*A LOCAL-RATE-OF-RESPONSE AND
INTERRESPONSE-TIME ANALYSIS
OF BEHAVIORAL CONTRAST¹*

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Three pigeons were exposed to a two-component multiple schedule in which a variable-interval 3-min schedule was always in effect in one component. The schedule in the other component was either variable-interval 3-min or extinction in alternate blocks of sessions. When the schedule was changed from multiple variable-interval 3-min variable-interval 3-min to multiple variable-interval 3-min extinction in the second and fourth phases of the experiment, overall response rates in the unchanged variable-interval 3-min component increased in two pigeons. Response rate declined when the schedule was changed to multiple variable-interval 3-min variable-interval 3-min again. Correlated with increases in overall response rate in the unchanged component were increases in local response rates at the beginning of the unchanged component and immediately after food presentation. Local rates 40 sec after food presentation did not increase greatly in the presence of the multiple variable-interval 3-min extinction schedule. An interresponse time analysis of three local rate samples showed small increases in the relative frequency of short-duration interresponse times at the beginning of the unchanged component and immediately after food presentation. Neither the postreinforcement pause nor the latency to the first response in the unchanged component changed systematically.

A multiple schedule arranges that two or more independent schedules of reinforcement, which are signalled by different exteroceptive stimuli, are successively presented to an animal. Reynolds (1961) demonstrated that changing a schedule in one component of the multiple schedule affects the rate of responding in another component. For example, if a pigeon is initially exposed to a *mult* VI (variable interval) 3-min VI 3-min schedule and the schedule is changed to *mult* VI 3-min EXT (extinction), response rate will increase in the VI 3-min component that was not changed. Reynolds (1961) described this increase in response rate in the unchanged component as positive behavioral contrast. Behavioral contrast occurs whenever response rate in the unaltered component of a multiple schedule changes in a direction away from response rate in the altered component.

A simple view of positive behavioral contrast is that response rate is constant regardless of where within the component it is measured, but Nevin and Shettleworth (1966) reported a transient behavioral contrast effect in which response rate in the first minute of the unchanged component was high and decreased to a constant level if the schedule in the preceding component arranged a low reinforcement frequency. If the component preceding the unchanged component scheduled a high reinforcement frequency, response rate during the first minute of the unchanged component was low and increased to a constant level. The transient behavioral contrast effect disappears after several sessions (Boneau and Axelrod, 1962; and Nevin and Shettleworth, 1966). In addition to transient behavioral contrast, there is a sustained positive behavioral contrast effect that is manifested as increased levels of responding late in the unchanged component (Nevin and Shettleworth, 1966). Thus, Nevin and Shettleworth (1966) demonstrated that positive behavioral contrast cannot always be described as a constant increase in response rate throughout the unchanged component.

The purpose of the present experiment was to extend Nevin and Shettleworth's (1966) findings by investigating responding after food

¹Supported by the author's USPHS pre-doctoral fellowship (MH45,890-01). This research is based on portions of a dissertation submitted to the Department of Psychology at the Florida State University in partial fulfillment of the requirements of the Ph.D. Degree. The author wishes to acknowledge her indebtedness to Michael Rashotte, under whose direction the research was conducted. Reprints may be obtained from the author: Psychology Dept., Eunice Kennedy Schriver Center, 200 Trapelo Road, Waltham, Mass. 02154.

was presented in the unchanged component of a schedule that has commonly yielded positive behavioral contrast. Pigeons were trained to key peck for grain on a *mult* VI 3-min VI 3-min schedule, and then shifted to *mult* VI 3-min EXT. Responding in the unchanged VI 3-min component was always evaluated with reference to responding in that component during the baseline *mult* VI 3-min VI 3-min condition. In addition to the traditional measure of response rate in the unchanged VI 3-min component over an entire session, the present experiment included measures of rate of response in selected portions of the unchanged components (local rate), distributions of interresponse times during the local rate sampling periods, postreinforcement pause, and latency to the first response in the unchanged component.

METHOD

Subjects

Three experimentally naive White Carneaux pigeons, obtained from the Palmetto Pigeon Plant, Sumter, South Carolina, were maintained at approximately 80% of their free-feeding body weights and were housed in a constantly illuminated room in individual cages where water was continuously available. The pigeons were from six to eight months old at the beginning of this experiment.

