CONTRAST AND AUTOSHAPING IN MULTIPLE SCHEDULES VARYING REINFORCER RATE AND DURATION

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Thirteen master pigeons were exposed to multiple schedules in which reinforcement frequency (Experiment I) or duration (Experiment II) was varied. In Phases 1 and 3 of Experiment I, the values of the first and second components' random-interval schedules were 33 and 99 seconds, respectively. In Phase 2, these values were 99 seconds for both components. In Experiment II, a random-interval 33-second schedule was associated with each component. During Phases 1 and 3, the first and second components had hopper durations of 7.5 and 2.5 seconds respectively. During Phase 2, both components' hopper durations were 2.5 seconds. In each experiment, positive contrast obtained for about half the master subjects. The rest showed a rate increase in both components (positive induction). Each master subject's key colors and reinforcers were synchronously presented on a response-independent basis to a yoked control. Richer component key-pecking occurred during each experiment's Phases 1 and 3 among half these subjects. However, none responded during the contrast condition (unchanged component of each experiment's Phase 2). From this it is inferred that autoshaping did not contribute to the contrast and induction findings among master birds. Little evidence of local contrast (highest rate at beginning of richer component) was found in any subject. These data show that (a) contrast can occur independently from autoshaping, (b) contrast assays during equal-valued components may produce induction, (c) local contrast in multiple schedules often does not occur, and (d) differential hopper durations can produce autoshaping and contrast.

Key words: positive contrast, autoshaping, multiple schedules, local contrast, positive induction, rate of reinforcement, duration of reinforcement, key peck, pigeons

Brown and Jenkins' (1968) work on the phenomenon of autoshaping suggests that the pigeon's key peck can be supported by Pavlovian as well as by operant contingencies. In their study, a keylight was illuminated for 8 sec before the response-independent presentation of a grain reinforcer. Separating successive keylight-food presentations was a variable intertrial interval (ITI), during which the key was dark. After six to 119 keylight-food pairings, pigeons began pecking the illuminated key, even though reinforcement was independent of behavior. The similarities between this autoshaping procedure and the traditional Pavlovian delay conditioning paradigm are apparent: in the autoshaping procedure and in conventional Pavlovian conditioning, a stimulus (in this case the keylight) that had no prior relation to a behavior (key pecking) comes to elicit that behavior after repeated pairings with a biologically significant event (access to grain). Thus, according to a Pavlovian account, autoshaped responding is a conditioned response, controlled by the relation between the keylight and the grain reinforcer (see Moore, 1973).

Gamzu and Williams (1973) underscored the relationship between autoshaping and Pavlovian conditioning by showing that keylight-food pairings are not sufficient to support autoshaping. Rather, it is dependent on the keylight being a differential predictor of reinforcement—in this case, signalling a higher frequency of reinforcement in the presence of the keylight than during the ITI. These results are analogous to the finding in the Pavlovian literature that there must be a correlation between conditioned and unconditioned stimuli to elicit conditioned responding (e.g., Rescorla, 1967).

Gamzu and Schwartz (1973) extended the generality of these findings to multiple (*mult*) schedules by altering Gamzu and Williams' procedures so that the key was illuminated with a second color, rather than darkened during the ITI. This change made the auto-shaping procedure akin to a multiple schedule providing response-independent reinforcement. They found that responding was maintained only when one component of the multiple schedule provided a higher reinforcement frequency than the other component.

In addition to showing that multiple schedules can support autoshaped responding, Gamzu and Schwartz' results suggest a possible relation between autoshaping and the multiple-schedule phenomenon of positive behavioral contrast (see Reynolds, 1961a). Schwartz and Gamzu (1977, p. 73) defined positive contrast as "an increase in responding in an unchanged component of a multiple with decreases in responding in the other component". Reynolds (1961a) found that positive contrast occurred in the unchanged component of a multiple schedule when the conditions of reinforcement are changed from *mult* variable-interval (VI) 3-min VI 3-min to *mult* VI 3-min Extinction (EXT). According to Gamzu and Schwartz, this positive contrast effect may be a consequence of the elicitation of autoshaped responding by the differential reinforcement frequencies found in *mult* VI EXT schedules. These autoshaped key pecks sum with the operant pecks normally emitted during the unchanged VI component to synthesize contrast. This interpretation, which Schwartz and Gamzu (1977) called the additivity theory of contrast, is quite different from other interpretations of contrast, which have emphasized factors such as reinforcement-frequency reduction (Reynolds, 1961 a,b,c,d,) response-rate reduction (Terrace, 1963 a,b; 1966; 1972), or, generally, a "worsening" of conditions (Bloomfield, 1969; Premack, 1969).

The additivity account has received empirical support from numerous sources (*e.g.,* Keller, 1974; Rachlin, 1973; Redford and Perkins, 1974; Schwartz, 1974, 1975; Schwartz, Hamilton, and Silberberg, 1975; see Schwartz and Gamzu, 1977, for a review). Consider, for example, the study by Keller. He separated the response- and stimulus-reinforcer relations to which Gamzu and Schwartz attribute contrast by arranging multiple schedules on two keys,

instead of one. One key (signal key) cued which component of the multiple schedule was in effect. The second key (operant key) produced reinforcement according to the schedule cued by the signal key. Keller found that when one component of an equal-valued *mult* VI VI schedule was changed to EXT, response rates on the operant key did not increase, as is normally found in contrast studies. Instead, substantial signal-key pecking occurred during the unchanged component. However, when these signal-key pecks were added to the pecks on the operant key, contrast did obtain. Keller concluded that his procedure distinguished between two classes of key pecks: one class controlled by operant contingencies (pecks on the operant key), and one class controlled by Pavlovian contingencies (pecks on the signal key). Moreover, both classes of behavior can participate in producing positive contrast (also see Schwartz and Williams, 1972).

Despite the interpretive power of the additivity theory, it cannot account for all instances of positive contrast. For example, Hemmes (1973) assessed for positive contrast on *mult* VI 1-min EXT schedules when components were cued by different colored houselights. Since the stimuli cueing each component were not localized on the key, autoshaped key pecking could not sum with operant key pecking to produce contrast. Nevertheless, robust positive contrast obtained (see also Westbrook, 1973). One possible explanation for Hemmes' results is that there are two kinds of positive contrast, only one of which depends on an autoshaping process. Thus, contrast may occur in the absence of component stimuli eliciting autoshaped key pecking. Indirect support for such an interpretation comes from a recent study by Schwartz, Hamilton, and Silberberg (1975). In their study, which was based on the Keller procedure, virtually all signal-key pecking occurred during the first few seconds after entering the component associated with the higher frequency of reinforcement. They noted that while an autoshaping process seems to be responsible for this *local contrast* effect, *overall contrast,* which is characterized by a rate increase throughout the entire component, may be a consequence of other, non-Pavlovian factors (see Boneau and Axelrod, 1962; Malone and Staddon, 1973; Nevin and Shettleworth, 1966; Rachlin, 1973). Boneau and Axelrod, for example, found two types of

positive contrast—a local-contrast effect that lasted only a few sessions, and an overall contrast effect that lasted many sessions. Thus, studies where contrast occurs under conditions not predicted by an additivity account need not constitute an experimental disproof of the contribution of an autoshaping process to positive contrast effects. In addition, one finding additivity theory cannot account for is negative contrast (decreases in response rate in the unchanged component of a multiple schedule concomitant with rate increases in the other). Here, however, Schwartz (1975) argued that negative and positive contrast are not due to the same or related processes.

