A RE-EXAMINATION OF LOCAL CONTRAST IN MULTIPLE SCHEDULES¹

STEVEN L. BUCK, BARRY ROTHSTEIN, AND BEN A. WILLIAMS

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Pigeons were presented with multiple schedules of alternating 90-sec components. When components in which grain was never presented alternated with components in which grain was presented on a variable-interval schedule, the average rate of responding in the variable-interval components increased, showing overall positive behavioral contrast. Unlike previous reports, this study found that the response rates for all birds increased toward the end of the variable-interval components as training proceeded. This increase in local response rate disappeared when the multiple schedule was composed solely of variable-interval components and reappeared when the variable-interval components were again alternated with extinction. This finding cannot be predicted or explained by recent theories of behavioral contrast based on autoshaping, and thus questions their sufficiency. We suggest that this local response-rate increase results from the predictable change from high to low density of reinforcement at the end of the fixed-duration component. Thus, the present effect apparently illustrates a different type of interaction between components of a multiple schedule than that described by previous theories of contrast. In a given procedure, either or both types of interaction may occur; neither provides a complete account of behavioral contrast.

Key words: behavioral contrast, multiple schedules, local response-rate analysis, sequential effects, pigeons

When two variable-interval (VI) schedules of grain presentation, which are independent and associated with different stimulus conditions alternate in a multiple schedule, a decrease in the density of reinforcement in one component will usually increase a pigeon's overall rate of key pecking during the unchanged component. This increase in response rate is termed positive behavioral contrast (Reynolds, 1961). Such an increase averaged over the entire component is termed an overall positive contrast effect; an increase in response rate in one portion of the component is termed a local positive contrast effect. Several investigators have shown that overall changes in response rate may be accompanied by particular patterns of local contrast within the component (*cf.* Arnett, 1973; Nevin and Shettleworth,

1966; Rachlin, 1973). All of these investigators agree that overall positive contrast is usually associated with a greater increase in response rate at the beginning of the component than later in the component. In addition, Arnett (1973) showed an increase in local response rate following delivery of grain, whenever it occurred in the component.

Despite the apparent unanimity of the above results, other patterns of local contrast may occur when other procedures are employed. A different local contrast effect is suggested by experiments of Pliskoff (1961, 1963) and Wilton and Gay (1969), which demonstrated that the overall level of contrast in one component of a multiple schedule depends on the density of reinforcement in the following component. For example, Pliskoff (1963) showed that a pigeon's rate of key pecking was higher in the presence of a signal indicating that the next component would have a lower density of reinforcement than in the presence of another signal indicating that the next component would have a higher density of reinforcement. Similarly, Wilton and Gay (1969) used a four-component multiple schedule in which two components had the same reinforcement densities,

¹Preparation of the manuscript was supported by a NSF grant, number NSF GB30572x, to George S. Reynolds and by a NSF grant, number NSF GB42887, to Ben A. Williams. The authors wish to thank Mark Fridovich, John Hale, Jay Moore, and Tibor Safar for their helpful comments. Reprints may be obtained from Steven L. Buck, Department of Psychology, University of California, San Diego, P.O. Box 109, La Jolla, California 92037.

but differed in that one was followed by a decrease in reinforcement density, while the other was followed by an increase. Again, the component followed by the decreased reinforcement density produced a higher response rate than the component followed by increased reinforcement density.

While the aforementioned studies describe overall contrast effects, they suggest that an analogous local contrast effect may obtain. In Pliskoff (1963), for example, an exteroceptive stimulus indicating an impending reduction in reinforcement density occasioned elevated response rates. In the usual multiple schedule with fixed-duration components, the passage of time since the beginning of the component also indicates the approach of a change in reinforcement density. Thus, a decrease in reinforcement density at the end of a fixed-duration VI component should increase local response rate as the end of the component approaches. This would produce a local contrast in the same direction as that usually observed at the beginning of the component having the higher reinforcement density, but occurring at the end of the component.

