

*DISCRIMINATION OF A RESPONSE-INDEPENDENT COMPONENT IN A MULTIPLE SCHEDULE<sup>1</sup>*

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Pigeons were trained to respond in non-differential reinforcement pre-discrimination training, with a multiple variable-interval 1-min variable-interval 1-min schedule. Each bird then received discrimination training with a multiple variable-interval 1-min variable-time 1-min schedule. Thus, discrimination training was between response-dependent (variable-interval) and response-independent (variable-time) schedules with the rate of reinforcement equated. In Experiment I, only three sessions of non-differential reinforcement preceded discrimination training and for half the birds, a 0° line was correlated with the response-dependent schedule; for the remaining birds the 0° line was correlated with the response-independent schedule. Post-discrimination gradients of excitatory stimulus control were obtained from the former group, while the latter group showed little evidence of post-discrimination stimulus control by the 0° line. Differential responding to the variable-time schedule was not accompanied by behavioral contrast to the variable-interval schedule. In Experiment II, 20 sessions of non-differential reinforcement preceded discrimination training and the 0° line was correlated with variable-time reinforcement for each bird. Differential responding to the 0° line was accompanied by negative induction to the variable-interval schedule and by inhibitory stimulus control about the 0° line during a post-discrimination generalization test.

Considerable interest has recently centered on the determinants of two characteristics of discrimination learning: behavioral contrast and inhibitory stimulus control. An increase in the rate of responding to one discriminative stimulus ( $S_1$ ), for which the rate of reinforcement does not change, 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  $S_2$ . 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 about  $S_2$  is obtained.

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Behavioral contrast and inhibitory stimulus control are commonly, but not universally, obtained products of discrimination training. It has been suggested that two basically different types of discrimination learning may result from multiple schedule training (Jenkins, 1965). One type of discrimination learning (Jenkins, 1965) would establish only excitatory stimulus control for  $S_1$ : the organism learns to respond to  $S_1$ , and to respond at a lower rate in its absence. This type of discrimination learning sharpens the post-discrimination excitatory gradient about  $S_1$ , without producing either behavioral contrast or post-discrimination inhibitory stimulus control (Terrace, 1968). Terrace's (1966) errorless discrimination procedure, multiple schedules that leave the rate of responding to  $S_2$  unchanged (Weisman, 1969), and multiple schedules that increase the rate of reinforcement to  $S_2$  (Nevin, 1968) are examples of this type of discrimination learning.

Another type of discrimination learning (Jenkins, 1965) would be necessary to establish both excitatory stimulus control for  $S_1$  and inhibitory stimulus control for  $S_2$ : the organism learns to respond to  $S_1$  and to re-

spond at a lower rate to  $S_2$ . Inhibitory stimulus control and behavioral contrast are presumed to be consequences of an organism's learning to respond at a lower rate to  $S_2$  (Terrace, 1968; Weisman, 1969). Although discrimination learning was first investigated using a multiple schedule that alternated reinforcement and extinction (*mult VI EXT*), this second type of discrimination does not appear to be dependent upon the alternation of extinction with reinforcement. Behavioral contrast and inhibitory stimulus control (Weisman, 1969; 1970) can also occur when the rate of reinforcement correlated with  $S_2$  is not altered. Both phenomena were obtained when Terrace (1968) and Weisman (1969) reduced that rate of responding to  $S_2$  by differential reinforcement of low rate (DRL) while holding reinforcement frequency equal in  $S_1$  and  $S_2$ . Also, Weisman (1970) produced a reduction in the rate of responding to  $S_2$  using differential reinforcement of other behavior (DRO). Again, reinforcement frequency was equal in  $S_1$  and  $S_2$  and both behavioral contrast and inhibitory stimulus control were obtained. These investigators concluded that a change in the relative rate of reinforcement correlated with  $S_2$  was neither a necessary nor a sufficient antecedent of discrimination of the second type.

Although the studies just cited showed that the overall reinforcement frequency in  $S_1$  and  $S_2$  can be equated in discrimination training of the second type, they do not rule out local effects of non-reinforcement as a determinant of behavioral contrast and inhibitory stimulus control. In *mult VI DRL* and *mult VI DRO* discrimination training, non-reinforcement "forces" a reduction in the rate of responding to  $S_2$ . Terrace (1972) suggested that the bird avoids the emotional consequences of non-reinforcement when responses are held back, or inhibited, in the presence of  $S_2$ .

## EXPERIMENT I

When reinforcers are scheduled independently of responding (Zeiler, 1968; Rescorla and Skucy, 1969) the rate of responding is reduced. The response-independent variable-time schedule, termed VT by Zeiler (1968), reduced responding without reducing reinforcement frequency and did not require a forced reduction in responding, as in DRO or

DRL schedules, to maintain the rate of reinforcement. If differential responding in a multiple schedule is established without requiring a forced reduction in responding then, perhaps, the rate of responding to  $S_2$  would decrease without producing behavioral contrast or inhibitory stimulus control. The present experiments examined the by-products of discrimination between response-dependent and response-independent reinforcement, *mult VI VT*, with the rates of reinforcement in  $S_1$  and  $S_2$  equated.

