**FACTORS INFLUENCING INHIBITORY STIMULUS
CONTROL: DIFFERENTIAL REINFORCEMENT OF OTHER
BEHAVIOR DURING DISCRIMINATION TRAINING¹**

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Pigeons were trained to respond on a multiple variable-interval 1-min variable-interval 1-min schedule, then switched to a multiple variable-interval 1-min differential-reinforcement-of-other-behavior discrimination training. The rate of reinforcement was held constant during the shift from non-differential reinforcement to discrimination training. Behavioral contrast and post-discrimination inhibitory stimulus control followed the observation of a reduction in the rate of responding to the stimulus correlated with reinforcement for the non-occurrence of pecking.

The determinants of two characteristics of discrimination learning, behavioral contrast and post-discrimination inhibitory stimulus control, have been the center of considerable recent interest (Reynolds, 1961a; Jenkins, 1965; Terrace, 1966). An increase in the rate of responding to one discriminative stimulus (S_1) that follows a decrease in the rate of responding to another discriminative stimulus (S_2) is termed behavioral contrast (Reynolds, 1961). Behavioral contrast is normally observed during discrimination training if extinction is correlated with S_2 . The correlation of extinction with S_2 , of course, decreases both the frequency of reinforcement and the rate of responding to S_2 . However, recent evidence (Reynolds and Limpo, 1968; Terrace, 1968; Weisman, 1969) suggests that reduced reinforcement frequency is not a necessary condition for the occurrence of behavioral contrast. Most convincing are reports of behavioral contrast during discrimination training that left the rate of reinforcement to S_2 unchanged (Terrace, 1968; Weisman, 1969).

Inhibitory stimulus control has been observed during generalization tests administered after discrimination training with extinction correlated with S_2 (Jenkins and Harrison, 1962; Weisman and Palmer, 1969). That is, when S_2 , but not S_1 , is in the dimension varied during the post-discrimination generalization

test, a shallow U-shaped gradient of inhibition is obtained. Terrace (1968) observed behavioral contrast when responding to S_2 was reduced by differential reinforcement of low rate without a corresponding reduction in relative reinforcement density. A schedule in which responses terminating interresponse times longer than some specified duration are always reinforced, while responses terminating shorter interresponse times are never reinforced, is termed differential reinforcement of low rate (DRL). Weisman (1969) obtained both behavioral contrast and inhibitory stimulus control following a shift from a multiple variable-interval 1-min variable-interval 1-min schedule (*mult* VI 1-min VI 1-min) to *mult* VI 1-min DRL with the rate of reinforcement during DRL equated with the rate of reinforcement that prevailed during VI 1-min. Perhaps a reduction in the relative reinforcement density correlated with S_2 is not a necessary antecedent of either behavioral contrast or inhibitory stimulus control.

In Reynold's (1961a) experiment, the rate of responding to S_2 was reduced by the differential reinforcement of other behavior (DRO). In this schedule, reinforcement occurs whenever the bird has not pecked for some specified time. Reynolds observed a reduction in the rate of responding to S_2 , but no behavioral contrast to S_1 . Reynolds and Limpo (1968) and Nevin (1968) pointed out that the rate of reinforcement correlated with S_2 in Reynolds (1961a) *mult* VI 3-min DRO 50-sec schedule increased by as much as a factor of three during discrimination training. When Nevin

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(1968) varied the rate of DRO reinforcement correlated with S_2 he obtained induction, a reduction in the rate of responding to S_1 , when the rate of DRO reinforcement in S_2 exceeded the rate of VI reinforcement in S_1 . In the present experiment, the effects of *mult* VI DRO were again under investigation, but instead of increasing (Reynolds, 1961a) or systematically varying (Nevin, 1968) DRO reinforcement frequency, the present work sought to equate the rate of DRO reinforcement in S_2 with the rate of reinforcement provided by VI in S_1 .

METHOD

Subjects

Four experimentally naive, male, Silver King pigeons, 6 to 8 yr old were maintained at about 75% of their free-feeding weight during the experiment.

Apparatus

A Lehigh Valley Model 1519 pigeon chamber was used. The center key was transilluminated by an Industrial Electronics Engineers in-line display cell. Six orientations of a $\frac{1}{8}$ in. (3.175 mm) wide by $\frac{7}{8}$ in. (22.225 mm) high white line ($\pm 90^\circ$, -60° , -30° , 0° , $+30^\circ$, and $+60^\circ$ of departure from a vertical line orientation) and a green surround were projected by the display cell. Reinforcement was 3-sec access to mixed grain. White noise and noise from an exhaust fan masked extraneous sound. Recording and scheduling equipment were located in a separate room.