The specification of the nature of local changes in response rate has become important because of recent theoretical accounts of contrast derived from the literature on autoshaping (*cf.* Gamzu and Schwartz, 1973; Rachlin, 1973). According to this view, contrast results from the excitation of particular responses, determined by the biology of the organism, simply by virtue of a signal of the transition from periods of low reinforcement density to periods of high reinforcement density. Thus, the rate increases seen in the typical positive contrast experiment are due to the addition of elicited pecks to those regularly maintained by the VI schedule. Although the accounts of Gamzu and Schwartz and of Rachlin differ in their degree of specification of the locus of elicited pecks within the component, both deal only with the transition from low to high reinforcement density at the beginning of the component. Neither theory is sufficient to explain local contrast, if it occurs, at the end of the component preceding a transition from high to low reinforcement density.

Previous studies of contrast have provided some evidence that rate does increase at the end of a component. In Procedure C of Nevin and Shettleworth (1966), a VI component (VI

10-min for two birds, VI 5-min for two other birds) alternated with an extinction (EXT) component having a zero rate of grain presentation. Two of the four birds exposed to this procedure showed some elevation of response rate at the end of the VI components, even though the procedure remained in effect for only four days. Bird 3, in fact, showed a stronger local contrast at the end of the VI component as training proceeded. More recently, Williams (1974) reported higher response rates in the second half of a VI component than in the first half, with the effect increasing with continued training. Like Nevin and Shettleworth's results, however, the effect did not occur for all subjects.

The present experiments were designed to investigate in detail local contrast effects at the end of a VI component of constant duration that was followed by an EXT component.

EXPERIMENT I

Subjects

Four White Carneaux pigeons were maintained at 75% of their free-feeding weights. The birds had served in a discrete-trials procedure but had never been exposed to the particular keylight or houselight stimuli employed here.

Apparatus

Two experimental chambers were used, chamber A for Birds B-22 and Y-21 and chamber B for Birds B-16 and B-5. Both chambers were lightproof, sound-insulated, metal chests. Ventilation and masking noise were provided by fans located outside each chamber. The interior dimensions of the subject's compartment were 26 cm by 27.5 cm by 36 cm for chamber A, and 25 cm by 28 cm by 29 cm for chamber B. A translucent, plastic response key was centered behind a 1.9-cm hole in a metal panel separating the subject's compartment from the stimulus and food-delivery devices in each chamber, 23 cm above the floor of chamber A and 21 cm above the floor of chamber B. A minimum force 0.10 N and 0.15 N was necessary to operate the response keys in chambers A and B, respectively. In each chamber, centered about 15 cm below the response key, was a 3.5-cm by 5.5-cm opening in the front panel through which a hopper filled with mixed grain could be made available. Both feeder

openings could be illuminated with white light by 7-W, 110-V ac lamps. The interior of each chamber could be illuminated with a blue 7-W, 110-V ac lamp located on the wall opposite the panel on which the key and feeder were located. The response keys could be trans-illuminated with a variety of shapes and colors by IEE model 10347-44 in-line projectors.

Timing, control, and recording were arranged by standard electromechanical switching equipment located in a separate room.

Procedure

After adapting to the experimental chamber and eating for several seconds from the raised, illuminated food hopper, each bird was exposed to a *mult* VI 30-sec VI 30-sec schedule, which was gradually increased to a *mult* VI 2-min VI 2-min over the next four sessions. This baseline training continued for approximately 50 sessions (48 for Birds B-5, B-16; 53 for Birds B-22 and Y-21). The two VI components making up the baseline training condition were associated with different keylight stimuli (inverted *versus* upright triangles) and with the presence or absence of the blue houselight. Components were strictly alternated and were 90 sec in duration. The end of one component was simultaneous with the beginning of the next. At the conclusion of the baseline training, the schedule was changed to a four-component multiple schedule (the VI EXT condition) consisting of VI 2-min, EXT, VI 2-min, and EXT in strict alternation. The two VI components maintained the same stimulus conditions as during baseline. The two EXT components had identical stimulus conditions, consisting of a red light projected on the response key with the houselight on for Birds B-5 and B-16, and with the houselight off for Birds B-22 and Y-21. This use of the houselight was included to investigate the role of shared features between the VI and EXT components in determining the degree of contrast. The manipulation had inconsistent effects, however, and is not discussed further.

