*BEHAVIORAL CONTRAST IN ONE COMPONENT OF A
MULTIPLE SCHEDULE AS A FUNCTION OF THE
REINFORCEMENT CONDITIONS OPERATING
IN THE FOLLOWING COMPONENT¹*

R. N. WILTON AND ROBERT A. GAY

UNIVERSITY OF TEXAS

The key pecks of four pigeons were reinforced on a variable-interval 5-min schedule which operated in each of the four components of a multiple schedule, indicated by red, green, yellow, and blue stimuli and presented in such an order that the red stimulus always preceded the yellow and the green stimulus always preceded the blue. After establishing baseline rates, the reinforcement schedule associated with the blue and yellow components was altered so that one was now an extinction schedule and the other was a variable-interval 1-min schedule. In a second experimental stage, the blue stimulus was interchanged with the yellow so that the red stimulus preceded the blue and the green stimulus preceded the yellow. In both experimental stages the response rate in the variable-interval 5-min component that preceded the extinction component was higher than the response rate in the variable-interval 5-min component that preceded the variable-interval 1-min component. The results were discussed in relation to the importance of stimulus ordering in experiments concerned with investigating behavioral contrast.

Reynolds (1961) defined behavioral contrast as a change in the rate of responding in a first component of a multiple schedule in a direction away from the rate of responding prevailing in the second component when that change follows some manipulation of the second component. Bloomfield (1967) suggested that contrast would be better defined as the change in the rate of responding in the first component in a direction away from a change of reinforcement frequency in the second component. Some clarification of the appropriateness of the two definitions of contrast can be made in studies which attempt separately to manipulate changes in reinforcement frequency and response rate in the second component (Reynolds, 1961; Terrace, 1966a; Bloomfield, 1967). The adoption of one of these definitions in preference to the other is somewhat arbitrary, but this paper adopts the definition proposed by Bloomfield. The reason for this is that in all the studies which will be referred to, the second component of a multiple schedule has been manipulated only by varying its reinforcement frequency, and generally, responding in that component has changed in the same direction as the

change in reinforcement frequency. Consequently, changes of response rate in the first component can be tied to changes in reinforcement frequency in the second component without implying that they do or do not generally relate to the response rate in that second component.

Two experiments by Pliskoff (1961, 1963), and experiments by Herrnstein (1955) and Leitenberg (1966), demonstrated contrast, and are especially interesting because they indicate that the level of contrast in one component of a multiple schedule depends on what other component follows. In a first experiment, Pliskoff (1961) trained birds on a two-component multiple schedule with a variable-interval 1-min (VI 1-min) schedule operating in each component. The duration of each component was 15 min, and the components regularly alternated. The final 3 min of each component was accompanied by the illumination of two lights. After initial baseline training on this schedule, the schedule operating in one component was changed to VI 10-min. As a result of this change, responding in the presence of the lights increased when the lights preceded the transition to the VI 10-min schedule and decreased when the lights preceded the transition to the VI 1-min schedule.

In a second experiment, Pliskoff (1963) trained birds on a three-component multiple schedule in which the duration of each com-

¹This research was supported by a grant from the University of Texas Graduate School under the NSF Graduate Fellowship Program. Reprints may be obtained from R. N. Wilton, Department of Psychology, University of Texas, Austin, Texas 78712.

ponent was 10 min. A component indicated by a white stimulus was followed equally often by a component indicated by a red stimulus and a component indicated by a green stimulus. During the final 2 min of the white component, the illumination of different signal lights indicated whether the red or the green component was to follow. After initial training with the same reinforcement schedule operating in the presence of each stimulus, the frequency of reinforcement available in the presence of the red stimulus was reduced, and the frequency of reinforcement available in the presence of the green stimulus was increased. After this change, the rate of responding in the presence of the signal that immediately preceded the (red) component with the reduced reinforcement frequency was higher than the response rate in the presence of the signal that immediately preceded the (green) component with the increased reinforcement frequency. Moreover, the response rates in the presence of the two signal lights became more differentiated as the discrepancy between the reinforcement frequencies in the red and green components was increased. If the frequency of reinforcement in the red component was further decreased, or the frequency of reinforcement in the green component was further increased, the rates of responding in the presence of the two signals became more widely separated.

These two experiments suggest that the degree to which responding in one component changes as a function of changes in the reinforcement frequency of another component depends on the position of that component with respect to the position of following components in the overall sequence of components.