The purpose of the present experiment was to assess directly the relationship between autoshaping and positive behavioral contrast. An important feature of the experimental design used in making this assessment is called the "yoked-control" paradigm (see Ferster and Skinner, 1957). For each pigeon (master bird) exposed to *mult* VI VI schedules, there is a second pigeon, called the "yoked control", which receives the same key colors and hopper presentations as the master bird. Each yoked control differs from its associated master bird only in that for the yoked control, hopper presentations are response independent. Thus, the master birds are exposed to multiple schedules similar to those used by Reynolds in demonstrating contrast, while the yoked controls are on an analog of the procedure used by Gamzu and Schwartz to show autoshaping on multiple schedules. The use of multiple schedules that differ only in response-reinforcer relations permits comparison of behavioral contrast in the master birds with the development and maintenance of autoshaped key pecking in the yoked controls.

In his original demonstration of positive contrast, Reynolds (1961*a*, procedure II) changed the conditions of multiple schedule reinforcement from nondifferential (*mult* VI VI schedules) to differential (*mult* VI EXT schedules), and then returned to the original nondifferential conditions. In the present experiment, a different approach was adopted: after a pretraining condition, each master bird was exposed first to differential conditions (*mult* VI 33-sec VI 99-sec schedules), then to nondifferential conditions (*mult* VI 99-sec VI 99-sec schedules), and finally to the original differential conditions. The rationale for this inversion in the usual sequence of conditions for producing contrast is theoretical: when groups are switched from differential to nondifferential condition, conditions in the first component are "worsened" (*i.e.*, they change from VI 33-sec to VI 99-sec). According to a view of contrast, such as that offered by Bloomfield (1969), any manipulation in a multiple schedule that "worsens" conditions should produce contrast in the unchanged VI 99-sec component. While this "worsening" of condition is, according to Bloomfield, conducive to obtaining contrast, the additivity theory does not make such a prediction: both components provide equal frequencies of reinforcement and, therefore, should not support autoshaped responding. Thus, the present experimental design counterpoises an autoshaping explanation of contrast with those offered by other theorists such as Bloomfield, Reynolds, or Terrace. In addition to comparing response rates between master bird-yoked control pairs, local response rates were recorded throughout each component to test for local-contrast effects.

EXPERIMENT I: VARIATION OF REINFORCEMENT RATE

Subjects

Sixteen adult male White Carneaux pigeons, deprived to 80% of their free-feeding weights, served. Eleven birds were experimentally naive, and the other five birds had brief histories of exposure to multiple schedules.

Apparatus

Each of 10 identical sound-attenuating chambers, measuring 27.5 by 32.5 by 29.0 cm, served as the experimental space. Three of the chamber walls were composed of galvanized steel. The front wall was made of stainless steel. Centered on this wall 5.5 cm from the floor was a food aperture measuring 5 by 5.5 cm. Three Lehigh Valley Electronics response keys were located 21 cm above the floor, 6.5 cm apart, center-to-center. Each key required a force of approximately 0.1 N to operate. A houselight was located above the center key, 26.2 cm from the chamber floor. Scheduling of experimental events, data collection, and analysis were accomplished with a Digital Equipment Corporation PDP 8/e computer located in an adjacent room using

SKED software provided by State Systems, Inc. of Kalamazoo, Michigan.

Procedure

Training procedures. After training the experimentally naive birds to eat reliably from the hopper, all birds were assigned to either the master or the yoked-control group. The master group (Birds M0 through M7) was composed of the five birds with histories of exposure to multiple schedules, plus three birds that were trained to peck the center key according to the forward-pairing autoshaping procedure of Brown and Jenkins (1968, Experiment 1). The yoked-control group (Birds Y0 through Y7) was composed of the eight remaining magazine-trained birds.

All birds were then placed on a pretraining program. Each master bird was exposed to a *mult* VI 33-sec EXT schedule. Associated with each schedule was a different key color, either red or green, which was counterbalanced among birds. The center key and houselight were illuminated continuously during a session, except when the grain hopper was presented. The VI 33-sec schedule (hereafter referred to as a random-interval or RI schedule) was arranged by interrogating a probability generator set at $p = 0.03$ by a 1-sec clock. The first response following an output of the probability generator produced 5 sec of access to grain. The RI schedule operated only in the presence of its associated key color. Reinforcements stored but not delivered during a given component were available when that component was presented again. Components strictly alternated every 27 sec exclusive of hopper time. Each daily session terminated after 80 component presentations.

A second chamber was electrically connected to each master-group chamber so that the keylight and hopper presentations to which each master bird was exposed were concurrently presented to its yoked partner in the second chamber. The important difference between master and yoked-control chambers was that reinforcement was response dependent in the former, and response independent in the latter. Thus, the yoked controls received reinforcement at the same interreinforcement interval that the master birds produced. Given moderate response rates in the master group (a prospect optimized by using master birds with established histories of key

pecking), the yoked controls were exposed to a multiple schedule composed of an EXT component and a response-independent RI 33-sec component (called hereafter a variable-time or VT schedule).

Since the pretraining condition mimics the differential condition of Gamzu and Schwartz (1973), it was expected that reliable autoshaped key pecking would be elicited among the yoked controls. This condition was used because Gamzu and Schwartz found that autoshaped key pecking is difficult to obtain unless substantial differences in reinforcement frequency between multiple-schedule components occur early in training. After either 15 or 30 days' exposure to this pretraining condition (see Table 1 for sequence of procedures for individual birds), all birds were placed in the first condition of the experimental paradigm. During this differential condition, the master group was exposed to a *mult* RI 33-sec RI 99-sec schedule. This was arranged by replacing the EXT component of the pretraining condition with an RI 99-sec schedule. The yoked-control group continued to receive response-independent reinforcement coincident with the response-dependent delivery of grain for birds in the master group. Hence, the yoked controls were exposed to the equivalent of a *mult* VT 33-sec VT 99-sec schedule. Each daily session terminated after presentation of 40 components. All other aspects of the differential condition were the same as during the pretraining condition.

