SOME TEMPORAL PROPERTIES OF BEHAVIORAL CONTRAST¹

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Pigeons were rewarded on a variable time interval for pecking a translucent key illuminated with either a 45° or a vertical line. The key illumination changed every 2 min during daily 1-hr sessions. When the rates of pecking were stable, reinforcement was omitted in the presence of the 45° line. Responding in the presence of the vertical line increased. This increase did not disappear when responses to the 45° line were once more reinforced, but when reinforcements for responses in the presence of the 45° line were again omitted, responding to the vertical line increased again. After the second alternation of these two procedures, the increased responding to the vertical line appeared when responses were not reinforced in the presence of the 45° line, and disappeared when reinforcement was available during both stimuli. In a second experiment, the key illumination changed between sessions only, so that 1-hr sessions of reinforcement and non-reinforcement occurred on alternate days. Responding to the vertical line still increased when responding to the 45° line was not reinforced, but the increase tended to disappear during the session.

Behavioral contrast may be defined as an increase in responding in the presence of one stimulus when responding to a second stimulus is no longer reinforced. It has been studied by a number of investigators (*e.g.*, Reynolds, 1961a; Catania, 1964; Bloomfield, 1966), and the results indicate that contrast is largely determined by the relative frequency of reinforcement in the component of the schedule in which it appears. However, the persistence and duration of the contrast effect have not been studied explicitly, although no decline has been observed over several weeks of training in the increased response rate which contrast involves (Reynolds, 1961a).

The two present experiments sought to answer three questions about contrast and its temporal properties: (1) does contrast persist with training, abolishing, and retraining of a successive discrimination; (2) does contrast appear with spaced variable-interval extinction (VI EXT) periods in multiple VI EXT; and (3) how long does the contrast effect last within VI periods if these are lengthened?

METHOD

Subjects

Six adult homing pigeons, which were locally obtained and experimentally naive at the outset, were maintained at 80 to 85% of their free-feeding body weights throughout the experiments.

Apparatus

In Exp. I, a standard pigeon chamber was used. A translucent response key, $\frac{3}{4}$ in. in diameter, was mounted on one wall 8 in. above the floor, with access to a grain magazine directly beneath. Stimuli, which consisted of an $\frac{1}{8}$ -in. wide illuminated line on a dark background at different orientations to the vertical, were projected on the key by an In-Line Digital Display Unit. In Exp. II, a different method of reinforcement was used. A pellet dispenser was modified to release one maple pea at a time into a small tray at floor level below the response key. This reinforcer has been used previously in discrimination learning experiments (Reid, 1958). A typical pea is about $\frac{3}{16}$ -in. in diameter and weighs approximately 0.15 g. The stimuli were mounted behind the response key, which was transparent, and illuminated by the house lights. Standard programming equipment in an adjoining

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room controlled the experimental events in both experiments.

Experiment I

Procedure. Three birds, 61, 62, and 63, were used. They were adapted to the box and trained to peck the key for 4-sec access to a grain mixture over a four-day period. After one session of reinforcement for each response (FR 1), the birds were moved to a variable-interval reinforcement schedule with a mean interreinforcement interval of 1 min (VI 1-min). A vertical (0°) line was projected on the key during FR 1 and VI 1-min schedules. The list of schedules used and the sessions spent on each are shown in Table 1. For most of training, *mult VI VI* and *mult VI EXT* alternated for 20 sessions each. Each component of both multiple schedules was present for 2-min periods in a daily session. The first component of the multiple schedule (always VI 1-min) was correlated with the 0° line on the response key, the second component (either

of *mult VI EXT* and *mult VI VI* continue. Responding does not return to the same level in the first component of the multiple schedule when the discrimination is abolished by reinforcing responses to S-, although the contrast effect in the next *mult VI EXT* phase is maintained. VI rate both in *mult VI VI* and *mult VI EXT* increases during training. The first return to *mult VI VI* from *mult VI EXT*

Table 1

Schedules Programmed in Exp. I

Schedules	Sessions
<i>mult VI VI</i>	20
<i>mult VI EXT</i>	20
<i>mult VI VI</i>	40
<i>mult VI EXT</i>	20
<i>mult VI VI</i>	20
<i>mult VI EXT</i>	20
<i>mult VI VI</i>	20

VI or EXT in successive phases of the procedure) with a 45° line. During the phases of discrimination training (*mult VI EXT*) the two stimuli were effectively a positive stimulus (S+) and a negative (S-), while during the non-discrimination phases (*mult VI VI*), both were S+.