## METHOD

### Subjects

Eight experimentally naive, male Silver King Pigeons, 6- to 8-yr old were maintained at about 80% of their free-feeding weights 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 0.125 in. (3.2 mm) wide by 0.875 in. (22.2 mm) high white line ( $\pm 90^\circ$ ,  $-60^\circ$ ,  $-30^\circ$ ,  $0^\circ$ ,  $+30^\circ$ , and  $+60^\circ$  of departure from a vertical line orientation) and a green surround were projected by the display cell. The reinforcer 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. Key-peck and fixed-ratio 45 (FR 45) training were completed 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 ( $0^\circ$ ) line on a green surround and the (blank) green surround alone appeared on the key in an irregular sequence (several independent 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  $0^\circ$  line and the blank green key (*mult VI 1-min VI 1-min*). Two sessions with *mult VI 30-sec VI 30-sec* were followed by three sessions with *mult VI 1-min VI 1-min*.

After non-differential reinforcement, the birds had 10 sessions of discrimination training with a *mult VI 1-min VT 1-min* schedule. Discrimination training sessions were identical to prior non-differential training sessions except that presentations of the reinforcer occurring in the presence of one of the visual stimuli were not dependent on responding. Instead, food was presented at the same temporal intervals as in VI 1-min but independently of responding (*mult VI 1-min VT 1-min*). Four birds had the  $0^\circ$  line on a green surround,  $S_1$ , correlated with VI 1-min and the blank green surround,  $S_2$ , correlated with VT 1-min; the remaining four birds had the blank green surround,  $S_1$ , correlated with VI 1-min and the  $0^\circ$  line on a green surround,  $S_2$  correlated with VT 1-min.

Each bird had a generalization test in extinction after discrimination training. The session in which the test was conducted began with four presentations of  $S_1$  correlated with VI 1-min reinforcement. The stimulus ( $S_2$ ) correlated with VT 1-min was not presented during this "warm-up".

During the generalization test, the stimuli were six orientations of the white line:  $\pm 90^\circ$ ,  $-60^\circ$ ,  $-30^\circ$ ,  $0^\circ$ ,  $+30^\circ$ , 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.

Following the generalization test the birds had eight sessions of non-differential reinforcement (*mult VI 1-min VI 1-min*). These sessions were included to assess behavioral contrast.

#### RESULTS

The rate of responding to  $S_1$  and  $S_2$  for three sessions of non-differential reinforcement (*mult VI 1-min VI 1-min*), 10 sessions of discrimination training (*mult VI 1-min VT 1-min*), and a final eight sessions of non-differential reinforcement (*mult VI 1-min VI 1-min*)

are presented in Figures 1 and 2. Figure 1 shows response-rate functions for birds that had the  $0^\circ$  line as  $S_1$  and Figure 2 shows the functions for birds that had the  $0^\circ$  line as  $S_2$ . Differential responding developed by the third session of discrimination training (*mult VI 1-min VT 1-min*) for seven of eight birds; Bird 2402 showed clear evidence of differential responding two sessions later. Responding to  $S_1$  increased gradually over the course of discrimination training, but remained at approximately the same rate during post-discrimination non-differential reinforcement. Presumably, if behavioral contrast had occurred during discrimination training, the rate of responding to  $S_1$  would have decreased over the course of post-discrimination non-differential reinforcement (Terrace, 1966). Responding to  $S_2$  de-

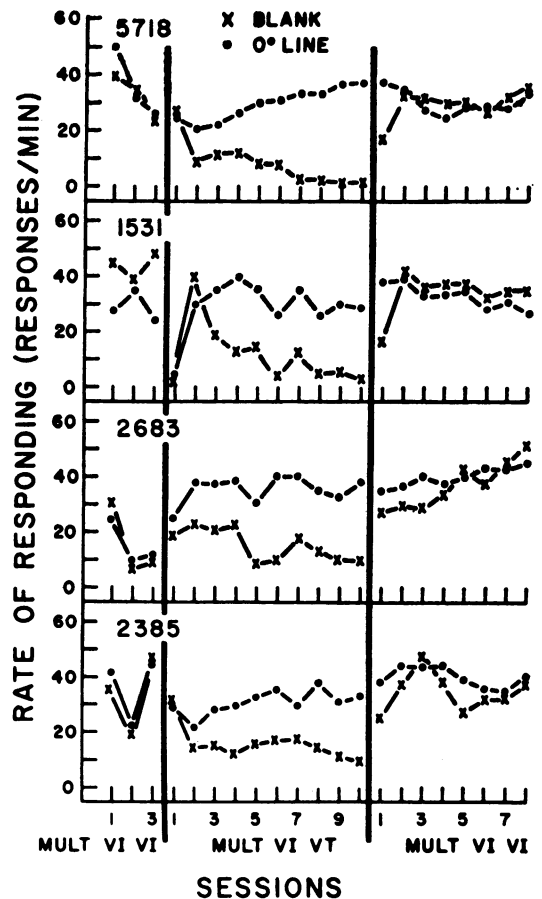


Fig. 1. The rates of responding to the  $0^\circ$  line and blank green key during differential and non-differential reinforcement in Experiment I. The blank green key was correlated with VT reinforcement.