After either 15 or 30 sessions of exposure to the differential condition, a nondifferential condition was imposed. This was arranged by replacing the RI 33-sec schedule with an RI 99-sec schedule. Hence, the master birds were exposed to a *mult* RI 99-sec RI 99-sec schedule, while the yoked controls were exposed to the equivalent of a *mult* VT 99-sec VT 99-sec schedule. All other aspects of this nondifferential condition were identical to the prior differential condition. Following exposure to this nondifferential condition, the original differential condition was reimposed in order to determine whether the behavior characterizing this condition was recoverable.

Contrast test. A two-criterion test of contrast, suggested by Schwartz and Gamzu (1977), was used in the present study: (1) when multiple schedule components were changed from differential to nondifferential, a rate increase

Table 1

Bird identification (1); key color of the first component (2); number of sessions in each condition (3); mean response rate in responses per minute during the last six sessions of a condition: during the first and second components (4) and (5) of the pretraining condition, during the first and second components (6) and (7) of the first condition, during the first and second components (8) and (9) of the second condition, and during the first and second component (10) and (11) of the final condition.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
			Mean Response Rate (resp/min) during Last 6 Sessions of a Condition							
			Pretraining (Differential)		Condition 1 (Differential)		Condition 2 (Nondifferential)		Condition 3 (Differential)	
Bird	First Component Key Color	No. of Sessions per Condition	RI 33-Sec Component	EXT Component	RI 33-Sec Component	RI 99-Sec Component	RI 99-Sec Component	RI 99-Sec Component	RI 33-Sec Component	RI 99-Sec Component
M0	red	30	43.0	0.7	45.9	39.3	67.8	52.0	37.6	51.8
M1	green	30	160.1	3.9	139.9	65.3	102.1	94.4	168.0	57.8
M2	red	30	57.6	1.2	64.7	21.5	58.7	42.3	69.0	29.2
M3	red	30	177.4	34.8	58.0	51.1	72.6	58.8	94.2	60.3
M4	green	30	90.2	12.9	93.4	51.6	105.0	79.3	131.1	70.7
M5	red	15	50.0	4.9	55.5	28.5	59.1	46.8	87.1	41.4
M6	green	15	37.9	2.9	32.9	27.6	67.8	51.1	70.3	59.8
M7	red	15	56.2	0.5	89.4	24.0	83.9	47.3	92.9	54.5
			VT 33-Sec Component	EXT Component	VT 33-Sec Component	VT 99-Sec Component	VT 99-Sec Component	VT 99-Sec Component	VT 33-Sec Component	VT 99-Sec Component
Y0	red	30	9.0	0.3	5.1	0.2	4.9	0.1	6.9	0.4
Y1	green	30	119.7	3.0	62.7	0.2	9.0	0.2	15.1	0.3
Y2	red	30	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Y3	red	30	22.2	0.2	9.1	0.1	0.2	0.0	7.5	0.1
Y4	green	30	11.4	0.2	12.9	0.0	0.0	0.0	0.0	0.0
Y5	red	15	0.0	0.0	1.2	0.0	1.0	0.0	7.5	0.1
Y6	green	15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Y7	red	15	0.1	0.0	26.8	0.9	0.9	0.0	23.6	1.8

in the unchanged component and a rate decrease in the changed component were required; (2) when conditions were returned to differential from nondifferential, rates in the unchanged and changed components were required to decrease and increase respectively.

RESULTS

In this study, the baseline for defining contrast is dependent on the steady-state performances during the first differential condition (*i.e., mult* RI 33-sec RI 99-sec). Figure 1 presents these data in terms of response rates (responses per minute) during each of the last five sessions for all master birds during each component. Vertical dashed lines separate successive conditions. During the second and third conditions, response rates are presented during each of the first and last five sessions. The changed and unchanged VI components are represented respectively by closed circles and by lines without points.

If rate changes between experimental conditions are defined on the basis of the median daily rate during the last five days of a given condition, only three subjects (M1, M2, and M5) met the criterion for positive contrast. M7 failed to show contrast because its response rate in the changed component rose across all conditions. The remaining birds (M0, M3, M4, and M6) showed positive induction: a response-rate increase in both the changed and unchanged components during the second experimental condition.

During pretraining, only half of the yoked controls responded during the VT 33-sec component. Across-condition rate comparisons for the yoked controls that did respond during the main experimental procedure are presented in Figure 2. This figure is identical to Figure 1, except that it presents response rates for birds in the yoked-control group. No data are presented for Y2 and Y6 because these birds failed to respond throughout all experimental
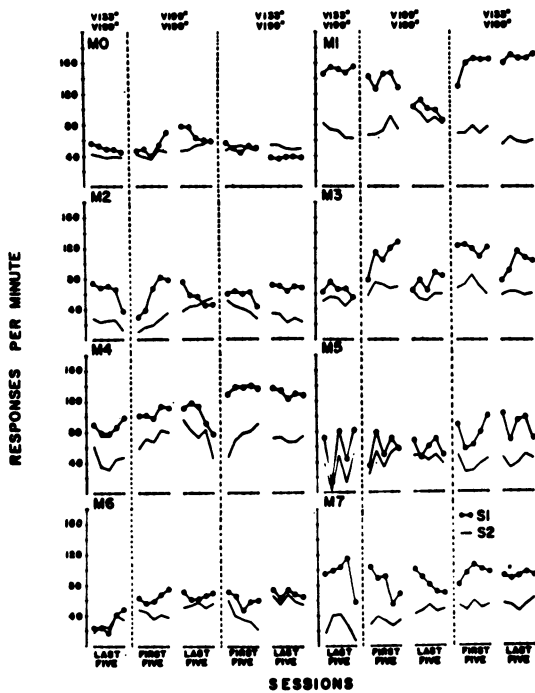
Fig. 1. Master-group response rates in responses per minute during the first and last five sessions of a condition. Vertical dashed lines separate conditions. Each condition is labelled at the top. S1 (changed component) and S2 (unchanged component) are represented by closed circles and solid lines respectively.

conditions (see Table 1). Inspection of Figure 2's curves shows that (1) autoshaped key-pecking rates were low, (2) response rates were reliably higher in the presence of the component that changed between conditions than in the presence of the unchanged VT 99-sec component, and (3) differential conditions (mult VT 33-sec VT 99-sec schedules) supported higher response rates than nondifferential conditions (mult VT 99-sec VT 99-sec schedules).

To determine whether local contrast occurred for birds in the master and yoked-control groups, the response rate during the component providing the higher frequency of reinforcement was recorded in 3-sec classes during the last six sessions of the first experimental condition. Figure 3 presents these data as responses per second in the richer component in successive ninths of the component. Curves in the top panel are from the master group; curves in the bottom panel are from those yoked controls for which response rates exceeded five per minute (see Table 1). This

criterion was adopted to ensure the stability of the curves presented. Data from M7 met this criterion, but due to a programming error, local response rates were not collected for this bird. Only two birds, M3 and M5, of eight, showed clear-cut local contrast—a higher rate at the beginning of the richer component than elsewhere. Most master-group and yoked-control birds showed only minor rate changes, except for M1, for which the highest rate was at the *end* of the component.