Apparatus

The experimental chamber was a Model 1419 two-key Lehigh Valley Electronics Company pigeon chamber. Only the left response key was used, and a force of 15 g (0.15N) was required to operate it. Centered below the response keys was a solenoid-operated hopper that presented mixed grain (Purina) for 4 sec. Industrial Electronics Engineers' (IEE) in-line projectors transilluminated the response key with various colors during different parts of an experimental session. The light bulbs in the IEE Units were 2.8 W. The key was not lighted during hopper presentations. Standard relay equipment and a PDP 8/I computer interfaced through a Grason-Stadler SCAT system was used to control the experimental conditions and to record data. External counters were used to monitor the SCAT system's data recording.

Procedure

Shaping and training. The pigeons were magazine trained and their behavior was shaped by the method of successive approximations until consistent key pecking occurred (Ferster and Skinner, 1957). The next 250 pecks produced food. The pigeons were then exposed briefly to an ascending series of variable-interval schedules ending in a multiple VI 3-min VI 3-min schedule of food presentation. (The VI schedule arranges that a response produces a food presentation according to a variable series of intervals having a given mean, and the multiple (*mult*) schedule arranges the successive presentation of two or more reinforcement schedules, which are signalled by different exteroceptive stimuli.) Baseline data were gathered from each subject under this *mult* VI 3-min VI 3-min schedule. Green and white keylights identified the two components of the multiple schedule. The duration of each component was 3 min. The two components of the multiple schedule alternated regularly in all phases of the experiment.

After a relatively stable overall rate of response was observed in the *mult* VI 3-min VI 3-min phase of this experiment, one component of the multiple schedule was changed from VI 3-min to extinction for several sessions. Subsequently, the schedule was again *mult* VI 3-min VI 3-min, then *mult* VI 3-min EXT, and finally *mult* VI 3-min VI 3-min. Table 1 shows the number of sessions each pigeon was exposed to the two schedules of this experiment and the associated key colors. The criterion for changing the schedule to *mult* VI 3-min EXT for the second time was near-baseline levels in overall and local response rates (see data-collection section.)

Each session was terminated after 40 food presentations during all *mult* VI 3-min VI 3-min phases of the experiment and after 20 food presentations in the *mult* VI 3-min EXT phases. The interreinforcement intervals of the VI 3-min schedule used were arranged in the following arithmetic distribution 330, 270, 120, 180, 0, 60, 360, 210, 300, 240, 30, 120, and 90 sec.

Failures of the SCAT system in several sessions resulted in the pigeons being subjected to periods in which the response key was lighted but reinforcement was not available.

Table 1
Experimental Procedures

Pigeon	Schedule	Number of Sessions	Stimuli	
			Unchanged Component	Changed Component
#3004	<i>mult VI 3-min VI 3-min</i>	22	Green	White
	<i>mult VI 3-min EXT</i>	64		
	<i>mult VI 3-min VI 3-min</i>	50		
	<i>mult VI 3-min EXT</i>	14		
	<i>mult VI 3-min VI 3-min</i>	5		
#7962	<i>mult VI 3-min VI 3-min</i>	57	White	Green
	<i>mult VI 3-min EXT</i>	60		
	<i>mult VI 3-min VI 3-min</i>	11		
	<i>mult VI 3-min EXT</i>	20		
	<i>mult VI 3-min VI 3-min</i>	5		
#3209	<i>mult VI 3-min VI 3-min</i>	70	White	Green
	<i>mult VI 3-min EXT</i>	60		
	<i>mult VI 3-min VI 3-min</i>	21		
	<i>mult VI 3-min EXT</i>	11		
	<i>mult VI 3-min VI 3-min</i>	17		

Sessions in which these periods of extinction occurred were most frequent for one pigeon (presumably due to the time of day at which it was run) and were not included for any pigeon in the data presented in this paper.

Data-collection procedures. Statistics describing key pecking in the unchanged component were computed on the basis of six measures taken during that component. A seventh measure was made during the changed component. The first three measures involved selective sampling of responding during different portions of the unchanged component. Each measure nominally lasted for 15 sec and was response initiated. Measure 1 was initiated by the first peck in each unchanged component, Measure 2 by the first key peck after each food presentation in the unchanged component, and Measure 3 by the first key peck 40 sec after the first postreinforcement key peck. Any response sample was terminated early by the presentation of food or by the end of the component, but the information collected up to that point was stored. In Measure 4, key pecking during the entire unchanged component was recorded. Measures 5 and 6 were taken between termination of a food presentation and the next key peck, and between initiation of the unchanged component and the first key peck, respectively. One measure of key pecking was taken during the entire unchanged component (Measure 7).