Pliskoff's results are of considerable importance because they seem to indicate that a contrast effect which occurs in one component of a multiple schedule will be influenced by the schedule operating in the component whose onset usually follows it. This means that the ordering of components in a multiple schedule probably affects the amount of contrast that can be obtained in that schedule. The present experiment investigated ordering effects in a study designed to produce results which could add generality to Pliskoff's findings, and provide stronger grounds for inference to the factors operating to influence contrast in other studies (Reynolds, 1961; Terrace,

1966a; Bloomfield, 1966). The design of the experiment was based on that of Pliskoff's second (1963) study. Two different exteroceptive stimuli, indicating two different components of a multiple schedule, were associated with the same reinforcement schedule, but were differentiated in that one was always immediately followed by a third component with a schedule of higher reinforcement frequency, while the other was always immediately followed by a fourth component with a schedule of lower reinforcement frequency. The reinforcement frequencies in these third and fourth components were made as disparate as possible to maximize the possibility that responding in the component that preceded one of them would be maximally differentiated from responding in the component that preceded the other. The design was similar to the design of studies which have investigated contrast in the context of discrimination learning in that the 2-min components of the schedule were of relatively short duration (see Nevin and Shettleworth, 1966), and response rates were noted both before and throughout discrimination learning.

METHOD

Subjects

Four adult homing pigeons, 22Y, 23Y, 24Y, and 25Y, locally obtained and experimentally naive when the experiment began, were maintained at about 80% of their free-feeding weights.

Apparatus

The apparatus consisted of a standard operant conditioning chamber containing a 1.25-in. diameter translucent key that could be illuminated from behind by a red, green, yellow, or blue light. Reinforcement consisted of a 3.5-sec exposure to a grain magazine centered below the response key. Recording and scheduling equipment, consisting of relays, timers, and counters, was contained in an adjoining room.

Procedure

The four birds were first trained to peck the response key, which was illuminated by a white light, by the automatic key-peck training method of Brown and Jenkins (1968). The birds were then shifted to a VI 5-min schedule,

the intervals of which were generated by a progression given by Fleshler and Hoffman (1962). The color of the response key was then alternated in a semi-random fashion between red and green. Each color presentation lasted for 2 min, and at the end of 2 min, regardless of whether there was a color change, any reinforcements set up but not obtained were cancelled. A session ended after the first 2-min presentation that followed the twenty-second reinforcement.

After at least 30 sessions on the above procedure, the stimuli were changed for the four birds. The response key was now illuminated, for 2 min, by one of four colors: red, green, blue, or yellow. These colors alternated in a semi-random fashion, under the restriction that blue always followed green, and blue never occurred except when it followed green, yellow always followed red, and yellow never occurred except when it followed red, and yellow and blue each preceded red the same number of times that they preceded green.

Initially, the key pecks of Birds 22Y, 23Y, and 25Y were reinforced on a VI 5-min schedule in each component, but after 10 sessions the birds were switched to a procedure whereby different schedules operated in the blue and yellow components. Bird 24Y was switched to the four colors before the other birds, and from the beginning experienced different schedules in the blue and yellow components. This meant that 24Y experienced more experimental sessions with the different reinforcement schedules operating, and that its baseline response rates in the red and green VI 5-min components were taken in the absence of experience with the blue and yellow stimuli.

For Birds 24Y and 22Y, an extinction schedule operated in the blue component and a VI 1-min schedule operated in the yellow component; for Birds 23Y and 25Y, the extinction schedule operated in the yellow component and the VI 1-min schedule operated in the blue component. As before, sessions ended after the first 2-min stimulus presentation following the twenty-second reinforcement. Birds 22Y, 23Y, and 25Y were given 25 sessions on this procedure; Bird 24Y was given 50 sessions.

All birds were then shifted back to a constant VI 5-min schedule, but the colored stimuli were ordered as before, except that the positions of the yellow and blue stimuli were

interchanged. Thus, the red stimulus was now always followed by the blue, and the green stimulus was always followed by the yellow. The session length was now thirty 2-min presentations, the approximate duration of a session in the previous phase. Thus, this second baseline period of responding on VI 5-min consisted of sessions that lasted for about the same time as those in the preceding experimental phase, rather than for the same number of reinforcements as in the first baseline period.