Procedure

Key-peck training was followed by sessions in which the requirement for reinforcement was increased to 45 responses (FR 45). Key-peck and FR 45 training were complete in three to four sessions; the visual stimuli on the key during this preliminary training were those presented during the first phase of the experiment proper.

Throughout the experiment a visual stimulus appeared on the key during 60-sec trials and the key was darkened during alternated 10-sec timeout for 28 trials per session. A white vertical (0°) line on a green surround and the (blank) green surround alone appeared on the key in an irregular sequence (several inde-

pendent randomized orders were used) of approximately 14 presentations of each stimulus during each session.

During the non-differential reinforcement phase of the experiment, identical but independent 1-min variable-interval schedules of reinforcement were correlated with the 0° line and the blank green key (*mult* VI 1-min VI 1-min). Non-differential reinforcement consisted of two sessions with *mult* VI 30-sec VI 30-sec followed by 20 sessions with *mult* VI 1-min VI 1-min.

After non-differential reinforcement the birds had 14 sessions of discrimination training with a *mult* VI 1-min DRO schedule. During this training, the DRO schedule was correlated with the 0° line on the green surround. Timing of the DRO requirement commenced with the onset of a 0° line trial, but during the trial, began with the last response. In order to maintain equality between the rates of reinforcement prevailing during VI 1-min, correlated with the blank green key, and DRO, correlated with the 0° line, it was necessary to adjust the minimum period of not responding reinforced by the DRO schedule during each session of discrimination training. In practice, adjustments in the duration of the DRO requirement, in 4-sec steps, were made during blackouts preceding DRO trials. Both increases and decreases in the DRO requirement were required to maintain equal reinforcement rates in the two components of the schedule. However, over sessions the duration of the DRO gradually increased, as a consequence of reduced responding to S_2 , from DRO 4-sec to DRO 32-sec. Discrimination training was identical to prior non-differential reinforcement, except for the change in reinforcement schedules.

Each bird had a generalization test in extinction after discrimination training. The session in which the test was conducted began with four reinforcement (VI 1-min) presentations of the blank green key; the 0° line was not presented during this "warm-up". During the generalization test, the stimuli were six orientations of the white line: $\pm 90^\circ$, -60° , -30° , 0° , $+30^\circ$, and $+60^\circ$ departures from vertical, each on a green surround, and the green surround (blank key) alone. These stimuli were each presented 10 times in randomized blocks of seven 30-sec trials separated by 5-sec blackouts.

RESULTS

If reinforcement density was nearly equal for the two stimuli presented during *mult* VI 1-min DRO the effect of only a reduction in the rate of responding to the 0° line can be assessed. Shown in Fig. 1 are the rates of reinforcement, either reinforcements per minute (the left-hand ordinate) or average inter-reinforcement interval (the right-hand ordinate) for 14 sessions of *mult* VI 1-min DRO discrimination training. In order to avoid overlap, reinforcement rates for the 0° line are shown just to the left, and reinforcement rates for the blank green key just to the right of the point at which both would usually be plotted. Adjustment of the rate of reinforcement for the non-occurrence of pecking appears to have been successful, since reinforcements were ob-

Fig. 1. The rates of reinforcement correlated with the 0° line and blank green key during *mult* VI 1-min DRO. The rates were displaced laterally in plotting to avoid overlap.

Fig. 2. The rates of responding to the 0° line and blank green key during the last 10 sessions of non-differential reinforcement and 14 sessions of discrimination training.

tained at nearly the same rate during DRO as during VI 1-min.

Response rate functions for the last 10 sessions of non-differential reinforcement (*mult* VI 1-min VI 1-min) and 14 sessions of discrimination training (*mult* VI 1-min DRO) are presented in Fig. 2. Each bird showed a reduction in the rate of responding to the 0° line after the switch from VI 1-min to DRO reinforcement. Behavioral contrast was ob-

served in each case: the rate of responding to the blank green key increased as the rate of responding to the 0° line decreased. Contrast was most evident in the functions obtained from Birds 2889, 2291, and 2390, but contrast was apparently also obtained with Bird 2489: the rate of responding during 10 of 14 discrimination training sessions exceeded the highest response rate obtained during non-differential reinforcement. In the present experiment, the increase in the rate of responding to the blank green key was not immediate, and was, in fact, generally preceded by a decrease in the rate of responding to both stimuli.