Separate IRT distributions were taken in the three 15-sec sampling periods and through-

out the unchanged component. There were 16 bins in each IRT distribution, and the bin-width or class interval size all distributions was 0.25 sec, with the overflow bin (bin 16) accumulating IRTs of 4 sec or more. Neither the latency to the first response of a component nor the postreinforcement pause was included in the IRT distribution for the unchanged component (Measure 4).

RESULTS

In this data presentation, attention is focused on a comparison of responding in the unchanged component during the *mult VI 3-min VI 3-min* and the *mult VI 3-min EXT* schedules. These schedules were presented sequentially over five phases of the experiment so that a variety of comparisons is possible. However, since the first *mult VI 3-min EXT* phase was studied for the largest number of sessions and, therefore, provides information relevant to the duration of several of the properties of behavioral contrast, the data presentation emphasizes performance during this period. The subsequent phases of the experiment involved procedures that would help to verify that the effects observed in the first *mult VI 3-min EXT* period were replicable and were related to the *mult VI 3-min EXT* schedule and not other variables such as the passage of time.

Overall response rates in the unchanged and changed components of the multiple schedule

Fig. 1. Overall rates of response (responses per second) for three pigeons in the changed and unchanged components of the multiple schedule plotted as a function of sessions. The horizontal lines indicate the median response rate in the unchanged component over the last 10 sessions of Phases I and II. The solid lines represent responding in the unchanged component, and the dotted lines represent responding in the changed component.

are plotted in Figure 1 as a function of sessions for all pigeons in all phases of the experiment. The left panel of each portion of this figure shows the rate of response in each component of the multiple schedule during the last 10 sessions of exposure to the *mult VI 3-min VI 3-min* baseline condition. The remaining panels of Figure 1 show response rates during the initial *mult VI 3-min EXT* phase, and for the subsequent *mult VI 3-min VI 3-min*, *mult VI 3-min EXT*, and *mult VI 3-min VI 3-min* phases, respectively.

The first two panels of Figure 1 indicate that overall response rate in the unchanged component increased for Pigeons 3004 and 7962 for the duration of the *mult VI 3-min EXT* phase. There was no clear indication of an increase in response rate over the baseline level for Pigeon 3209 during the initial *mult VI 3-min EXT* condition of this experiment. The second panel of Figure 1 also shows that for all of the subjects, response rates in the extinction component were very low for the duration of the first *mult VI 3-min EXT* phase.

The third panel of Figure 1 shows that overall response rate in the unchanged component decreased in all pigeons when the schedule was changed from *mult VI 3-min EXT* to *mult VI 3-min VI 3-min*. The response rates in the changed component increased for all pigeons when the *mult VI 3-min VI 3-min* schedule was present in Phase 3. A number of computer failures during the second presentation of *mult VI 3-min VI 3-min* occurred with Pigeon 3004. A relatively large number of sessions (50) in this portion of the experiment resulted for Pigeon 3004 as continued attempts were made to obtain a reasonably long series of sessions without failure. A comparison of response rates in panels 3 and 4 of Figure 1 shows an increase in the unchanged component and a decrease in the changed component for Pigeons 3004 and 7962 when the *mult VI 3-min EXT* schedule was introduced for a second time. Response rate declined in the unchanged component and increased in the changed component for all pigeons when the schedule was changed from *mult VI 3-min EXT* to *mult VI 3-min VI 3-min* in the last phase.

The following figures show the local response rates in a particular 15-sec sampling period taken after the first response (a) at the

beginning of the unchanged multiple schedule component, (b) after each presentation in the unchanged component, and (c) 40 sec after each food presentation in the unchanged component.

The local response rate data for Pigeons 3004, 7962, and 3209 during the changed component are presented in Figures 2, 3, and 4. Two of the pigeons showed little difference between the three local response rate measures on the baseline *mult VI 3-min VI 3-min* schedule; Pigeon 3004 evidenced a higher local response rate at the beginning of the unchanged component than in the other two local response rate samples. When the pigeons were exposed to the *mult VI 3-min EXT* schedule in Phase 2, responding increased at the beginning of the unchanged component and immediately after a food presentation. Response rates 40 sec after a food presentation were not greatly affected by the *mult VI 3-min EXT* schedule.