Results. Figure 1 plots response rates in the first component of the schedule over blocks of five sessions. The response rates sustained by VI are higher in *mult VI EXT* than in the *mult VI VI* phase preceding; but VI rates in *mult VI EXT* are not always higher than the rates in the succeeding *mult VI VI* phase. The principal reason for this result seems to be the shifting VI performance from one *mult VI VI* phase to the next. The rate in *mult VI VI* phases increases, then levels off as alternations

Fig. 1. Responding in the first component (always VI 1-min) of either *mult VI VI* or *mult VI EXT* for three birds. The second component is labeled above the panels.

was sustained for 40 days, but the response rates did not fall to their previous level on *mult* VI VI. But VI rates in the next *mult* VI EXT session increased again, above the level on the previous *mult* VI EXT phase, indicating that the contrast effect reached a stable level. Observation of the birds' behavior suggested that the failure to return to the rate sustained by *mult* VI VI originally was due, in part at least, to the adoption of a better response topography. After having responded at a rate of about 1.5 responses per sec, the birds were standing close to the key, in a position to strike it easily, a characteristic not present in behavior during the first *mult* VI VI phase.

Figure 2 shows ratios plotted by dividing VI rate in successive *mult* VI EXT phases by VI rate in either the preceding (filled circles) or the succeeding (open circles) *mult* VI VI phase. By the third alternation of *mult* VI VI and *mult* VI EXT, both ratios have converged. This indicates that a stable level of contrast had been reached.

Experiment II

Procedure. Three birds, 57, 58, and 59, were adapted to the box, trained to eat promptly from the maple pea dispenser, then trained to peck the key over a period of four days. Next, the birds were trained on VI 1-min with a filled red circle $\frac{1}{2}$ -in. in diameter displayed behind the transparent key. Twenty VI sessions lasting 1 hr each were programmed, by

Fig. 2. Ratio of VI rate in *mult* VI EXT to VI rate in preceding (filled circles) and succeeding (open circles) *mult* VI VI phases. Points are plotted for the three successive *mult* VI EXT phases and labeled 1-3 on the abscissa.

which time response rates had stabilized at a baseline level, upon which contrast effects could be observed later in the experiment. In order to test the effects of *mult* VI EXT with spaced presentations of the two components, EXT was introduced in the presence of a green circle of the same dimensions as the red, on alternate days. Each VI and EXT ses-

Fig. 3. Mean rate (M rate) and mean rate for the first 4 min of each session divided by M rate (I/M ratio) are shown for three birds throughout *mult* VI EXT, VI, and *mult* VI VI. Points joined by solid lines show responding to red (always VI 1-min), points joined by broken lines responding to green (first EXT, then omitted for six sessions, then VI). Although responding to red and green are shown together, red and green sessions occurred on alternate days. The caption above the first column indicates that EXT days preceded VI days in *mult* VI EXT. Broken lines in lower panels are drawn at the value of 1.0, to indicate when there is faster responding at the beginning of the session.

sion lasted 1 hr and were separated by 23 hr spent in the living cage. Twenty alternations of VI and EXT took place, during which responding reached a stable level. Next, EXT sessions were omitted and VI sessions were programmed each day. But after six days, when all response rates had not returned to baseline level, *mult* VI VI was programmed, with responses to both red and green stimuli reinforced on alternate days. Fifteen more

alternations of the two components were completed.