DISCUSSION

Response-Rate Variability

In the present experiment, between-condition rate changes were defined in terms of median daily rates over the last six sessions of a given condition. This measure was selected because of its insensitivity to the substantial session-to-session variability seen in response rates in Figure 1. A similar measure was adopted by Boakes, Halliday, and Mole (1976), who also found substantial daily rate changes in their contrast procedures. Although this measure is by no means atypical, its use could be questioned, for were certain statistical tests applied to the median-defined rate changes in this study—say, a sign-test comparison of rates during each of the last five sessions of the baseline condition with the corresponding session number in the contrast manipulation—acceptable levels of significance would often not have been reached. Nevertheless, we view this drawback as insubstantial, primarily because the two-criterion test for contrast used in this study is a conservative measure, even when based on six-session medians. By an alternative scheme—defining contrast only in terms of mean rate changes in the experimental phase from the baseline condition—substantial percentage increases in response rates in the unchanged component can be noted. Based on the mean data presented in Table 1, the three birds showing contrast by the two-criterion test (M1, M2, and M5) had rate increases in the unchanged component of 45%, 97%, and 64% respectively. The comparable measure for the four birds evidencing induction (M0, M3, M4, and M6) showed rate increases of 32%, 15%, 53%, and 85% respectively. Hence, we believe the contrast and induction effects labelled in this study are more robust than would be suggested by some tests of statistical significance.
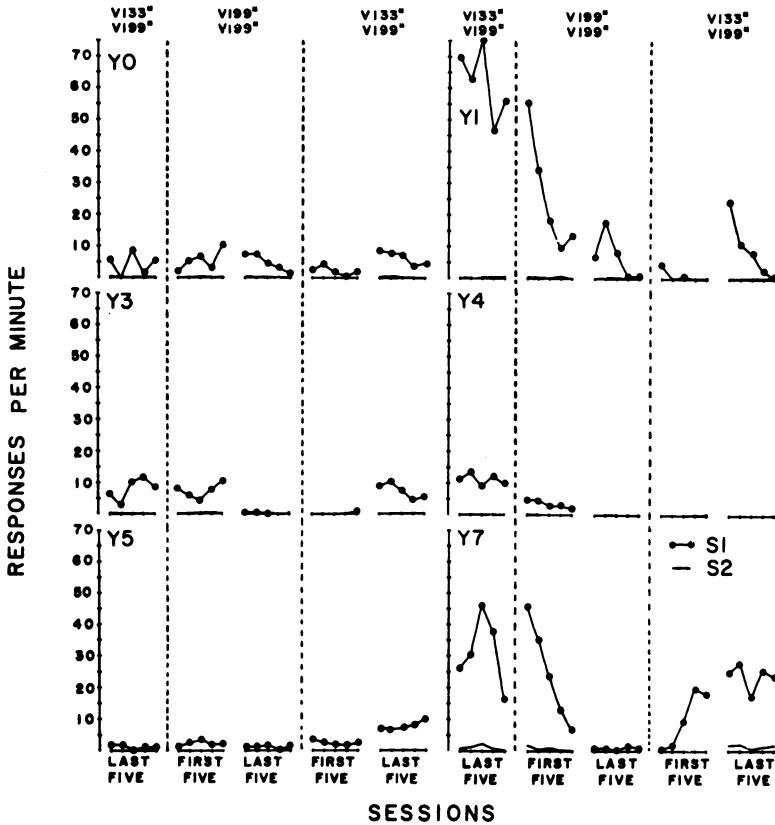
Fig. 2. Yoked-control response rates in responses per minute during the first and last five sessions of a condition. Vertical dashed lines separate conditions. Each condition is labelled at the top. S1 (changed component) and S2 (unchanged component) are represented by closed circles and solid lines respectively.

Contrast Test

In most contrast assays, the introduction of differential multiple schedule conditions has two effects: (1) production of contrast, and (2) education of autoshaped pecking (see Keller, 1974). The present experiment attempted to dissociate these two phenomena experimentally. For the yoked controls, autoshaped key pecking was expected during differential conditions and primarily in the changed component. For the master-group subjects, however, the rate increases characterizing contrast were expected during nondifferential conditions and in the unchanged component. As shown in Figures 1 and 2, these expectations were borne out: in seven of eight master-group subjects, rates in the unchanged component increased during nondifferential conditions; yet none of the yoked controls showed a similar rate increase. Moreover, when autoshaped key pecking did occur in the yoked controls, it occurred in the changed compo-

nent. Hence, autoshaping could not contribute to the rate increases seen in the unchanged component of the master-group subjects.

As regards the contrast assay, contrast without autoshaping did occur for M1, M2, and M5, even though the key peck served as the operant and the discriminative stimuli were presented on the key. This finding suggests that additivity theory cannot stand as an exclusive account of contrast. However, not all of the master-group subjects showed positive contrast during this assay. Four subjects showed positive induction—that is, a rate increase in both the changed and unchanged components. This finding in no way qualifies the prior conclusion that additivity theory is inadequate to account for between-condition rate changes in the master group: since the contrast tests were during conditions that eliminate autoshaping, additivity theory predicts rate decreases in the master group, not the increases that generally obtained.
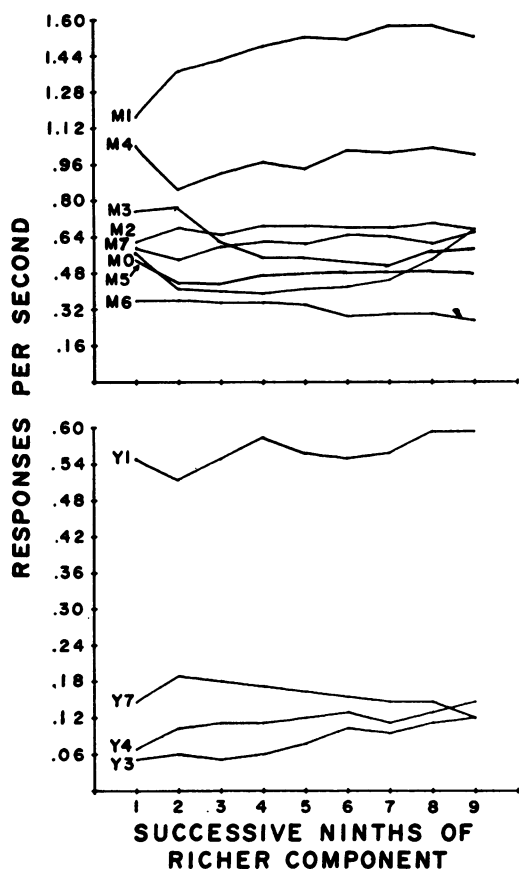
The finding of rate increases in the master

Fig. 3. Master (top panel) and yoked-control (bottom panel) response rate in responses per second as a function of successive ninths of richer component of Condition 1.