Local response rates returned to their baseline levels for all pigeons when the schedule was changed from *mult VI 3-min EXT* to *mult VI 3-min VI 3-min*. When the *mult VI 3-min EXT* schedule was presented in Phase 4, response rates at the beginning of the unchanged component and immediately after a food presentation increased for Pigeons 3004 and 3209. During Phase 4, Pigeon 7962 evidenced an increase in response rate only at the beginning of the unchanged component. When the *mult VI 3-min VI 3-min* schedule was presented in Phase 5, all response rates returned to their baseline level with the exception of the rate immediately after food presentation for Pigeon 3209.

The changes in IRT distribution throughout the five phases were generally correlated with the changes in local response rate. Each time the *mult VI 3-min EXT* schedule was introduced, the proportion of short IRTs increased. Generally, this increase was greatest for the IRTs at the beginning of the unchanged component and immediately after a food presentation, but the magnitude of the effect was not as great as for the local response rates.

Postreinforcement pause and latency to the first response at the beginning of the unchanged component did not show any consistent pattern of change in any phase of this experiment.

Fig. 2. Local response rates plotted as a function of sessions for Pigeon 3004. Mes 1, Mes 2, and Mes 3 refer to the response samples of 15 sec duration taken in the beginning 15 sec of the unchanged component, and immediately after reinforcement, and 40 sec after reinforcement, respectively.

DISCUSSION

The present data confirm and extend findings that the positive behavioral contrast effect may be more precisely characterized than as an increase in overall response rate in the unchanged component of a multiple schedule. There were definite patterns of responding that became evident only when samples of behavior were taken within the unchanged component.

Two of the three pigeons showed behavioral contrast in the overall response rate. There is no obvious reason for the failure of Pigeon 3209 to show behavioral contrast. Although the overall response rate of this pigeon during baseline was considerably higher than that of Pigeons 7962 and 3004, there was no indication that it was at a ceiling. In fact, in the thirty-fifth session of the baseline *mult* VI 3-min VI 3-min phase, Pigeon 3209 was responding at a rate of 2.40 responses per second in the unchanged component. The highest response

rate observed during any *mult* VI 3-min EXT condition was 1.81 responses per second.

One interesting aspect of the data of Pigeon 3209 is that increases in local response rates at the beginning of the unchanged component and immediately after a food presentation occurred during each *mult* VI 3-min EXT condition in the absence of a behavioral contrast effect in the overall response rate. Pigeon 3209 was exposed to the baseline condition longer than the other two pigeons because of an extremely unstable response rate. Possibly the 10 sessions selected to represent baseline response rates were not adequate to evaluate the effects of the *mult* VI 3-min EXT schedule on overall response rate in the unchanged component. If the presence of local rate effects in the absence of a behavioral contrast effect in the overall rate is not due to an unstable baseline, perhaps the data of Pigeon 3209 suggest an independence of the local and overall response rate effects observed. More experimentation is needed to evaluate this possibility.

Fig. 3. Local response rates plotted as a function of sessions for Pigeon 7962. Mes 1, Mes 2, and Mes 3 refer to the response samples of 15 sec duration taken at the beginning of the unchanged component, immediately after reinforcement, and 40 sec after reinforcement, respectively.

The local rate of response data from the three samples taken within the unchanged component of the multiple schedule are fairly orderly from pigeon to pigeon and condition to condition. All three pigeons showed marked increases in the local rate of response

at the beginning of the unchanged component whenever the *mult* VI 3-min EXT schedule was present. Since this increase was always evident for the duration of a *mult* VI 3-min EXT condition, these data do not support the finding that response rate increases observed at

Fig. 4. Local response rates plotted as a function of sessions for Pigeon 3209. Mes 1, Mes 2, and Mes 3 refer to the response samples of 15 sec duration taken at the beginning of the unchanged component, immediately after reinforcement, and 40 sec after reinforcement, respectively.

the beginning of unchanged components last for only a few sessions (Boneau and Axelrod, 1962; Nevin and Shettleworth, 1966).