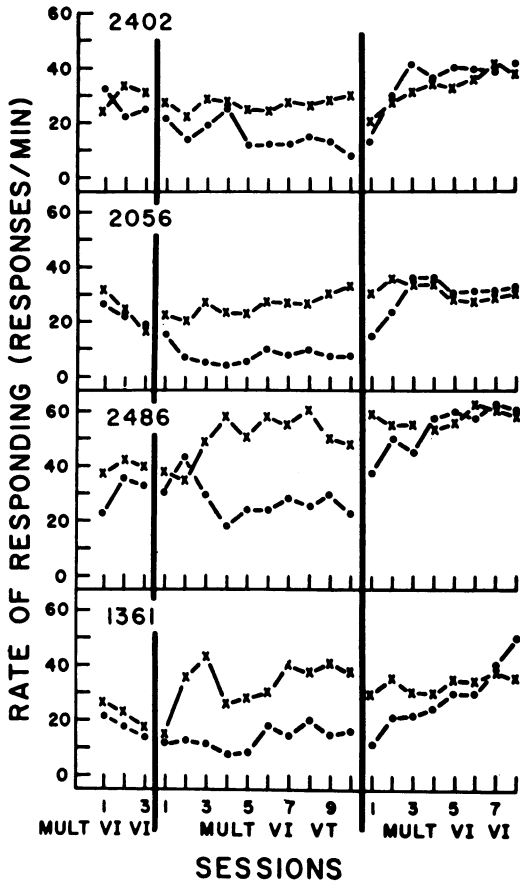


Fig. 2. The rates of responding to the 0° line and blank green key during differential and non-differential reinforcement in Experiment I. The blank green key was correlated with VI reinforcement.

creased gradually during discrimination training, then increased to the rate of responding during S<sub>1</sub> over the first few (1 to 3) sessions of post-discrimination non-differential reinforcement.

The rates of reinforcement, reinforcements per minute, correlated with S<sub>1</sub> and S<sub>2</sub> during 10 sessions of discrimination training are shown for birds trained with the 0° line correlated with VI 1-min in Figure 3, and for birds trained with the 0° line correlated with VT 1-min in Figure 4. In order to avoid overprinting, 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. In general, *mult VI* 1-min *VT* 1-min appears to have distributed reinforcement equally to S<sub>1</sub> and S<sub>2</sub>. An exception occurred

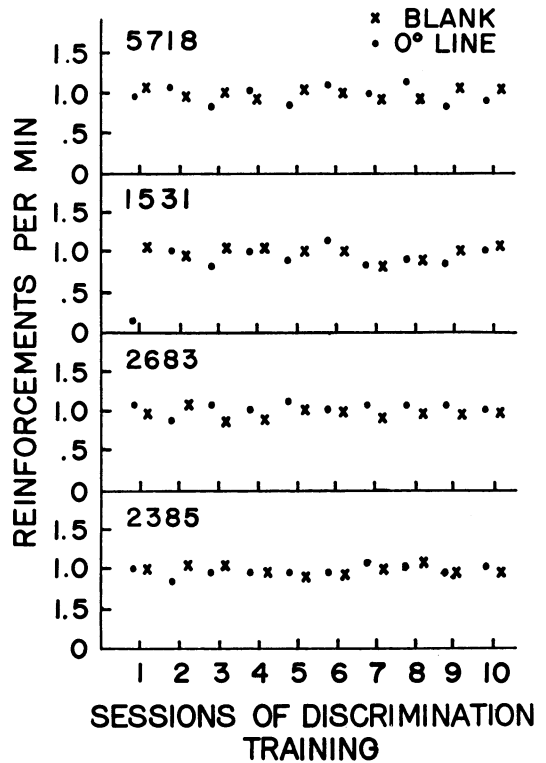


Fig. 3. The rates of reinforcement correlated with the 0° line and blank green key during discrimination training in Experiment I. The blank green key was correlated with VT reinforcement. Reinforcement rates were displaced laterally in plotting to avoid overlap.

during the first session of discrimination training for Bird 1531. A low rate of responding emitted to both S<sub>1</sub> and S<sub>2</sub> by Bird 1531 (see Figure 1) resulted in a marked decrease in reinforcement frequency in the presence of the 0° line, (see Figure 3) correlated with response-dependent VI 1-min reinforcement during the initial discrimination session. However, VI reinforcement frequency returned to approximately one per minute in all later sessions.