Training on the VI EXT condition continued for 20 sessions. The baseline schedule was then restored for 15 sessions, after which the VI EXT condition was restored for 20 sessions. The stimuli signalling the various components were unchanged throughout training, except that the state of the houselight (on or off) during EXT components was reversed between

manipulation 1 and 2 for each subject. Table 1 shows the stimulus conditions for each subject during each phase of training. Sessions were terminated after 50 repetitions of the two-component multiple schedule during baseline, and after 25 repetitions of the four-component multiple schedule during the VI EXT conditions.

The schedules of reinforcement consisted of 18 intervals derived from the progressions of Fleshler and Hoffman (1962). A single tape served for both VI components in each multiple schedule. A grain presentation that began at the end of a component could continue into the beginning of the other component, but grain presentations arranged but not collected at the end of a component were cancelled.

RESULTS AND DISCUSSION

As can be seen in Table 2, all four pigeons showed overall positive contrast in both manipulations, although the amount of contrast varied considerably across components, birds, and manipulations.

Figure 1 shows the local response rates during the VI 2-min components for the last five sessions of both baseline conditions and both manipulations. Patterns of responding varied slightly across birds, but during the manipulation all birds showed an increase in response rate within the VI component as the EXT component approached. Comparison of contrast manipulations to their respective baselines shows that the slopes of the response-rate curves increased during the contrast manipulations. The differential rates within a component typically first appeared during the first five sessions of the *mult* VI 2-min EXT VI 2-min EXT schedule, although sometimes it appeared as late as Sessions 16 to 20. In all cases, the effect increased with further training, and disappeared immediately when the birds were returned to baseline.

Table 3 shows the ratios of the number of responses that occurred in the second half of each VI component to the number of responses that occurred in the first half of that component, for each of the last five sessions of baseline 2 and manipulation 2. The larger the ratio, the greater is the local contrast effect at the end of that component for a given session. Comparison of sets of ratios for corresponding baseline and manipulation sessions gives a measure of session-to-session variability and

Table 1

Keylight stimuli and houselight state associated with each component of the multiple schedules in Experiment 1.

Component				Component			
VI 2-min	EXT	VI 2-min	EXT	VI 2-min	EXT	VI 2-min	EXT
BIRD B-22				BIRD B-5			
ΔHL	—	▽	—	Baseline 1	ΔHL	—	▽
ΔHL	Red	▽	Red	Manipulation 1	ΔHL	Red + HL	▽
ΔHL	—	▽	—	Baseline 2	ΔHL	—	▽
ΔHL	Red + HL	▽	Red + HL	Manipulation 2	ΔHL	Red	▽
BIRD Y-21				BIRD B-16			
Δ	—	▽HL	—	Baseline 1	Δ	—	▽HL
Δ	Red	▽HL	Red	Manipulation 1	Δ	Red + HL	▽HL
Δ	—	▽HL	—	Baseline 2	Δ	—	▽HL
Δ	Red + HL	▽HL	Red + HL	Manipulation 2	Δ	Red	▽HL

shows little overlap between the ratios for baseline and manipulation conditions for a given VI component.

As can be seen from Figure 1, all birds tended to respond faster during the VI 2-min component for which the houselight was off (the no-HL component) than during the VI 2-min component for which the houselight was on (the HL component). This was true both for baseline and manipulation conditions. In general, local contrast tended to appear sooner and to be greater in magnitude for the no-HL component.

Three of the four birds tended to pause briefly before beginning to key peck after the transition from EXT to VI 2-min components. This is rather surprising, since Arnett (1973), Nevin and Shettleworth (1966), and Rachlin

(1973) found increases in local response rate at the beginning of the higher density component. The reasons for such pauses in the present study are unknown, but may be related to the bird's previous experience with discrete-trial experiments, or to procedural differences between this and the three aforementioned studies (see General Discussion). The pause, if it appeared, invariably began during the first five sessions. In some cases, it became more pronounced with further training, but in other cases it did not, and in one case (B-5, manipulation 2), the pause disappeared with training. The relationship between local contrast at the end of the VI 2-min component and the pause at the beginning of the component is a matter for further investigation. It does seem, however, that the present local contrast effect is

Table 2

Mean response rates (R/Min) during VI and EXT components of multiple schedules in baseline and manipulation condition in Experiment 1.