After 17 sessions on the second baseline procedure, another experimental phase began, where the yellow stimulus again indicated VI 1-min for Birds 24Y and 22Y, and extinction for Birds 23Y and 25Y, and where the blue stimulus again indicated extinction for Birds 24Y and 22Y, and VI 1-min for Birds 23Y and 25Y. The birds were given 22 sessions on this procedure which, except for the change in position of the yellow and blue stimuli, was exactly the same as the first experimental procedure.

RESULTS

Figure 1 describes the course of the experiment for the four birds. Response rates in the red component are indicated by filled circles, and response rates in the green component are indicated by open circles. Response rates in the blue and yellow components are indicated by lines without circles; responding in the blue component is indicated by the broken line, responding in the yellow component is indicated by the unbroken line. For each bird the figure is divided into four sections, each section representing a different stage in the experiment. The first and third sections show response rates in those sessions when a VI 5-min schedule operated throughout, and hence show VI 5-min baseline response rates in the red and green components which are unaffected by different reinforcement conditions in the blue and yellow components. For Bird 24Y, sessions comprising the first baseline stage were taken before those of the other birds, although they are aligned with them in the figure. The second and fourth sections of the figure show response rates during those sessions when a VI 5-min schedule operated in the red and green components, and when different schedules operated in the

Fig. 1. Response rates on VI 5-min throughout the experiment. First and third sections show responding in baseline sessions, second and fourth sections show responding in experimental sessions. Open circles indicate response rate during green, filled circles indicate response rate during red. The lines without circles indicate responding in the blue and yellow components; the broken line indicates responding in the blue component, the unbroken line indicates responding in the yellow component. The arrow indicates the stimulus color preceding the extinction component.

blue and yellow components. For Birds 24Y and 22Y, the blue component was here correlated with an extinction schedule, and the yellow component was correlated with a VI 1-min schedule. For Birds 23Y and 25Y, the blue component was correlated with the VI 1-min schedule, and the yellow component was correlated with the extinction schedule. In the second and fourth sections, the VI 5-min component that preceded the extinction component is indicated by an arrow.

Figure 2 is drawn up in the same manner as Fig. 1, and utilizes some of the data of Fig. 1 by showing the difference in rate between the red and green VI 5-min components. The second and fourth sections of Fig. 2 show the rate of responding in the VI 5-min component that preceded the extinction component minus the rate of responding in the VI 5-min component that preceded the VI 1-min component. The first and third sections of Fig. 2 show the rate of responding in the VI 5-min component that was to precede the extinction component in the next second or fourth section minus the rate of responding in the VI 5-min com-

ponent that was to precede the VI 1-min component in the next (second or fourth) section. Thus, for Birds 24Y and 22Y, the first and second sections of Fig. 2 show the rate of responding in the green component minus the rate of responding in the red component, while the third and fourth sections show the reverse. And for Birds 23Y and 25Y, the first and second sections show the rate of responding in the red component minus the rate of responding in the green component, while the third and fourth sections show the reverse.

Consider now the second stage, where for all birds the yellow component always followed the red and the blue component always followed the green. Figure 1 shows that for Bird 24Y there was an immediate differentiation of responding between the VI 1-min and extinction components: responding in the yellow VI 1-min component increased and responding in the blue extinction component decreased. Responding in both the red and green VI 5-min components showed some immediate increase. Figures 1 and 2 show

Fig. 2. The difference between the response rates in the red and green VI 5-min components. The second and fourth sections show the response rate of the VI 5-min component followed by extinction minus the response rate of the VI 5-min component followed by VI 1-min. The first and third sections show the response rate of the VI 5-min component to be followed in the next section by extinction minus the response rate of the VI 5-min component to be followed by VI 1-min in the next section.

that at first there was no obvious differentiation between the response rates of the red and green VI 5-min components, but that after about 12 sessions of discrimination training, responding in the green component increased rather suddenly above responding in the red component; *i.e.*, the response rate of the VI 5-min component that preceded the extinction component was elevated above the response rate of the VI 5-min component that preceded the VI 1-min component (Fig. 2). In subsequent sessions the rate of responding in each VI 5-min component declined to its previous baseline level (*cf* Terrace, 1966*b*).

Bird 23Y shows almost exactly the same changes as Bird 24Y. An immediate differentiation of responding between the yellow extinction component and the blue VI 1-min component was accompanied by an approximately equal rate increase in each VI 5-min component. Then, after about 10 sessions of discrimination training, a differentiation of responding between the VI 5-min components appeared (Fig. 1 and 2), because of an even further increase in the response rate of the VI 5-min component that preceded the extinction component (Fig. 1).