Autoshaped Responding

Autoshaped responding, like this study's contrast effects, did not occur in each bird. Observation of the yoked controls during the VT 33-sec component suggests that their low autoshaped rates were due to inchoate key pecking: all birds, even the two that failed to respond on the key at all, showed high frequencies of key-directed pecking that did not actually impact the key. This phenomenon of "air" pecking has been analyzed by Spealman (1976). He found in multiple schedule procedures similar to the one used here that often the majority of autoshaped, key-directed movements do not strike the key. "Air" pecking may also contribute to the low rates seen occasionally in other autoshaping studies (see, for example, Herrnstein and Loveland, 1972; Hursh, Navarick, and Fantino, 1974; Schwartz, Hamilton, and Silberberg, 1975). Except for this failure to find robust responding, the results from the yoked controls closely conform with those from Gamzu and Schwartz, whose paradigm the yoked control's procedure was designed to duplicate.

Local Response Rates

Findings of positive local contrast have often been reported in differential multiple-schedule procedures (e.g., Arnett, 1973; Boneau and Axelrod, 1962; Catania and Gill, 1964; Nevin and Shettleworth, 1966; Spealman, 1976; Staddon, 1969; Williams, 1965), and in autoshaping procedures (e.g., Rachlin, 1973; Schwartz, Hamilton, and Silberberg, 1976; Spealman, 1976). Yet, Figure 3's plots of local response rates failed to show reliable local contrast. In fact, most of the curves showed only minor rate changes as a function of time in the richer component. While these curves are incompatible with the local-rate analyses cited above, they are by no means unprecedented. For example, Buck, Rothstein, and Williams (1975) found that while one pigeon on mult VI EXT schedules showed local contrast (Bird G-5 from Figure 2 of that study), most birds had essentially constant rates, or showed their highest local rates at the end of the VI component. As regards autoshaping procedures, several studies (e.g., Ricci, 1973; Newlin and LoLordo, 1976; Wasserman, 1973) have presented data consistent with the findings in Figure 3. In the Wasserman study, for example, pigeons' re-

group's unchanged component during nondifferential conditions is consistent with most major theoretical accounts of contrast, which are not based on autoshaping processes. For example, Bloomfield's (1969) account predicts a rate increase in the unchanged component because the three-fold reduction in the changed component's reinforcement frequency presumably "worsened" conditions. However, the rate increases that occurred in the changed component for the subjects showing positive induction certainly belie the view that conditions were "worsened". Clearly, Bloomfield's explanation of contrast cannot explain the high incidence of positive induction found in the present study. This problem is not unique to Bloomfield's account, however: no theory of contrast of which we are aware accounts for both positive contrast and positive induction.

sponse rates during 8-sec autoshaping trials were recorded in 2-sec classes. While three of six subjects showed clear-cut local contrast, the rest exhibited only minor rate changes throughout each trial. These data, in conjunction with the findings presented in Figure 3, suggest that it is premature to characterize local contrast as a reliable phenomenon in response-dependent or -independent (autoshaping) multiple-schedule procedures.

In this experiment, contrast and autoshaping were studied in multiple-schedule situations where the between-condition manipulation was alteration of the frequency of reinforcement. The next experiment addressed whether contrast and autoshaping can be supported by multiple schedules varying not frequency of reinforcement, but reinforcer duration.

EXPERIMENT II: VARIATION OF REINFORCER DURATION

Shettleworth and Nevin (1965) exposed two birds to *mult* VI 2-min VI 2-min schedules in which the duration of access to the grain reinforcer was varied independently in the two components. They found that while the response rate in a component varied systematically with the relative access to reinforcement that component provided, there was no evidence of positive contrast. This finding is consistent with others (*e.g.*, Fantino, Squires, Delbrück, and Peterson, 1972; Schneider, 1973) in demonstrating that rate and duration of reinforcement may not be equivalent in their effects on behavior. One prediction that might be made from Shettleworth and Nevin's results is that differential durations will not support autoshaping: if contrast is due to an autoshaping process, their failure to find contrast suggests that one would fail to find autoshaping in multiple schedules providing unequal durations of response-independent reinforcement. One purpose of Experiment II was to test this prediction experimentally—to determine whether differential durations of reinforcement can support autoshaped key pecking.

The format used in this study was similar to that of Experiment I. A yoking procedure is used, with master-yoked control pairs exposed to differential, nondifferential, and differential conditions, in that order. Differential conditions are arranged by using in each

multiple-schedule component equal-valued VI schedules providing different durations of access to the grain hopper; nondifferential conditions, during which reinforcement duration and frequency are the same for both components, are arranged by reducing hopper duration in the first component to the same duration as in the second component.

There are several advantages of applying Experiment I's procedure to the study of the variation of reinforcer duration in Experiment II:

1. The contrast assay among the master-group birds attempts a generalized replication of Shettleworth and Nevin's failure to find contrast. In light of the fact that they used only two subjects, such an attempt seems in order.

2. It is possible to determine whether differential durations of response-independent reinforcement can support autoshaped responding. Since there are no published demonstrations of autoshaped key pecking maintained by differential reinforcer durations, finding sustained key pecking would extend the generality of the differential conditions capable of supporting autoshaping to differential hopper durations.

3. It permits a test of the additivity theory in another context. Since the second condition of Experiment II is nondifferential, the additivity theory would predict no contrast among the master-group birds when that condition is introduced. This prediction holds whether or not autoshaped key pecking occurs among the yoke controls in the first differential condition. On the other hand, other accounts of contrast (*e.g.*, Bloomfield, 1969) should predict contrast during the nondifferential condition because the decrease in reinforcer duration can be said to have "worsened" conditions.

METHOD

Subjects

Ten adult male White Carneaux pigeons, maintained at 80% of their free-feeding weights, served. Five of the birds had histories of exposure to multiple schedules, and five were experimentally naive.

Apparatus

The apparatus was the same as in Experiment I.

Procedure

After magazine training the experimentally naive birds, all birds were assigned to either the master or yoked-control groups. The master group (Birds M8 through M12) was composed of the five birds with experimental histories, and the yoked-control group (Birds Y8 through Y12) was composed of the magazine-trained birds.

All birds were then placed on a training procedure identical to that of Experiment I except that: (1) hopper durations for master and yoked-control birds were increased to 7.5 sec; and (2) each of 30 daily pretraining sessions terminated after 60 component presentations.

After this pretraining experience, which was used to optimize prospects for obtaining autoshaped key pecking among the yoked controls in subsequent conditions, all birds were placed on the experimental paradigm. During all three conditions of this paradigm, the master birds were exposed to *mult* RI 33-sec RI 33-sec schedules. Given moderate response rates among the master birds, the yoked controls were exposed to schedules akin to *mult* VT 33-sec VT 33-sec schedules. During the first and last conditions, which were differential, first- and second-component reinforcement consisted of access to the grain hopper for 7.5 and 2.5 sec respectively. During the second condition of the experimental procedure, which was nondifferential, reinforcement in both components consisted of 2.5-sec access to grain. All conditions terminated after 30 daily sessions. All other aspects of the experimental design were identical to Experiment I (see Table 2 for order of procedures for Experiment II).