Post discrimination generalization gradients for birds trained with the 0° line as S<sub>1</sub> are shown in Figure 5. Gradients of excitatory stimulus control that peaked at S<sub>1</sub> were obtained from each bird and the gradients obtained from Birds 5718, 1531, 2385 were steep and convex. Response strength in the line orientation dimension was greater than to S<sub>2</sub>, the blank green key (G), plotted as "X" to the right in Figure 5. Post-discrimination generalization gradients for birds trained with the 0° line as S<sub>2</sub> are shown in Figure 6. Respond-

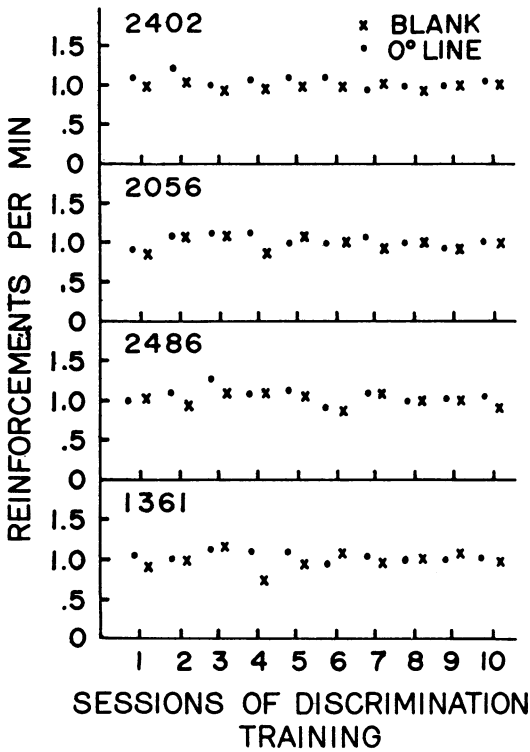


Fig. 4. The rates of reinforcement correlated with the 0° line and blank green key during discrimination training in Experiment I. The blank green key was correlated with VI reinforcement. Reinforcement rates were displaced laterally in plotting to avoid overlap.

ing to  $S_2$  was never reduced below the level of responding to at least some of the adjacent generalization stimuli. The stimulus functions obtained from Birds 2402, 2056, and 2486 are nearly flat, but a shallow excitatory gradient about  $S_2$  was obtained from Bird 1361. Thus, no U-shaped gradients of inhibitory stimulus control were obtained. Response strength to  $S_1$ , the blank green key, is plotted as "X" at the right of Figure 6. Fewer responses were emitted to stimuli in the line orientation dimension than to the blank green key, but each bird responded at least occasionally to each stimulus presented in the test. During the generalization test, response strength in the line orientation dimension was consistent, across birds, with the rate of responding to  $S_2$  during prior discrimination training: Birds 2486 and 1361 responded at a higher rate to  $S_2$  during discrimination training and in the line orientation dimension than Birds 2402 and 2056.

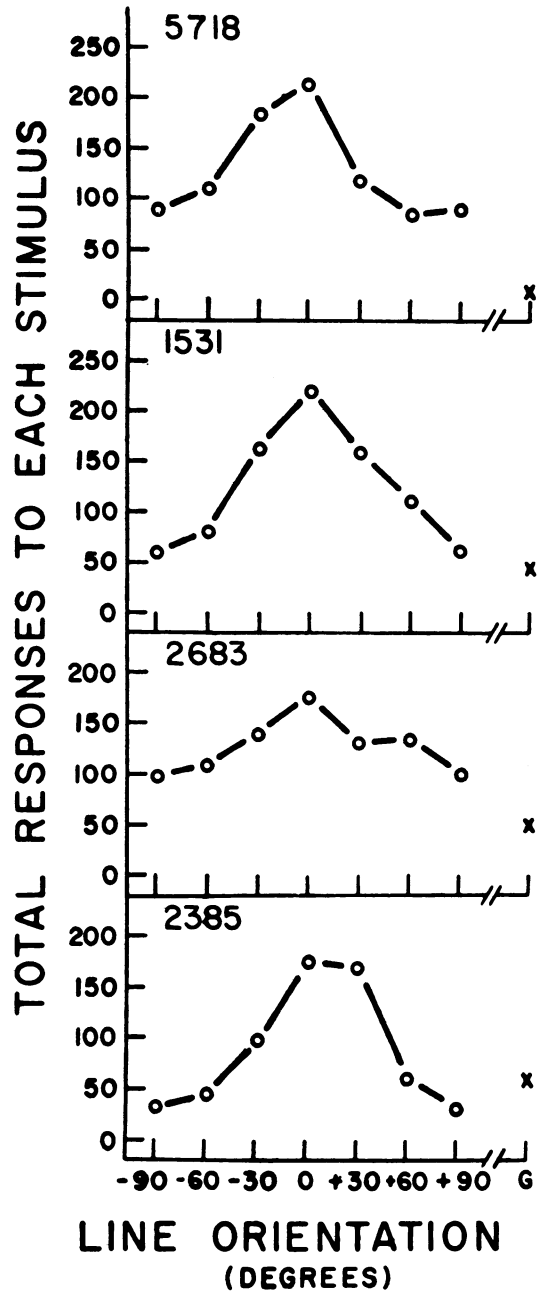


Fig. 5. Post-discrimination line orientation gradients for the stimulus correlated with VI 1-min during mult VI 1-min VT 1-min training in Experiment I.