Bird	Component	Base 1	Manipulation 1		Base 2	Manipulation 2	
		Last 5 Sessions	1-5	16-20	Last 5 Sessions	1-5	16-20
B-22	VI 2-min HL	55.9	59.3	56.9	52.0	60.9	63.0
	VI 2-min no HL	58.2	72.3	62.8	64.0	70.7	75.5
	EXT	—	0.6	0.3	—	0.3	0.2
B-5	VI 2-min HL	35.3	53.5	61.4	40.3	49.1	56.9
	VI 2-min no HL	42.1	59.5	61.5	51.3	54.2	74.8
	EXT	—	9.3	3.4	—	0.3	0.2
Y-21	VI 2-min HL	102.4	119.2	128.9	110.0	121.6	114.5
	VI 2-min no HL	92.8	110.7	117.0	102.7	126.5	103.5
	EXT	—	29.9	2.6	—	1.1	2.0
B-16	VI 2-min HL	34.3	64.7	44.2	42.7	70.5	61.3
	VI 2-min no HL	32.6	68.0	40.6	41.9	55.4	60.8
	EXT	—	3.8	0.2	—	0.2	0.2

Fig. 1. Response rates in successive tenths of the VI components during the last five sessions of the *mult* VI VI baselines and the *mult* VI EXT VI EXT manipulations. Components in which the houselight was illuminated are shown by filled triangles during baseline and by open triangles during the contrast manipulation. Components in which the houselight was not illuminated are shown by filled circles during baseline and by open circles during the contrast manipulation.

Table 3

Ratios of responses in first half of each VI component to responses in second half of the component for each of the last five sessions of the second baseline and manipulation in Experiments 1 and 2.

		B-22		B-5		Y-21		B-16	
Sess		Comp 1	Comp 2	Comp 1	Comp 2	Comp 1	Comp 2	Comp 1	Comp 2
EXPERIMENT 1									
Baseline	1	1.033	0.956	0.933	1.043	1.017	1.015	0.956	0.981
	2	1.076	1.039	0.997	1.014	0.965	0.997	0.918	1.079
	3	1.036	1.049	0.966	0.958	1.012	1.048	0.919	0.976
	4	1.021	0.961	0.979	0.974	0.970	0.997	0.952	1.116
	5	1.096	0.995	1.060	0.955	0.981	1.025	1.003	1.028
Manipulation	1	1.340	1.285	1.164	1.236	1.144	1.111	1.354	1.092
	2	1.285	1.185	1.175	1.293	1.214	1.156	1.395	1.168
	3	1.019	1.446	1.210	1.293	1.162	1.140	1.351	1.366
	4	1.206	1.268	1.173	1.378	1.156	1.113	1.261	1.503
	5	1.228	1.215	1.092	1.284	1.127	1.055	1.174	1.432
EXPERIMENT 2									
		G-5		G-6		G-7		G-8	
Baseline	1	1.050		1.122		1.261		1.009	
	2	1.033		1.060		1.044		0.975	
	3	0.965		1.015		1.050		0.970	
	4	1.005		1.019		1.018		0.994	
	5	1.092		1.104		1.026		1.054	
Manipulation	1	1.029		1.265		1.092		1.071	
	2	1.031		1.262		1.112		1.101	
	3	1.061		1.187		1.094		1.065	
	4	1.044		1.496		1.153		1.125	
	5	1.039		1.213		1.073		1.014	

not dependent on the presence of the initial pause. If the initial pauses are excluded by ignoring the first two or three bins of each graph in Figure 1, rate increases still occurred during the remainder of the component's duration.

EXPERIMENT 2

Interpretation of the results of Experiment 1 is confounded because the birds used were not naive, and because no data were collected that demonstrate that obtained reinforcement density was constant within the VI 2-min components. While neither of these factors seems a likely explanation for the obtained effects, the disparity of the results with previous findings raises the question of how the present experiment differed. For that reason, Experiment 2 was conducted with naive subjects and with a record of obtained reinforcement density within the components. In addition, the procedure was simplified by eliminating the differential illumination of the houselight, and by reducing the components of the multiple schedule from four to two.

METHOD

Subjects

Four experimentally naive White Carneaux pigeons (G-5, G-6, G-7, and G-8) were maintained at 80% of their free-feeding weights.