RESULTS

Figure 4 presents for the master-group birds the response rate in the presence of each multiple-schedule component during each of the last five sessions of the first condition, and during each of the first and last five sessions of the second and third conditions. The hopper durations in each component of the multiple schedule are indicated at the top of Figure 4. First- and second-component response rates are indicated by closed circles and lines without points respectively. M12's data are not presented because following pretraining, this subject had near-zero rates in the second component during the first and second conditions. Hence, its data are not amenable to a contrast assay. In terms of the two-criterion test for positive contrast described in Experiment I, M10 and M11 show positive contrast, and M8 and M9 show positive induction.

Table 2

Bird identification (1); key color of the first component (2); mean response rate in responses per minute during the last six sessions of a condition: during the first and second components (3 and 4) of the pretraining condition, during the first and second components (5) and (6) of the first condition, during the first and second components (7 and 8) of the second condition, and during the first and second components (9 and 10) of the final condition.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		*mean response rate (resp/min) during the last six sessions of a condition*							
	First Component Key Color	*Pretraining (Differential)*		*Condition 1 (Differential)*		*Condition 2 (Nondifferential)*		*Condition 3 (Differential)*	
Bird		*7.5-Sec Hopper*	*EXT*	*7.5-Sec Hopper*	*2.5-Sec Hopper*	*2.5-Sec Hopper*	*2.5-Sec Hopper*	*7.5-Sec Hopper*	*2.5-Sec Hopper*
M8	red	72.7	1.3	70.4	73.6	80.9	117.2	86.5	90.7
M9	green	77.8	1.1	57.3	29.3	68.5	47.7	71.2	23.1
M10	red	107.3	5.5	98.8	56.5	84.6	95.9	111.1	70.8
M11	green	185.4	1.6	116.2	66.6	88.3	85.2	106.5	61.9
M12	red	146.0	1.8	155.7	6.8	79.4	4.0	108.9	70.9
Y8	red	80.5	2.3	12.8	0.0	0.0	0.0	5.9	0.0
Y9	green	18.4	0.3	25.9	0.4	0.4	0.0	0.0	0.0
Y10	red	30.4	0.7	0.1	0.0	0.0	0.0	0.0	0.0
Y11	green	1.5	0.2	0.6	0.2	0.2	0.3	0.5	0.2
Y12	red	4.4	1.1	3.4	1.0	0.6	0.4	0.1	0.0

Response-rate data for the yoked controls are presented in Figure 5. Curves are presented only for Y8 and Y9, the only birds for which response rates exceeded five per minute during any of the three experimental conditions. Responding in these two birds was quite characteristic of other autoshaping studies: response rates were higher during differential than during nondifferential conditions, and virtually all responding occurred to the stimulus signalling the greater reinforcer duration. Moreover, observation during differential conditions showed substantial rates of "air" pecking during the component associated with the 7.5-sec hopper cycle, even among the subjects that had zero and near-zero rates of autoshaped key pecking.

For the last six sessions of the first differential condition, responses during the 27-sec component cueing the 7.5-sec hopper duration were recorded in 3-sec classes for the master and yoked-control groups. These data are presented in Figure 6 as the response rate in the richer component as a function of successive ninths of that component. As in Experiment I, curves are presented only if based on a mean response rate in excess of five per minute. Little evidence of local contrast was found among either master-group birds (top panel) or their yoked controls (bottom panel). In fact, all curves have positive slopes, showing that highest local rates occurred at the end of the component, not at its beginning.

DISCUSSION

The data from Experiment II are quite similar to those from Experiment I. A consistent finding in both studies was that positive contrast occurred in some, but not all, master-group birds. A second correspondence was that when contrast failed to obtain in either study, positive induction was often seen. Nor were the rates of autoshaped key pecking reliable in either study. As regards Experiment II,
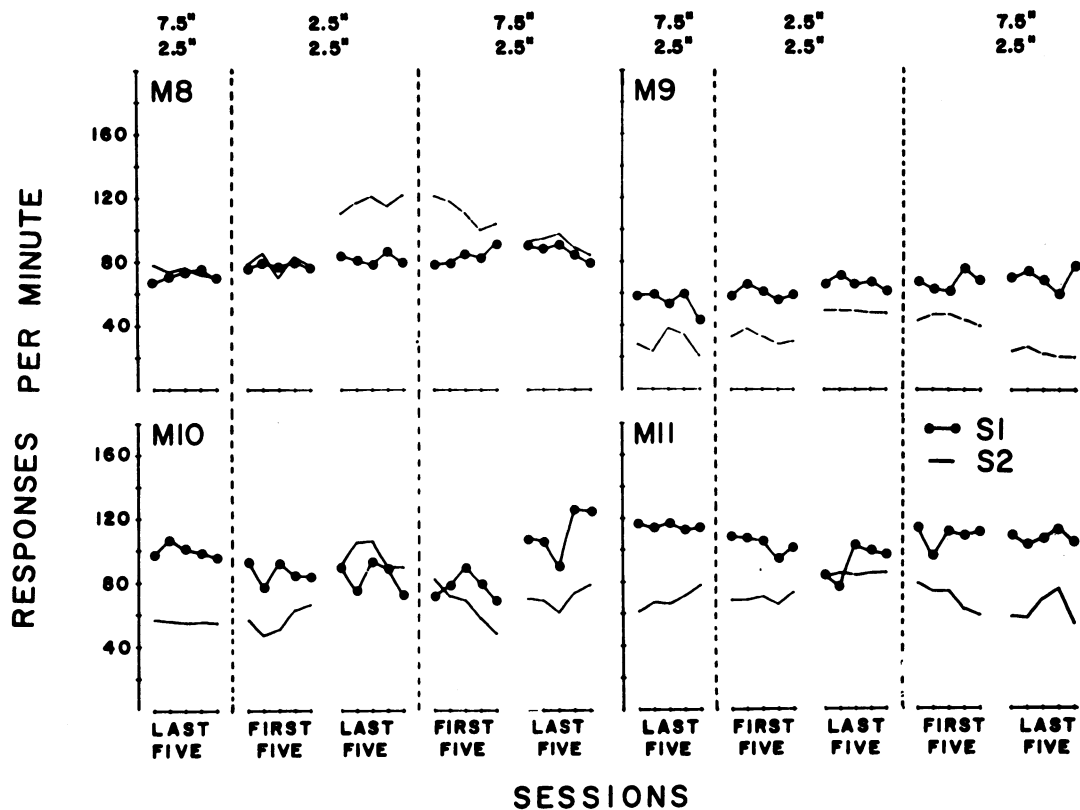