DISCUSSION

In the context of recent research in the area of stimulus control, the results of Experiment I remind us that a number of current notions about inhibitory stimulus control are prob-

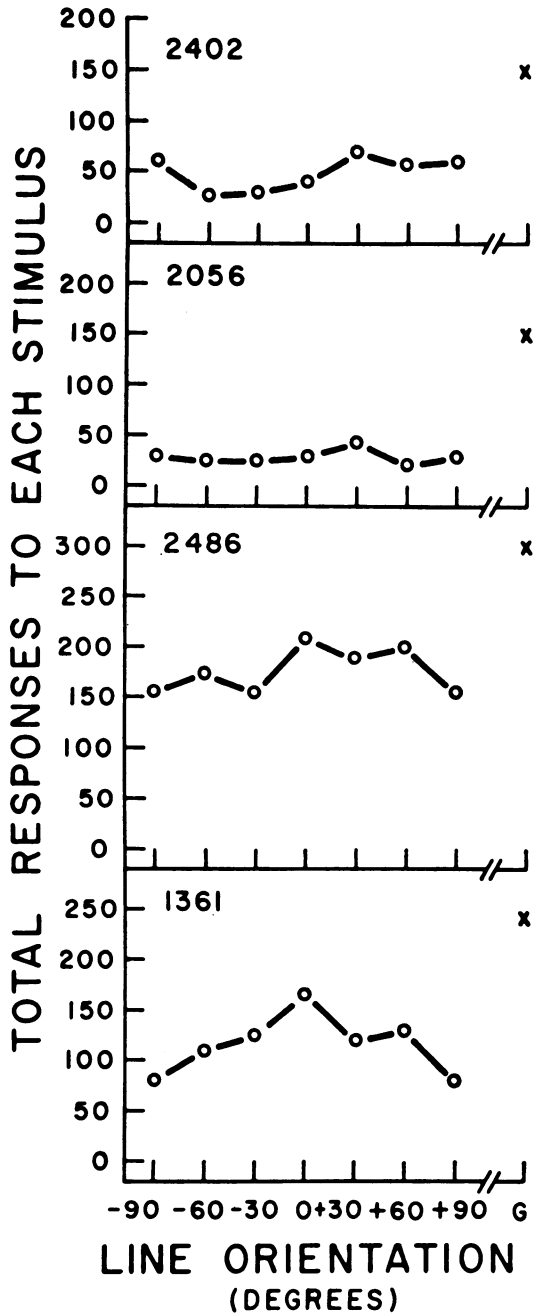


Fig. 6. Post-discrimination line orientation gradients for the stimulus correlated with VT 1-min reinforcement during *mult* VI 1-min VT 1-min training in Experiment I.

ably in error. (a) Some authors (Rescorla, 1969; Hearst, Besley, and Farthing, 1970) have argued that sharpened excitatory stimulus control and the gradient of inhibitory

stimulus control may be products of the same antecedents. That is, both are due to changes in the excitatory strength of  $S_2$ . Comparison of post-discrimination line-orientation gradients obtained in the present study with gradients obtained following non-differential VI 1-min reinforcement in this laboratory (Weisman and Palmer, 1969) suggests that *mult* VI 1-min VT 1-min discrimination training sharpened the gradient of excitation about  $S_1$ . However, correlation of response-independent VT reinforcement with  $S_2$  did not generate a gradient of inhibitory control about  $S_2$ . Also, gradients obtained by Terrace show that errorless discrimination learning sharpens excitatory stimulus control (Hilgard and Bower, 1966, p. 521) without generating a gradient of inhibitory stimulus control (Terrace, 1972). Clearly, excitatory and inhibitory stimulus control are not necessarily products of identical antecedents. (b) Behavioral contrast and inhibitory stimulus control have been produced (Reynolds, 1961; Terrace, 1968) and eliminated (Reynolds, 1961; Nevin, 1968) by, respectively, decreasing and increasing the relative rate of reinforcement correlated with  $S_2$ . Discrimination training has also been conducted with equal relative rates of reinforcement in  $S_1$  and  $S_2$ . When DRL (Weisman, 1969) or DRO (Weisman, 1970) is correlated with  $S_2$ , behavioral contrast and inhibitory stimulus control were observed. When VT was correlated with  $S_2$  in Experiment I, neither phenomenon was observed. It would appear that not even equalization of the rates of reinforcement in  $S_1$  and  $S_2$  is predictive of the presence or absence of behavioral contrast and inhibitory stimulus control. (c) A gradual reduction in the rate of responding to  $S_2$  has also been labelled as a determinant of behavioral contrast (Terrace, 1968) and inhibitory stimulus control (Weisman, 1969). Reduced responding in the presence of  $S_2$  has preceded the observation of a gradient of inhibition in virtually every published account of the phenomenon. As the present work demonstrated, however, reduced responding to  $S_2$  can also precede the observation of horizontal gradients about  $S_2$ . Also, the response rate to  $S_2$  can be reduced by increasing reinforcement frequency in  $S_2$  (Nevin, 1968), or by satiation of the reinforcer delivered in  $S_2$  (Premack, 1969), without generating behavioral contrast or inhibitory stimulus control.

