3-min intervals, although the decrease in responding during this interval was very slight for Bird 105. Four birds showed an increase in response rate during the first 1-min interval of a cycle. Birds 108 and 105 showed no local positive contrast in response rate. The local contrast effects in rate, especially positive contrast, tended to develop earlier than the pause effects. Elevations in response rate for the birds that did show an effect were observed during the first two or three intervals of a component within the first five sessions of the condition.

As well as taking time to develop, local contrast effects took time to dissipate. On return to the baseline schedule in Condition 3, Birds 77 and 96 were still showing local contrast effects after eight sessions when the condition was terminated. With extended training, these local effects disappeared in the other birds, so it is likely that this would have occurred for these two birds as well.

DISCUSSION

The present results replicate Staddon's (1969) finding of local positive and negative contrast on a *mult* FI 1-min FI 3-min schedule

of reinforcement: large negative local contrast effects developed during the first 3-min interval and small, but reliable, positive local contrast effects during the initial 1-min interval, of a cycle. Similar behavior patterns were observed in birds previously exposed to schedules consisting of either 1-min or 3-min intervals. Boneau and Axelrod (1962) reported a transient increase in response rate in VI schedule components that followed a period of extinction, and Catania and Gill (1964) found a comparable change in performance in the first of six 1-min intervals, presented following periods of extinction. Others also have reported local negative (Nevin and Shettleworth, 1966) and positive (Arnett, 1973; Nevin and Shettleworth, 1966) contrast effects for response rate during the initial seconds of multiple VI schedule components. Arnett (1973) also reported an elevation in responding (positive local contrast) following food presentation on a *mult* VI 3-min EXT schedule. Unlike the effects reported by Nevin and Shettleworth, the local contrast effects found here were still strong after more than 30 sessions of training. The local contrast effects reported by Arnett and by Staddon were also sustained.

Overall contrast effects were observed in the Nevin and Shettleworth (1966) and Arnett (1973) studies, but both reports pointed out that the overall and local effects were at least partially independent. For example, one of Arnett's birds displayed a considerable local effect, but no overall behavioral contrast. The data from this present study also indicate that there is no obvious direct relationship between the two types of contrast effect. Local effects developed slowly, were reliable and sustained. Overall positive effects, when they were observed, tended to be transient and inconsistent; overall negative contrast, which was shown toward the end of the condition, was probably due to the large local negative contrast effects that developed.

The experiment reported here is the first study of overall behavioral contrast to employ fixed-interval schedules in both components of the multiple schedule. Of the studies using VI schedules, Terrace's (1968) study is most comparable to the present experiment. He exposed pigeons to a *mult* VI 1-min VI 5-min schedule, following training on either *mult* VI 1-min VI 1-min or *mult* VI 5-min VI 5-min. All birds trained on the VI 1-min schedule showed sub-

stantial, but transient, overall positive contrast effects. However, only one of the three birds in the VI 5-min group showed negative contrast; another bird showed induction.

The present results are similar to those reported by Terrace (1968). Two of four birds trained on the FI 1-min schedule showed a transient positive contrast effect, while both birds with previous experience on the FI 3-min schedule showed an induction effect. Schwartz (1975), using a *mult* VI 3-min VI 72-sec schedule, observed negative contrast effects in all of four birds within the first few sessions of exposure to this schedule. However, two of the four did show a brief induction effect in the first one or two sessions. An induction effect for a brief period following a change to a two-valued schedule in which, overall, conditions have improved is not surprising. Before the conditions of reinforcement associated with the two stimuli are differentiated, one might expect a general increment in response rate as the result of the overall increase in the rate of reinforcement. Moreover, this effect should persist longer on FI, as compared to VI, schedules since the discrimination between components occurs more slowly in the former case.

In sum, it seems that positive overall contrast, although frequently transient, is generally a more reliable phenomenon than negative overall contrast in multiple schedules involving either FI or VI schedule components.

As yet, theorists have not provided an entirely satisfactory explanation for behavioral contrast. Mackintosh (1974) and Schwartz and Gamzu (1977) presented detailed surveys of the contrast literature and the various explanations that have been advanced since Reynolds (1961*a*) first drew attention to the phenomenon. The recent finding that food-related responses (pecking in pigeons) are induced in the presence of stimuli that predict the presentation of food (Brown and Jenkins, 1968; Staddon and Simmelhag, 1971) led Gamzu and Schwartz (1973) to suggest that a positive behavioral contrast is the result of these classically conditioned (autophased) key pecks combining with the ongoing operant pecking. While this "additivity theory" of contrast accounts quite readily for positive effects, there is some question as to whether negative contrast can be accounted for within a similar

framework. Schwartz (1975; Schwartz and Gamzu, 1977) suggests that a different mechanism may be involved in negative contrast. Rachlin (1973), on the other hand, feels that positive and negative contrast are symmetrical phenomena—stimuli associated with high rates of reinforcement induce food-related responses, and stimuli signalling low reinforcement rates inhibit them. He also suggests that these effects are most likely to be observed just following a stimulus transition

The local contrast effects reported here fit Rachlin's (1973) interpretation quite readily. In fact, the use of fixed-interval schedules, which generate very stereotyped pause-and-run behavior patterns, permits a very clear picture of excitatory and inhibitory effects following a stimulus change. Pecking begins sooner during the initial intervals of the FI 1-min components and starts much later during the first of the four 3-min intervals on the two-valued schedule. These local effects are conditioned (learned), appearing only after several sessions of experience with the *mult* FI 1-min FI 3-min schedule. Local effects tend to develop more quickly on schedules with VI components. This is to be expected, however, since fixed-interval schedules are more complex, requiring the bird to come under temporal, as well as situational, stimulus control (*cf.* Staddon, 1972). Situational control develops first, setting the occasion for the animal to make a temporal discrimination. On VI schedules, no temporal discrimination is required.

The transient overall positive effect at the outset of Condition 2, particularly the consistent decrease in postreinforcement pause during 1-min intervals, is difficult to interpret in terms of current theories of contrast. It is possible that autophased pecks are occurring early in these intervals, reducing the pause duration. However, we are then left with the problem of accounting for the disappearance of this effect in all but the initial intervals of a cycle. Rachlin's (1973) theory, indeed, would predict a result opposite to the one observed here; an initial reduction in pause during the first interval of a cycle which, as the result of conditioning, gradually occurs in other intervals as well.

The Condition 2 performance of the birds initially trained on the *mult* FI 1-min FI 1-min schedule reveals another interesting feature. On first exposure to the 3-min intervals

of the *mult* FI 1-min FI 3-min schedule, these birds increased, rather than decreased, their rate of responding. This, of course, was because they were still making postreinforcement pauses more appropriate to 1-min than to 3-min intervals, and then responding steadily until reinforcement occurred. Such an increase in response rate, as the result of reinforcement omission, has been explained by some (Amsel, 1958; Terrace, 1966) as an emotional reaction or frustration effect, an unconditioned response to the loss of reinforcement. It has also been treated as a behavioral contrast effect, since theorists who take this position also suggest that overall positive contrast is due to increased emotionality resulting from the reduction in reinforcement rate in the other component. Staddon (1967; Staddon and Innis, 1969) has shown, however, that performance changes associated with reinforcement omission can be accounted for simply in terms of the absence of the inhibitory after-effects of reinforcement. In the present study, once the differential temporal properties of the two schedule components started to be discriminated, pauses in the longer intervals increased to a more appropriate duration and response rate returned to baseline.

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