Bird 22Y is unusual in that responding in the yellow VI 1-min component was not differentiated from responding in the blue extinction component until quite late in discrimination training, and was even then not well differentiated (Fig. 1). As in the case of Birds 24Y and 23Y, responding in each VI 5-min component showed some immediate increase, but this was not followed by any further increase specific to the VI 5-min component that preceded the extinction component (Fig. 1 and 2). This lack of differentiation between responding in the red and green VI 5-min components may have been connected with the poor differentiation in responding between the extinction and VI 1-min components.

Bird 25Y, like Birds 24Y and 23Y, showed an almost immediate differentiation between responding in the VI 1-min and extinction components; responding in the blue VI 1-min component increased and responding in the yellow extinction component decreased (Fig. 1). The rates of responding in the red and green VI 5-min components, however, showed no change compared to their baseline rates of section one, and at no point was the re-

sponse rate of the red component differentiated from the response rate of the green component (Fig. 1 and 2). No reason for this is evident.

At the beginning of stage three of the experiment, the blue and the yellow stimuli were interchanged. Thus, for all birds, for the remainder of the experiment, the red component was always followed by the blue and the green component was always followed by the yellow. In stage three, a VI 5-min schedule operated in each of the components, producing a second series of baseline sessions (Fig. 1 and 2).

In the fourth stage of the experiment, the blue and yellow stimuli were again correlated with the schedules that they had been correlated with in the second stage. In two respects the results from the fourth stage are similar to those from the second stage. First, all birds showed an early differentiation of responding between the VI 1-min and extinction components. In particular, Bird 22Y showed a more distinct differentiation between the VI 1-min and extinction components than it had in the previous block of discrimination training sessions of section two (Fig. 1). Second, all birds responded at a higher rate in the VI 5-min component that preceded the extinction component than they did in the VI 5-min component that preceded the VI 1-min component (Fig. 1 and 2). When compared with the baseline sessions of section three, Birds 24Y, 23Y, and 25Y showed higher responding in the VI 5-min component that preceded the extinction component, and no elevation or less of an elevation in the VI 5-min component that preceded the VI 1-min component. Bird 22Y, while showing different response rates in the VI 5-min components, failed to show a consistent change in either of the VI 5-min response rates (Fig. 1).

In the case of Birds 24Y, 22Y, and 25Y, it is again apparent from Fig. 1 that the differentiation of responding that occurred between the red and green VI 5-min components was due to the fact that the rate of responding in the VI 5-min component that preceded extinction increased rather suddenly after about 10 to 15 days following the switch to discrimination training from the baseline procedure of stage three. In the case of Bird 23Y, the differentiation between responding in the VI 5-min components occurred almost immediately.

The results from stage 2 and stage 4, when taken together, indicate that the differentially higher response rate in the VI 5-min component preceding extinction occurred by virtue of that fact, rather than by virtue of some other characteristic of the following stimulus. Taking stage 2 only, the argument could be put forward, say for Bird 24Y, that the blue extinction component affected the green component rather than the red component because blue lies nearer to green on the wavelength dimension. But the fact that the red component, rather than the green component, was affected in stage 4, when the extinction component was again blue, but when blue now followed red rather than green, shows that the effect was primarily one of the ordering of the stimuli rather than their similarity.

DISCUSSION

Normally, responding in one component of a multiple schedule increases if the reinforcement frequency in another component is reduced, and decreases if the reinforcement frequency in another component is increased (Reynolds, 1963). In the present experiment, both an increase and a decrease in reinforcement frequency occurred; the VI 5-min schedule in one component was changed to a VI 1-min schedule, the VI 5-min schedule in another component was changed to extinction. Several points can be made about subsequent responding in the two unchanged VI 5-min components.