The results of Experiment I are in line with Terrace's (1972) suggestion that only forced reduction in the rate of responding to  $S_2$  results in the second type of discrimination learning. Reduced responding to  $S_2$  generated by errorless discrimination (Terrace, 1966) or in Experiment I by response-independent reinforcement does not appear to generate behavioral contrast and inhibitory stimulus control as by-products.

EXPERIMENT II

In Experiment I, only a few sessions of non-differential reinforcement preceded *mult* VI VT training. Thus, behavioral contrast was evaluated in part by comparison with non-differential reinforcement sessions administered after discrimination training. In Experiment II, as in prior work (Weisman, 1969; 1970), considerable non-differential reinforcement, 20 sessions, preceded discrimination training, but as in Experiment I non-differential reinforcement sessions also followed discrimination training. It was anticipated that additional non-differential reinforcement sessions would provide a more stable "baseline" for assessment of behavioral contrast during discrimination training.

METHOD

Subjects

Six experimentally naive, adult male Silver King pigeons were maintained at about 80% of their free-feeding weights during the experiment.

Procedure

The procedure was identical to that used in Experiment I with two exceptions. Twenty, rather than only three, sessions of *mult* VI 1-min VI 1-min non-differential reinforcement preceded *mult* VI 1-min VT 1-min discrimination training. Also, in Experiment II, each bird had the 0° line correlated with VT 1-min reinforcement in order to focus on stimulus control in the  $S_2$  dimension.

RESULTS

Response rate functions for the final three sessions of pre-discrimination *mult* VI 1-min VI 1-min non-differential reinforcement, 10 sessions of *mult* VI 1-min VT 1-min discrimination training, and eight sessions of post-dis-

crimination *mult* VI 1-min VI 1-min non-differential reinforcement are shown in Figure 7. Differential responding to  $S_1$  and  $S_2$  during discrimination training was obtained from four of six birds. During later non-differential reinforcement, responding to  $S_2$  gradually accelerated and returned to the rate of responding emitted to  $S_1$  for these same four birds. The rate of responding to  $S_1$  during discrimination training generally decreased below the

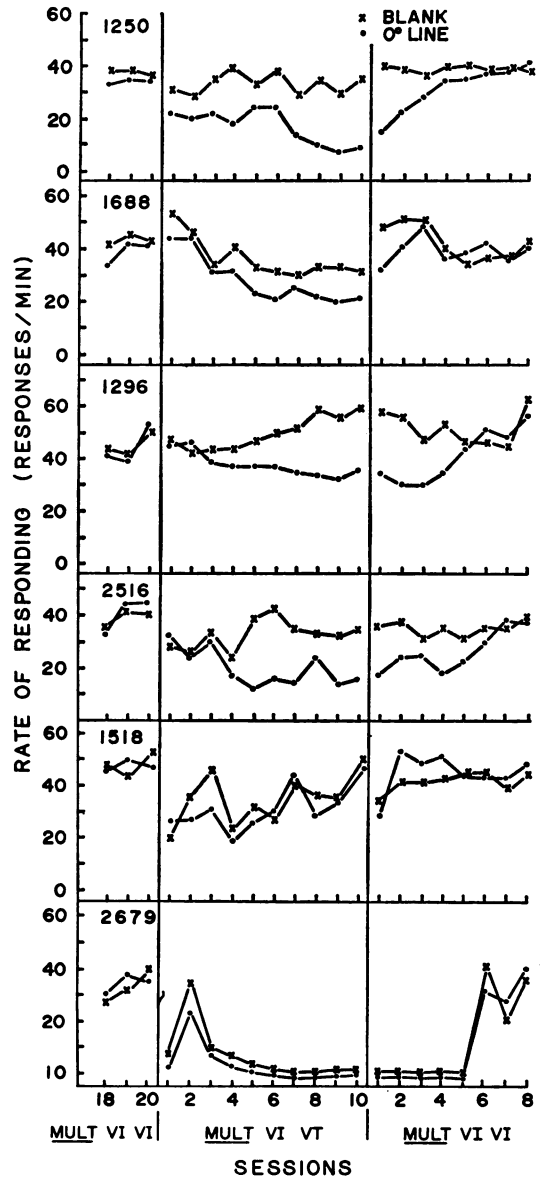


Fig. 7. The rates of responding to the 0° line and blank green key during differential and non-differential reinforcement in Experiment II.

rate of responding to the same stimulus during pre- and post-discrimination non-differential reinforcement. Differential responding was not obtained for Birds 1518 or 2679. Responding was initially reduced to both stimuli and Bird 2679 virtually ceased responding during the last five sessions of discrimination training.