The results of a post-discrimination generalization test, administered to each bird, are shown in Fig. 3. Responding generally increased in a U-shaped function about the 0° line. However, the inhibitory stimulus control functions shown in Fig. 3 are somewhat irregular: response strength was often as great, or greater, at stimuli adjacent to the 0° line (30° or 60°) as at the $\pm 90^\circ$ line orientation. Response strength to the blank green key, plotted on a separate ordinate to the right of each stimulus control function in Fig. 1, was considerably greater than in the line orientation dimension.

DISCUSSION

Previous research with *mult* VI DRO schedules suggests that the rate of responding in the VI component is a continuous function of the relative rate of reinforcement in the DRO component. Similar findings have been reported for *mult* VI FR (Reynolds, 1961*b*) and *mult* VI DRL schedules (Bloomfield, 1967). Stated in terms of the behavioral interactions obtained, the rule states that contrast results from decreases, and induction from increases, in the relative rate of reinforcement correlated with S_2 . It would appear, however, that a change in relative rate of reinforcement is neither a necessary nor a sufficient antecedent of behavioral contrast and inhibitory stimulus control: (a) Behavioral contrast and inhibitory stimulus control have been observed following discrimination training with equated reinforcements in the present study using *mult* VI DRO and by Terrace (1968) and by Weisman (1969) using *mult* VI DRL. (b) Behavioral contrast and inhibitory stimu-

Fig. 3. Post-discrimination line orientation gradients for the stimulus correlated with DRO during prior *mult* VI 1-min DRO.

lus control are sometimes absent after the reduction of reinforcement frequency in S_2 , for example following *mult* VI EXT without errors (Terrace, 1966) and following multiple tandem schedules that did not reduce the rate of responding to S_2 (Yarczower, Dickson, and Gollub, 1966). Two of these studies (Terrace, 1968; Yarczower, *et al.* 1966) provided evidence concerning behavioral contrast, but did not explicitly examine inhibitory stimulus control.

Terrace (1968) suggested that a discriminative stimulus becomes functionally negative as a result of a reduction in the rate of

responding in its presence and that the characteristics of such negative control are behavioral contrast and inhibitory stimulus control. On examination, the evidence cited in support of the response-rate reduction hypothesis is essentially the same as the evidence against the reinforcement-rate reduction hypothesis. However, the suggestion that a reduction in the rate of responding to S_2 is a sufficient antecedent for behavioral contrast and inhibitory stimulus control is challenged by evidence already discussed. Reynolds (1961a) and Nevin (1968) reduced the rate of responding to a stimulus correlated with DRO by increasing the rate of DRO reinforcement: Reynolds did not observe contrast and Nevin obtained neither behavioral contrast nor inhibitory stimulus control under those conditions. That a reduction in the rate of responding to S_2 is a necessary antecedent is thus far uncontested, but clearly not all of the procedures that generate orderly gradual response-rate reductions to S_2 generate behavioral contrast and inhibitory stimulus control as well.

A methodological criticism is occasionally raised against the use of the line orientation dimension in obtaining inhibitory gradients. It is possible that in acquiring the discrimination between line present and line absent the bird has learned to look at, and to peck at, one local area of the key, say the top of the key. Thus, when the line is absent from the upper portion of the key a high rate of responding is obtained and when the line is present at the same location a low rate of responding is obtained. During the generalization test the orientation of the line is varied, thus removing the line from the upper (and supposedly attended to) portion of the key to a greater or lesser extent depending on the amount of rotation. This hypothetical description places the various orientations of the line and the absence of the line in the same dimension, and, if correct, suggests that the resulting U-shaped gradient is not necessarily a result of inhibitory stimulus control. The results of two recent experiments render the present argument less plausible than it first appeared. In Nevin's (1968) experiment *mult VI EXT*, but not *mult VI DRO* with increased DRO reinforcement, generated inhibitory stimulus control. In Weisman's (1969) experiment, a shift from *mult VI 1-min VI 1-min* to

mult VI 1-min VI 5-min, but not from *mult VI 5-min VI 5-min* to *mult VI 1-min VI 5-min*, generated inhibitory stimulus control. Both experimenters obtained post-discrimination gradients on the line orientation dimension. The presence or absence of inhibitory stimulus control was apparently determined by a different independent variable in each experiment. Moreover, it is difficult to see how either procedure bore any obvious relation to the way the bird looked at the key.

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