Results. Figure 3 (upper panels) shows the response rates to red and green throughout this procedure. In spaced *mult* VI EXT the usual contrast effect is found in all cases, but is smaller in magnitude than obtained previously by the present author (Bloomfield, 1966). The lower panels show a ratio calculated by dividing the response rate in the first

Fig. 4. Responses per second in 2-min periods within selected VI sessions. Sessions 2, 4, 10, and 16 came from the EXT VI column in Fig. 3; session 40 from the VI VI column. Dotted lines show the baseline response rate.

4 min of the session by the mean rate (M rate) over the whole hour. Hence, an I/M ratio in excess of 1.0 indicates faster responding at the beginning of the session. Birds 57 and 58 have ratios slightly but consistently greater than 1.0, while Bird 59 has a ratio of more than 2.0. Response rates to red in the six VI sessions fall off a little, and decline fully to their previous baseline level when green also is correlated with VI.

Figure 4 shows in more detail the contrast effect obtained with this spaced multiple schedule. As training on *mult* VI EXT proceeds, the response rate at the beginning of the session tends to rise above the baseline rate (broken lines). Birds 57 and 58 show this effect slightly, but Bird 59 shows a high response rate for 15 to 20 min within the session, which then declines to the previous baseline level. Session 40 is taken from the final *mult* VI VI training, and shows that there is no residual increase in responding at the beginning of the session when the EXT component of the multiple schedule is replaced by VI. The original performance on VI is recovered in the final *mult* VI VI sessions.

DISCUSSION

The two experiments answer the questions raised about the temporal properties of behavioral contrast. Contrast does persist through training and retraining of a discrimination between the same S+ and S-, although the present results indicate that the baseline rate of responding may shift initially. This finding adds emphasis to the need to take both initial and final measures of baseline rate in such experiments. Contrast appears to be permanent: whenever a stimulus-correlated EXT period alternates with a stimulus-correlated VI period, the VI rate is higher than the baseline in *mult* VI VI.

The results of Exp. II are not so clear. First, it could be argued that the 23-hr period between sessions acted as a time-out procedure to produce its own contrast effect (Reynolds, 1961a). If the 23-hr time out was responsible for increasing the response rate in the first 4 min of VI sessions in the *mult* VI EXT schedule, then such an effect should have appeared also in *mult* VI VI. Such was not the case. Second, in a procedure which alternates stimuli every few minutes, it is rela-

tively easy to demonstrate the control of the stimuli over the bird's behavior, but when one stimulus is present over a whole session, as in Exp. II, the role played by the stimuli could be questioned. It is possible that a discrimination could be formed on some basis other than S+ and S- stimuli: for instance, a certain number of unreinforced responses could serve as a negative stimulus in EXT sessions. The first reinforcement in a VI session was sometimes delayed by as much as 2.5 min on the VI schedule used, but still little responding occurred in EXT in the first 2 min of the session. After session 10, most EXT responding occurred in the second half-hour of each session. Hence, it seems reasonable to suppose that since responding did not occur at the onset of S-, yet did occur at the onset of S+, the spaced schedule may be compared to the usual *mult* VI EXT schedule on matters of the extent of stimulus control.

Experiment II thus suggests that contrast is not a transient phenomenon depending upon the immediate replacement of EXT by VI. With 23 hr separating EXT and VI periods, contrast still appears. But in another respect, contrast is transient: although it reliably appears at the beginning of VI periods in spaced *mult* VI EXT, it declines within a 1-hr session on VI.

Contrast persists then, between, but not within, cycles of a multiple schedule. The "excitatory" effect of extinction (Reynolds, 1961d) appears each time an extinction session with S- precedes a reinforcement session with S+: but as responses to S+ are reinforced, the effect disappears. The law relating contrast to relative reinforcement frequency in one component of a multiple schedule must be qualified in this respect. Certainly, from the experiments quoted in the Introduction, the increase in responding during a VI period characteristic of contrast is related to the difference in reinforcement frequencies between VI and the other component. But the relationship holds for the first few minutes of VI only. Longer VI periods lead to a decline in contrast and a return to VI baseline rate. Perhaps the relativity of response rates and reinforcement frequencies in a multiple schedule should be regarded as an excitatory effect of the drop in reinforcement frequency from one component to the other, superimposed on a VI baseline rate.

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