Fig. 4. Master-group response rates in responses per minute during the first and last five sessions of a condition. Vertical dashed lines separate conditions. Each condition is labelled at the top. S1 (changed component) and S2 (unchanged component) are represented by closed circles and solid lines respectively.
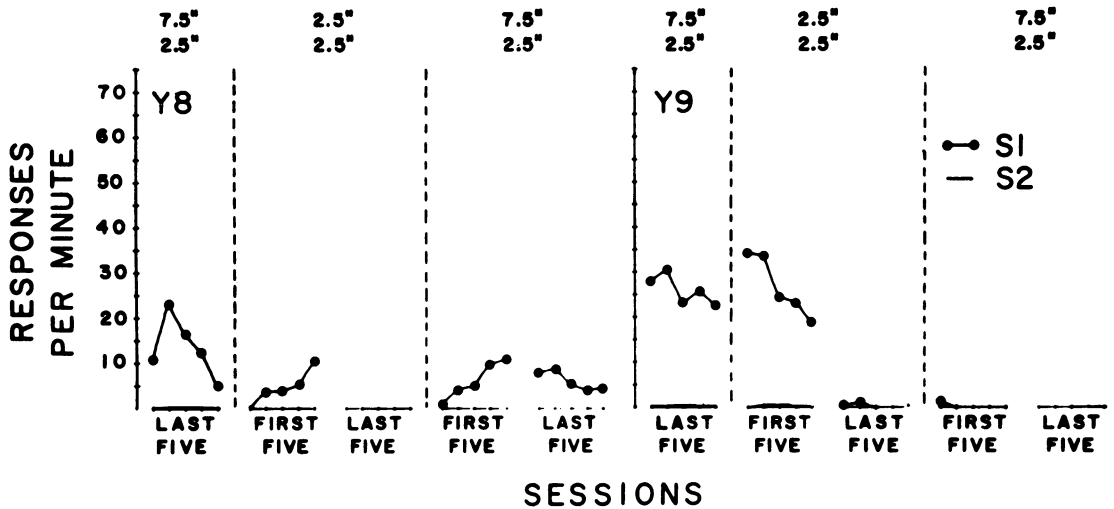
Fig. 5. Yoked-control response rates in responses per minute during the first and last five sessions of a condition. Vertical dashed lines separate conditions. Each condition is labelled at the top. S1 (changed component) and S2 (unchanged component) are represented by closed circles and solid lines respectively.

only two of five yoked controls persisted in key pecking during the first differential condition, and only one in five continued responding throughout the second differential condition. Nevertheless, autoshaped key pecking did obtain, demonstrating that differential hopper durations, like differential reinforcement frequencies, can sustain autoshaped responding. Among those yoked controls in Experiments I and II that failed to respond during differential conditions, "air" pecking was prevalent. This finding suggests that pecking movements, if not key pecking, were readily elicited by the richer component during differential conditions. Finally, analysis of local response rates during the richer component of both experiments produced the same finding: little evidence of local contrast. In fact, the curves of Experiment II had positive slopes, demonstrating that response rates increased as time passed in the richer component.

The empirical correspondences between these experiments are consistent with Premack's (1965) notion that reinforcement time, defined as the product of a reinforcer's rate and duration, is the variable controlling the strength of a response. This definition assumes an equivalence between rate and duration of reinforcement in supporting behavior. In Experiments I and II, the first component's relative reinforcement time (cumulative hopper time in the first component divided by the cumula-

tive hopper time in both components) equalled 0.75 during differential conditions and 0.5 during nondifferential conditions. In other words, differential and nondifferential conditions in Experiment I equalled those conditions in Experiment II when defined in terms of reinforcement time. The fact that the data from these experiments produced similar results in contrast and autoshaping assays is consistent with the proposition that the rate and duration of reinforcement have qualitatively similar effects on behavior (also see Catania, 1963; Neuringer, 1967; Schwartz, 1969; Ten Eyck, 1970).

In four of five subjects in the master group, response rates in the unchanged 2.5-sec hopper component increased when nondifferential conditions were introduced. In two subjects, these rate increases occurred only in the unchanged component (positive contrast); in the other two subjects, rates increased in both components (positive induction). These data are important because they essentially duplicate the findings of Experiment I. Hence, it is unlikely that the high incidence of contrast and induction in either Experiment I or II was a happenstance.

A second reason why these rate increases in Experiment II are of interest is because they do not conform to the findings of Shettleworth and Nevin. In their study, response rates in the unchanged component did not vary
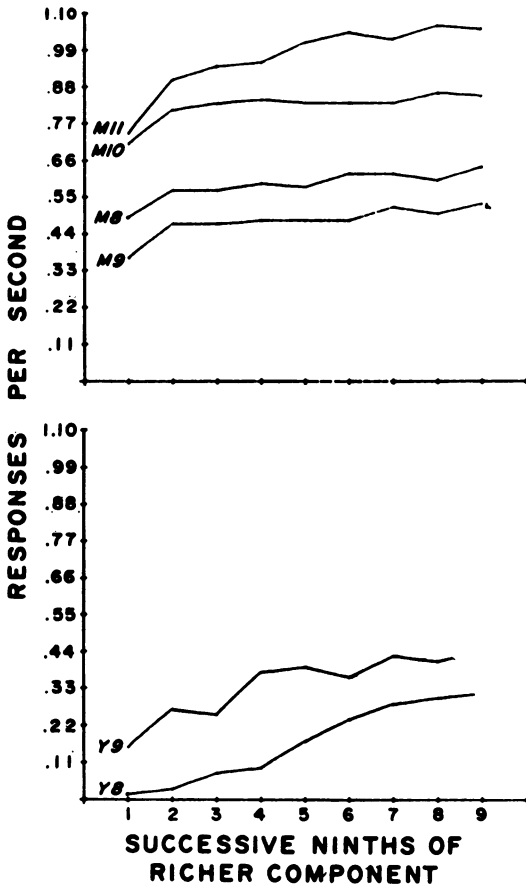
Fig. 6. Master (top) and yoked-control (bottom) response rate in response per second as a function of successive ninths of richer component in Condition 1.

systematically with changes in the other component's hopper duration. Because of many procedural differences between Experiment II and their procedure, it is not practical to speculate on the likely causes for empirical differences between these studies. In any case, the finding of positive contrast in some subjects of Experiment II demonstrates that variation of reinforcer duration in multiple schedules can produce contrast.

As regards the additivity theory, comparison between response-rate data from the master and yoked-control groups shows a serious problem for this account: rates in the unchanged component of the master group increased after introduction of the nondifferential condition; yet among the yoked controls, nondifferential conditions failed to support responding. These rate increases, which took the form of either positive contrast or positive

induction, cannot be explained by any autoshaping process. Yet, other accounts, such as Bloomfield's, are of some value, at least in explaining the finding of positive contrast: rates in the unchanged component increased not because of autoshaping, but because of a "worsening" of conditions in the changed component. Bloomfield's account also encounters problems, however, because it cannot explain why a "worsening" of conditions leads to response-rate increases in the changed component for some subjects.