Apparatus

The experimental chambers from Experiment 1 were used. Sessions for Birds G-5 and G-7 were conducted in chamber A; those for Birds G-6 and G-8 were conducted in chamber B. Timing of the VI 2-min schedule of grain presentation was controlled by a tape having a 20-interval Fleshler and Hoffman (1962) progression.

Procedure

After adapting to the chamber, each bird was trained to eat from the feeder by raising the food tray without regard to the pigeon's behavior and lowering it after the bird had eaten for a few seconds. When each bird ate from the tray within a few seconds of its presentation, the birds were trained to peck the

response key by presenting the food tray: first for successively closer approximations to a key peck, and then for the first 10 pecks that followed. Each pigeon was then placed on an ascending series of VI schedules of grain presentation in the presence of an upright white triangle projected through the otherwise dark response key. The houselight was never illuminated in any phase of this procedure. After the first four or five sessions, the schedule remained a simple VI 2-min schedule of grain presentation for the remainder of the 26 sessions of baseline training. Each baseline session lasted 90 min, during which data were recorded in 60 successive 90-sec blocks to facilitate comparison with components of the subsequent multiple schedule. At the end of each 90-sec block, a stepper reset and caused a 0.2-sec darkening of the response key. Each bird was then exposed to 30 sessions of the *mult* VI 2-min EXT contrast manipulation. Each component of the multiple schedule lasted 90 sec, occurred 30 times during a session, and alternated with the other component. The EXT component was accompanied by a homogeneously red keylight. After manipulation 1, the birds were re-exposed to the baseline schedule for 15 sessions and to the manipulation condition (manipulation 2) for 20 sessions.

During feeder operation, the response key remained lighted and component transitions could occur. Unlike Experiment 1, any grain presentations arranged by the tape timer but not collected at the end of a VI component were saved until the next occurrence of the VI component. Data recorded included all that of Experiment 1, plus the obtained frequency of

reinforcement in each successive tenth of the VI components of each session.

RESULTS AND DISCUSSION

Table 4 shows the average response rates during baselines and manipulations. All four birds showed an overall contrast effect in manipulation 1. During manipulation 2, however, the degree of contrast was reduced, at least partly because the rate of responding during the first baseline training was not recovered during the second baseline for several subjects.

The local rate effect found in Experiment 1, an increase in response rate within the VI component, was apparent here as well. Figure 2 shows the local rate distribution for the last five baseline sessions, the first five sessions of the *mult* VI EXT, and the last five sessions of *mult* VI EXT, for each contrast manipulation. In general, the response-rate elevation toward the end of the VI component increased with training, with the amount of increase varying across subjects. Accordingly, the local rate differences were greater at the end of the second manipulation than at the end of the first manipulation. The only subject not showing the local rate differences at the end of the first manipulation, G-8, did develop the increasing local rate during manipulation 2. Session-to-session variability for the last five sessions of the second baseline and manipulation is shown in Table 3.

That local rate differences took longer to develop in Experiment 2 is not surprising, considering differences in the baseline training. In Experiment 1, two differently signalled, 90-sec

Table 4

Mean response rates (R/Min) during VI and EXT components of multiple schedules in baseline and manipulation conditions in Experiment 2.

Bird	Component	Base 1	Manipulation 1		Base 2	Manipulation	
		Last 5 Sessions	1-5	26-30	Last 5 Sessions	1-5	26-30
G-5	VI 2-min	66.4	96.9	96.2	110.2	142.6	162.6
	EXT	—	9.6	<1.0	—	<1.0	<1.0
G-6	VI 2-min	85.7	94.4	97.0	69.2	74.2	86.7
	EXT	—	18.5	<1.0	—	<1.0	<1.0
G-7	VI 2-min	55.5	62.0	72.7	76.1	73.5	79.2
	EXT	—	11.2	<1.0	—	<1.0	<1.0
G-8	VI 2-min	23.7	29.4	52.2	51.6	61.2	59.6
	EXT	—	2.8	<1.0	—	<1.0	<1.0

Fig. 2. Response rates in successive tenths of the VI components during VI baselines and *mult* VI EXT manipulations for both replications of Experiment 2. Filled circles represent the last five sessions of baseline, open circles the last five sessions of the contrast manipulations, and the unconnected Xs the first five sessions of the contrast manipulation.

components alternated in a multiple-schedule baseline. In Experiment 2, a single VI schedule was interrupted at 90-sec intervals only by a momentary darkening of the response key. Discrimination of the 90-sec interval would be expected to proceed more slowly under the latter circumstances. This, in turn, should retard the appearance of the local rate differences, if the local rate effects are dependent on the bird's discrimination of an impending change in reinforcement density, as has been suggested.