The difference obtained between the rates of the two VI 5-min components can be considered first. The rate of responding in the VI 5-min component that preceded the extinction component was typically higher than the rate of responding in the VI 5-min component that preceded the VI 1-min component. As is shown most clearly in Fig. 2, this was true for two of the birds in the first block of discrimination training sessions and was true for all four of the birds in the second block of discrimination training sessions. The finding that the rate of responding in a component varies as a function of the schedule operating in an immediately following component is in accordance with the results obtained by Pliskoff (1961, 1963). The difference between the rates of responding in the two VI 5-min components did not usually occur until about the four-

teenth session of discrimination training. Possibly, the late development of such a difference may have been one consequence of a general difficulty in establishing sequential relationships when several components are involved in a schedule (but see Herrnstein, 1955). Also, the difference between the two VI 5-min response rates declined in the one bird (24Y) that was given an extended first block of discrimination training sessions. This was primarily due to a return of rate to a baseline level in the VI 5-min component that immediately preceded extinction. Terrace (1966b) reported a similar finding after extended training on a *mult* VI 1-min EXT schedule. After showing an initial increase in rate, responding in the VI component returned to its baseline level. In the bird given extended discrimination training in the present experiment, the difference between the two VI 5-min response rates, which had disappeared in the first extended block of discrimination training sessions, reappeared in the second block of discrimination training sessions. This reappearance of the rate difference between the two VI 5-min components may have depended either on the fact that the VI 1-min and EXT components following the VI 5-min components were interchanged, or on the fact that the stimuli correlated with the VI 1-min and EXT schedules were correlated with a different reinforcement schedule between the two blocks of discrimination training sessions.

Turning now to a consideration of the absolute rates in the VI 5-min components, although responding in the unchanged component that preceded extinction generally increased, responding in the unchanged component preceding the VI 1-min component did not decrease (*cf* Pliskoff, 1963). Rather, it also occasionally showed some increase. Thus, even in this component, the interaction of all the factors encouraging a rate increase outweighed the factors encouraging a rate decrease. The fact that differential rates of responding occurred in the unchanged components shows that the rate-increasing properties of extinction were more powerful in a component that was consistently and immediately followed by extinction. But clearly, they were also active in a component not immediately followed by extinction. The extent to which this depends on the fact that extinction often immediately preceded this component remains to be de-

terminated (Nevin and Shettleworth, 1966; Terrace, 1966a).

The present results are of particular relevance to studies that have investigated contrast in two-component multiple schedules (Reynolds, 1961, 1963; Bloomfield, 1966; Terrace, 1966b), for they suggest that contrast might vary as a function of the ordering of components. In a *mult* VI 1-min EXT schedule, for example, the VI component can be presented for either a constant or a variable period of time before it is followed by the EXT component. If the duration of a single presentation of the VI schedule is constant, as in a regular alternation schedule (Reynolds, 1961, 1963; Bloomfield, 1966), then a stimulus defined as the passage of a particular period of time since the onset of the VI component is always followed by a period of extinction. But, if the duration of a single presentation of the VI schedule varies, as in an irregularly alternating schedule (Terrace, 1966b), such a stimulus is often immediately followed by a further period in which the VI schedule operates, rather than by a period of extinction. In the present study, and in other studies (Herrnstein, 1955; Pliskoff, 1961, 1963; Leitenberg, 1966), the rate of responding in a period was affected by the schedule of reinforcement which had operated in immediately following periods. It seems likely, therefore, that it would be so affected in two-component schedules, and that differently ordered schedules, such as regular and irregular schedules, would generate different levels of contrast.

REFERENCES

- Bloomfield, T. M. Behavioral contrast and relative reinforcement frequency in two multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 151-159.
- Bloomfield, T. M. Two types of behavioral contrast in discrimination learning. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 155-161.
- Brown, P. L. and Jenkins, H. M. Auto-shaping of the pigeon's key peck. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 1-8.
- Fleshler, M. and Hoffman, H. S. A progression for generating variable interval schedules. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 529-530.
- Herrnstein, R. J. *Behavioral consequences of the removal of a discriminative stimulus associated with variable interval reinforcement*. Unpublished doctoral thesis, Harvard University, 1955.
- Leitenberg, H. Conditioned acceleration and conditioned suppression in pigeons. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 205-212.
- 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. S. Rate-change effects during a pre-schedule-change stimulus. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 383-386.
- Pliskoff, S. S. Rate-change effects with equal potential reinforcements during the "warning stimulus". *Journal of the Experimental Analysis of Behavior*, 1963, 6, 557-562.
- Reynolds, G. S. Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 57-71.
- Reynolds, G. S. Some limitations on behavioral contrast and induction during successive discrimination. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 131-139.
- Terrace, H. S. Stimulus control. In W. K. Honig (Ed.), *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 271-334. (a)
- Terrace, H. S. Behavioral contrast and the peak shift: effects of extended discrimination training. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 613-617. (b)

Received 28 June 1968.