The rates of reinforcement correlated with  $S_1$  and  $S_2$ , plotted as in Experiment I, are shown in Figure 8. Responding to  $S_1$  maintained approximately equal rates of reinforcement to  $S_1$  and  $S_2$  in Birds 1250, 1688, 1296, 2516, and 1518. Severely reduced re-

sponding to  $S_1$ , correlated with a VI 1-min schedule, correspondingly reduced the rate of reinforcement to  $S_1$  to near zero for Bird 2679.

Post-discrimination generalization gradients obtained in Experiment II are shown in Figure 9. Responding to the blank green key (B) is shown as "X" to the right in Figure 9. Incremental gradients of inhibitory stimulus control about  $S_2$  were obtained from the four birds that responded differentially to  $S_1$  and  $S_2$  during prior discrimination training. The remaining birds (1518 and 2679) responded about equally to  $S_2$  and the generalization stimuli. All of the birds responded, at least occasionally, to each of the stimuli presented during the generalization test.

DISCUSSION

Discrimination training and the generalization test were identical in Experiments I and II. However, an extensive history of non-differential reinforcement preceded discrimination training in Experiment II. Differential responding reduced responding to  $S_2$ , and the post-discrimination gradients differed between the experiments. In Experiment I, differential responding was established in each bird and the rate of responding to  $S_2$  was reduced to fewer than 10 responses per minute for six of eight birds. In Experiment II, differential responding was observed in only four of six birds and responding to  $S_2$  was reduced to 10 or fewer responses per minute for only one of these birds. Moreover, responding to  $S_2$  during post-discrimination non-differential reinforcement increased to the rate of responding prevailing in  $S_1$  more slowly in Experiment II than in Experiment I. Finally, and of considerable interest, stimulus control by  $S_2$  was not observed in Experiment I, but post-discrimination gradients of inhibitory stimulus control about  $S_2$  were obtained from each bird that showed differential responding in Experiment II.

GENERAL DISCUSSION

In Experiment II, as in Experiment I and in Halliday and Boakes' (1971) study of *mult* VI VT discrimination training, behavioral contrast was absent. However, behavioral contrast is not the only form of behavioral interaction obtained during discrimination learning (Reynolds, 1961). Halliday and Boakes

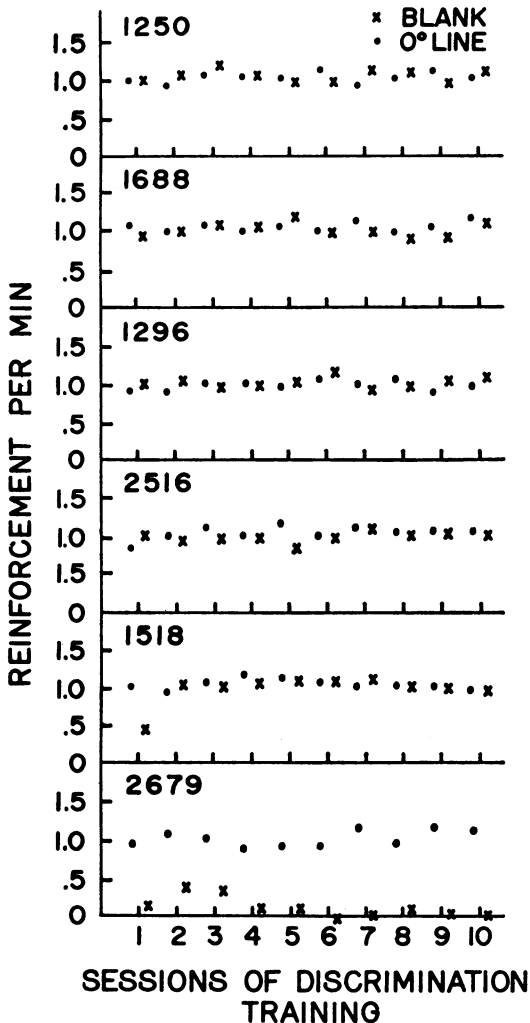


Fig. 8. The rates of reinforcement correlated with the 0° line and blank green key during discrimination training in Experiment II. Reinforcement rates were displaced laterally in plotting to avoid overlap.