GENERAL DISCUSSION

The results of Experiments I and II can be summarized as follows:

1. During the contrast tests, master-group rates reliably increased in the unchanged component, a result inconsistent with additivity theory. Approximately half of these subjects showed a corresponding rate decrease in the changed component, the result characterizing contrast. The rest showed a rate increase in both components (positive induction).

2. Yoked-control response rates during differential conditions were generally low and unreliable. Pecking that did not contact the key seemed a probable contributor to this finding. However, when responding occurred, it occurred only during differential conditions and primarily in the richer component, a result replicating Gamzu and Schwartz (1973).

3. Local response rates for master and yoked-control subjects showed little evidence of local contrast. In fact, most rates tended to be essentially constant or to increase throughout the richer component.

4. There were many empirical correspondences between experiments, suggesting a qualitative similarity (although not necessarily a functional identity) between the effects of reinforcer duration and frequency, and demonstrating that manipulation of reinforcer duration can produce contrast and autoshaped responding.

Contrast, Autoshaping, and Additivity

The purpose of the present study was to evaluate the relationship between autoshaping and positive contrast. Toward this end, a yoking procedure was used in which the contrast assay in the master group occurred during a different condition than the condition

needed to support autoshaping among the yoked controls. By counterpoising contrast and autoshaping in this manner, autoshaped key pecking could in no way contribute to any rate increase in the unchanged component during the contrast assay. This procedure clearly showed there is no inextricable link between autoshaping and rate changes in the unchanged component during contrast assays: 11 of 13 master-group subjects in both experiments increased response rates during the unchanged component, while none of their yoked controls did. This finding alone shows that some rate changes in contrast tests cannot be explained in terms of additivity theory.

This finding was not surprising. Additivity theory was expected to fail as an account of rate changes in the master group. This expectation followed from the fact that prior work on contrast and autoshaping suggested that there would be rate increases in the master group and rate decreases in the yoked controls during the contrast assay. One aspect of this study's findings was unexpected, however: only five of the 11 subjects for which rates increased during the unchanged component of the contrast test showed the corresponding rate decrease in the changed component that characterizes contrast; the other six subjects showed positive induction, a rate increase in both components. Additivity theory, of course, can account for none of these results. Hence, these data do not contradict additivity's failure as an exclusive account of rate changes in the master group; however, while other explanations (e.g., Bloomfield, 1969) can be invoked to account for the five subjects showing contrast, no traditional account, nor one that we can suggest, is capable of also explaining the high incidence of positive induction during this study's contrast assays.

Local Response Rates

Buck, Rothstein, and Williams (1975) exposed pigeons to *mult* VI EXT schedules in which components alternated every 90 sec. Unlike other studies where local contrast has been reported (e.g., Arnett, 1973; Nevin and Shettleworth, 1966; Rachlin, 1973; Spealman, 1976), they found either minor changes in response rates or that rates increased as a function of time in the presence of the VI component. The results of Experiments I and II

replicate and extend their findings: not only did master-group rates tend to be either constant or to increase as a function of time in the richer component, but they also seemed independent of whether differential conditions were based on unequal reinforcement frequencies or unequal hopper durations.

In recent accounts of additivity (Rachlin, 1973; Schwartz and Gamzu, 1977), differential multiple-schedule conditions are thought to elicit autoshaped key pecks primarily during the first few seconds of the stimulus associated with the richer component. The reason for this perspective is that several studies that have assessed the temporal patterning of autoshaped responding found the highest local rates at the beginning of the conditioned stimulus (e.g., Schwartz, Hamilton, and Silberberg, 1975; Spealman, 1976). Based on such findings, Rachlin and Schwartz and Gamzu have argued that local contrast is essentially an autoshaping phenomenon. Quite obviously, Buck et al. viewed their own data as being inconsistent with such an interpretation. How can an autoshaping process, which presumably elicits most pecking immediately after the conditioned stimulus has been introduced, account for their frequent finding that the highest rates are at the *end* of that stimulus' presentation?

The yoked-control data from Experiments I and II suggest a simple answer to this question: response rates during autoshaping procedures *can* be highest at the end of a components. Hence, Buck et al.'s data need not be inconsistent with additivity theory. In fact, the functional similarity of the local-rate data from the present study's master and yoked-control groups suggests that had Buck et al. measured local rate on an autoshaping procedure otherwise equivalent to the multiple schedule they used, they too would have often found autoshaped response rates increasing as a function of time in the presence of the richer component.

The similarity between the local-rate curves of master and yoked-control groups in Experiments I and II shows that Buck et al.'s findings need not run counter to additivity theory. However, the parsimony this conclusion introduces comes at the cost of complicating the description of many multiple-schedule effects. Before the Buck et al. study, differential multiple-schedule conditions were thought to produce the highest rates reliably at the begin-

ning of the richer component (see, for example, Rachlin, 1973; Schwartz and Gamzu, 1977). Now it appears that this result obtains only in some studies; in others, such as Buck *et al.* and the present experiment, the highest rates may occur at the end of the richer component. As yet there is no adequate specification for the factors responsible for these different characterizations of local rate. Until these factors are defined, the status of integrative accounts of multiple schedule performance, such as those presented by Rachlin and Schwartz and Gamzu, must remain unresolved. For example, rather than knowing, as Rachlin suggests, how autoshaping contributes to local contrast and matching on short-component multiple-schedules (see Shimp and Wheatley, 1971), it now appears that one does not really even know empirically what kinds of rate changes to expect. An obviously important goal for future work is the characterization of the processes controlling the direction of local rate changes on multiple schedules.

The present study altered the usual order of conditions for producing contrast in order to counterpoise an autoshaping account of contrast with others (*e.g.,* Bloomfield's). While this procedure worked successfully, there was a serendipitous finding—the high incidence of induction accompanying contrast. This unexpected result is one of several recently which suggests that the boundary conditions for producing contrast are still ill-defined. For example, Boakes, Halliday, and Mole (1976) noted that whether contrast obtains in a given study can depend on the baseline used; and the characteristics of that contrast, say, its temporal patterning, may vary between studies and even between subjects (Menlove, 1975; Williams, 1976). Perhaps, as Williams (1976) suggested, progress in delineating the mechanisms for contrast has been held back by the historical emphasis on unitary-process accounts (*e.g.,* Reynolds, 1961a; Gamzu and Schwartz, 1973). Surely, the results of the present study favor a multifactor approach. While additivity fails as an exclusive account of contrast, what of additivity in conjunction with another process, say a "worsening" of conditions? Such a two-factor explanation could account not only for finding contrast without autoshaping, as in the present study, but would still use additivity as the powerful explanatory notion that it has proven to be (Schwartz and Gamzu, 1977).

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