Of particular interest is whether the local contrast effect previously reported, an elevated rate at the beginning of the VI component, was found here. One subject, G-6, never showed the effect, but the remaining three did show an elevated initial rate at least sometime during training. Unexpectedly, the effect did not simply appear early in training and then decline. Instead, it varied across sessions somewhat erratically, with no obvious determinant of when the effect would or would not occur. Figure 3 shows such a pattern for one subject, G-8. Whereas the effect was only partially evident for the first 10 sessions, it became quite pronounced during the next 15 sessions, and then finally declined. After intervening baseline training, the effect never reappeared. In fact, no subject showed this usual local contrast effect (at the beginning of the VI component) at any time during the second manipulation.

Finally, the obtained reinforcement frequencies for successive tenths of the VI components were recorded in order that adventitious differences in local reinforcement rates could be ruled out as an explanation for the different response rates. Table 5 shows that while the distributions of food presentations were not constant, they differed from bird to bird, and were not correlated with the distribution of key pecks.

GENERAL DISCUSSION

Arnett (1973), Nevin and Shettleworth (1966), and Rachlin (1973), demonstrated a positive local contrast effect in multiple schedules at the beginning of the component having a higher density of reinforcement. The present study showed a different local contrast effect, namely, an elevation of local response rate as the end of the component having a higher density of reinforcement approaches. Consideration of analogous effects described by Pliskoff (1961, 1963) and Wilton and Gay (1969) (see Introduction) suggests that the present positive local contrast resulted from the predictable change from high to low reinforcement density at the end of the fixed-duration component. If this is correct, then other procedures in which component transition involves a reduction in reinforcement density at a predictable time should show positive local contrast at the end of that component (e.g., Procedure C from Nevin and Shettleworth, 1966). On the other

Table 5

Distribution of obtained food presentations within VI components of multiple schedules in Experiment 2.

Bin	Bird			
	G-5	G-6	G-7	G-8
1	61	77	45	69
2	73	84	60	50
3	76	68	65	72
4	85	79	77	72
5	82	75	74	73
6	83	75	67	69
7	72	73	60	63
8	71	81	66	66
9	67	78	60	63
10	78	62	57	62
Total S+	748	752	631	659
No. of Sessions	34	33	29	29

Fig. 3. Response rates for Bird G-8 in successive tenths of the VI components for five-session blocks during both replications of the contrast manipulation.

hand, procedures in which component duration is not constant for a sufficient number of sessions or is either extremely short or extremely long (e.g., Rachlin, 1973) or does not always lead to decreased reinforcement density (e.g., Procedure A from Nevin and Shettleworth, 1966) should not show the effect. The results of these studies appear to support the above predictions concerning local contrast.

This explanation is not sufficient, however, to explain why the present local contrast was not noted by Arnett (1973). In Arnett's study, component duration was always constant and the lower reinforcement density component reliably followed the unchanged component, conditions that are presumably necessary to produce local contrast at the end of the unchanged component. That these conditions were not sufficient to produce the effect suggests that other factors must interact. Several differences between Arnett (1973) and the present study merit consideration. First, the component durations used by Arnett were twice as long as those used for this study. It is possible that longer component durations suppress the effect by making component duration harder to discriminate, but this point has not been investigated. Second, an important procedural difference exists between the two studies. Arnett changed the schedule associated with one of the baseline components from VI to EXT to effect the contrast manipulation. The present procedure added a new stimulus to signal EXT and retained the VI schedule for both baseline components. How this procedural difference might facilitate the different local contrast effects is a matter of speculation. Third, in Arnett's study, large amounts of responding were maintained in the presence of the stimulus associated with EXT. In the present study, responding during EXT quickly dropped to a much lower level. Presumably, this was a function of the procedural differences discussed above.