Another notable feature of the local response rate data is the increase in the local rate immediately after food presentation. This increase was evident in all pigeons during the initial *mult VI 3-min EXT* condition. Only Pigeon 7962 did not show an increase in local response rate immediately after food presentation in the *mult VI 3-min EXT* schedule

used in the fourth phase of this experiment. An increase in local response rates immediately after food presentation has not been previously reported in the behavioral contrast literature. Wertheim (1965) reported response bursting after presentation of electric shock in a behavioral contrast experiment in which the duration of the response-shock interval of a multiple avoidance schedule was manipulated. The local response rate increase immediately after food presentation observed in

the present experiment indicates that Wertheim's (1965) results may generalize to behavioral contrast produced by schedules of food presentation.

In general, the local response rate 40 sec after food presentation increased very little during the *mult* VI 3-min EXT conditions of the present experiment. Some increase in the local rate of Pigeon 7962 forty seconds after food presentation was evident during the last 18 sessions of the first *mult* VI 3-min EXT condition, but this was not as large as the increase at the beginning of the unchanged component and after food presentation.

A comparison of the local response rate 40 sec after food presentation with the local rate at the beginning of the component and immediately after food presentation indicates that it is not always accurate to describe positive behavioral contrast as a general increase in response rate throughout the unchanged component of a multiple schedule. It appears that the largest response rate increase occurs after presentation of some distinct exteroceptive stimulus.

The local response-rate increase observed immediately after food presentation is similar to some data discussed by Falk (1971). Schedule-induced polydipsia (Falk, 1961), schedule-induced aggression (Flory, 1969), escape from fixed-ratio schedules of food presentation (Azrin, 1961), schedule-induced wheel running (Levitsky and Collier, 1968), and schedule-induced pica (Villareal, 1967, cited by Falk, 1971) are all behaviors that are most probable after food is presented on an intermittent schedule. Perhaps the enhanced response rate observed after presentation of food in the *mult* VI 3-min EXT phases is related to the adjunctive behaviors discussed by Falk (1971). It may be useful for future research on behavioral contrast to be directed toward determining its relation to adjunctive behavior.

The present data have definite implications for current descriptions of behavioral contrast. A simple interpretation of positive behavioral contrast is that all measures in the unchanged component reflect an increase in response rate. That is, postreinforcement pauses decrease in length, the latency to the first response in the unchanged component decreases, all local response rates increase, and all IRT distributions show an increase in short IRTs. Before the present experiment,

certain data on positive behavioral contrast indicated that this simple interpretation was not adequate (*e.g.*, Nevin and Shettleworth, 1966) and the present data confirm and extend these findings. The present results indicate that in addition to the increase in local response rate at the beginning of the unchanged component noted by Nevin and Shettleworth (1966), there is a rate increase immediately after a food presentation, which is not present 40 sec after a food presentation. Also, the present data indicate that IRT distributions at the beginning of the unchanged component and immediately after a food presentation are affected when frequency of food presentation is reduced in one component of a multiple schedule, but the effects are small and difficult to evaluate. The latency to the first response in the unchanged component and the post-reinforcement pause do not appear to be systematically related to positive behavioral contrast.

An accurate description of a phenomenon is a necessary prerequisite to understanding the conditions under which it occurs. Thus far, a thorough description of behavioral contrast has not been available, and this may account for some of the confusion that has characterized the behavioral contrast literature. Terrace (1966) held that a sufficient condition for the production of positive behavioral contrast is a reduction in response rate in the changed component of a multiple schedule. On the other hand, Reynolds (1961) contended that positive behavioral contrast occurs whenever the rate of reinforcement is reduced in the constant component. Later, Reynolds and Limpo (1968) showed that positive behavioral contrast can be produced when rate of response in the changed component is reduced in the absence of a change in rate of reinforcement. It is also known that the addition of response-contingent electric shock to one component of a multiple schedule will produce positive behavioral contrast in a component where shock is not present (Brethower and Reynolds, 1962).

One problem with the interpretation of the preceding experiments is that they have worked with a definition of positive behavioral contrast as an increase in the overall response rate of the unchanged component, and this may not be an adequate characterization. Instead of evaluating the effects of variables such

as frequency of food presentation and response rate on only overall response rate in the unchanged component, perhaps local rates should be examined. Behavioral contrast produced by a reduction in frequency of food presentation in one component of a multiple schedule might affect local response rates differently from a procedure yielding behavioral contrast by a reduction of response rate in the absence of a reduction in frequency of food presentation. Quite possibly, present descriptions of behavioral contrast in terms of an increase in overall response rate may be preventing a better understanding of the conditions producing behavioral interaction in multiple schedules.

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Received 19 June 1972.

(Final Acceptance 4 June 1973.)