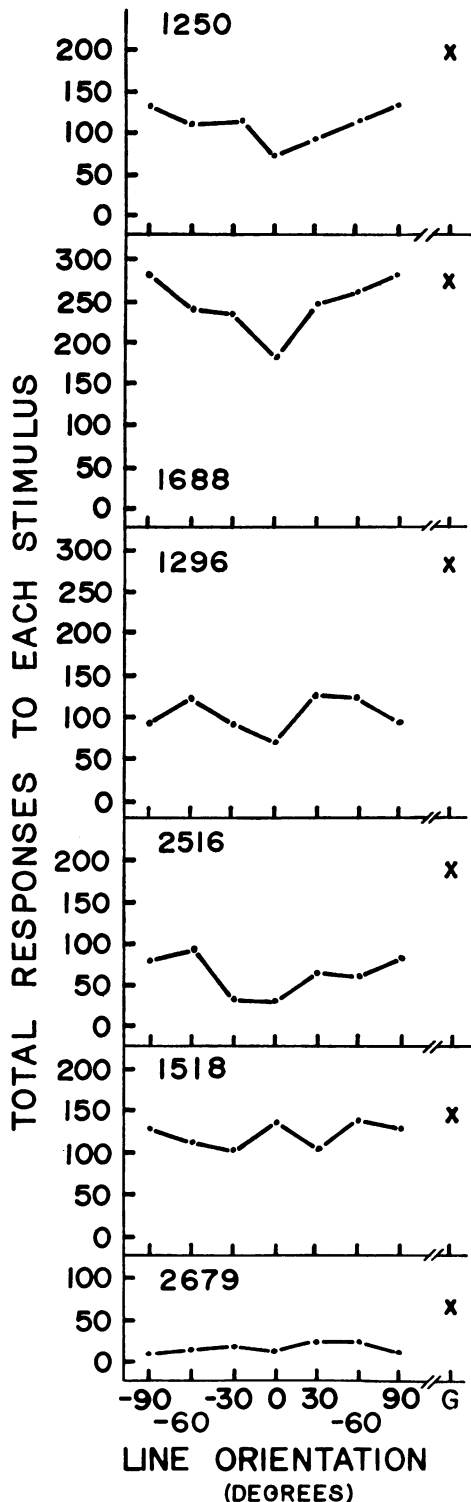


Fig. 9. Post-discrimination line orientation gradients for the 0° line correlated with VT 1-min reinforcement in Experiment II.

point out that responding to  $S_1$  decreased, rather than increased during *mult VI VT* and, indeed, the rate of responding to  $S_1$  was reduced during *mult VI VT* training in Experiment II of the present study. Overall, the rate of responding to  $S_1$  decreased from 5 to 18% across sessions after the shift from *mult VI VI* to *mult VI VT* in the Halliday and Boakes experiment and from 5 to 15% across *mult VI VT* sessions in Experiment II of the present study. Thus, responding to  $S_1$  changed in the same direction as to  $S_2$ , a decrease in rate from prior non-differential training, for birds that showed differential responding to  $S_1$  and  $S_2$ , although the reinforcement schedule correlated with  $S_1$  was not changed. This form of behavioral interaction is termed negative induction (Reynolds, 1961).

Evidence concerning negative induction occurring during discrimination training in Experiment I is unavailable: discrimination training began after only a very short history of non-differential reinforcement. Also, as already discussed, the course of discrimination learning differed considerably between Experiments I and II. In discrimination training, after 20 sessions of non-differential reinforcement differential responding was less marked and less frequent than in discrimination training administered after only three sessions of non-differential reinforcement. In this matter, neither procedure nor results from Halliday and Boakes' report are comparable to the present work, since six sessions with the VT schedule and a varying number of sessions of non-differential reinforcement preceded discrimination training in their study.

Due to technical difficulties, Halliday and Boakes were unable to assess stimulus control by  $S_2$ . In the present work, only the procedure of Experiment II generated inhibitory stimulus control. In Experiment II, incremental gradients about  $S_2$  were preceded not by behavioral contrast but by negative induction. Behavioral contrast and inhibitory stimulus control have been discussed as correlated by-products of discrimination training (Terrace, 1968; Weisman, 1970). It now appears that the observed correlation between behavioral contrast and inhibitory stimulus control may not reflect the action of a singular antecedent or type of discrimination learning. Certainly the results of Experiment II are not in line with a definition of contrast as an in-

crease in the strength of responding to  $S_1$  that results from alternating  $S_1$  with an inhibitory stimulus (Terrace, 1972); nor are they consistent with the view that inhibition and contrast are opposite sides of the same coin (Premack, 1969).

Response-independent VT schedules differ from DRO schedules principally in the absence of a contingency that postpones reinforcement, given a response. That is, VT does not schedule a contingency to force a reduced rate of responding. However, as yet unnoticed sources of aversiveness may operate: Halliday and Boakes (1972) found that VI was preferred to VT when scheduled concurrently. Perhaps, negative induction, no less than behavioral contrast, is a by-product of discrimination learning of the second type. A second possibility is that an "active holding back" or forced reduction in responding and passive reductions in responding (reduced excitation or response strength) are not differentiated by an incremental gradient about  $S_2$  (Hearst, Besley, and Farthing, 1970; Terrace, 1972). This latter suggestion is without empirical support; discrimination training thought to be based on reduced excitation, for example, errorless discrimination, has failed to yield inhibitory stimulus control (Terrace, 1972). On the other hand, the former suggestion will require independent evidence concerning the aversiveness of VT reinforcement.

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