The present results pose difficulties for two recent accounts of behavioral contrast. Gamzu and Schwartz (1973) suggested that positive contrast results from the addition of key pecks that are elicited by the signalled change from a low to a high density of reinforcement. Rachlin (1973) posed a special case of the Gamzu and Schwartz position, contending that the additional, elicited key pecks will be concentrated immediately after the transition from

low to high density of reinforcement. The present results show that sustained overall contrast may result even when no increase in local rates occurs at the beginning of the component. Indeed, most birds in Experiment 1 showed a pronounced drop in local rate at precisely the point Rachlin would predict an elevation. Rachlin also contended that a signal for decreased reinforcement density will have an inhibitory influence on key pecking. In the present procedure, a temporal signal of impending decrease in reinforcement density occasioned increased, rather than decreased, key pecking. Together with Arnett's (1973) demonstration of local contrast immediately after food presentation, the present results show that Rachlin's account of contrast is insufficient to explain the known local contrast phenomena.

The present results also suggest restrictions on the applicability of the more general hypothesis of Gamzu and Schwartz (1973). Although Gamzu and Schwartz made no prediction concerning the locus within a component of the elicited key pecks contributing to positive contrast, their theory does state that the additional key pecks defining contrast are elicited by a signal of increased reinforcement density. Their theory provides no obvious account of the addition of key pecks occasioned by a signal of impending decreased reinforcement density.

Neither of these theories provides a complete account of behavioral contrast. But perhaps this is not surprising when one considers the wide variety of procedures by which contrast has been produced. In addition to the usual method of reducing rate of reinforcement in one component, and the present procedure of adding a new component of lower reinforcement density, contrast has been found by reducing rate of responding in the absence of change in rate of reinforcement (Reynolds and Limpo, 1968), and by adding response-dependent shock to one component (Brethower and Reynolds, 1962). Other procedures have employed response-independent schedules of grain presentation (Gamzu and Schwartz, 1973). Finally, component durations have been varied from a few seconds (Shimp and Wheatley, 1971) to as long as 16 min (Rachlin, 1973).

In light of these varied procedures it is hardly surprising that different types of local contrast can be found. Indeed, it seems quite

possible that no single explanation of all the overall contrast phenomena can be offered. As Arnett (1973) suggested, the definition of overall contrast in multiple schedules is overly broad. What may be separate, independent interactions between components may all appear as overall behavioral contrast. Thus, different patterns of local contrast may indicate that entirely different types of interactions are occurring. Gamzu and Schwartz (1973) and Rachlin (1973) addressed one type of interaction in multiple schedules. The present investigation addressed another, perhaps entirely independent, interaction. Both interactions have similar effects on overall positive contrast, but have different effects on local positive contrast. What is needed is a local-rate analysis of the wide variety of contrast procedures to separate different multiple-schedule interactions.

REFERENCES

- Arnett, F. B. A local-rate-of-response and inter-response-time analysis of behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1973, **20**, 489-498.
- Brethower, D. M. and Reynolds, G. S. A facilitative effect of punishment on unpunished behavior. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 191-199.
- Fleshler, M. and Hoffman, H. A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1962, **64**, 529-530.
- Gamzu, E. and Schwartz, B. The maintenance of key pecking by stimulus-contingent and response-independent food presentation. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 65-72.
- Nevin, J. A. and Shettleworth, S. J. An analysis of contrast effects in multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 305-315.
- Pliskoff, S. Rate-change effects during a pre-schedule-change stimulus. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 383-386.
- Pliskoff, S. Rate-change effects with equal potential reinforcements during the "warning stimulus". *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 557-562.
- Rachlin, H. Contrast and matching. *Psychological Review*, 1973, **80**, 217-234.
- Reynolds, G. S. Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 57-71.
- Reynolds, G. S. and Limpo, A. J. On some causes of behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 543-547.
- Shimp, C. P. and Wheatley, K. L. Matching to relative reinforcement frequency in multiple schedules with a short component duration. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 205-210.
- Williams, B. A. The role of local interactions in behavioral contrast. *Bulletin of the Psychonomic Society*, 1974, **4**, 543-545.
- Wilton, R. N. and Gay, R. A. Behavioral contrast in one component of a multiple schedule as a function of the reinforcement conditions operating in the following schedule. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 239-246.

Received 29 January 1975.
(Final Acceptance 27 May 1975.)