**FACTORS INFLUENCING INHIBITORY STIMULUS
CONTROL: DISCRIMINATION TRAINING AND
PRIOR NON-DIFFERENTIAL REINFORCEMENT¹**

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In Exp. I, shallow U-shaped gradients of inhibition in the line-orientation dimension were obtained from birds that had a vertical (0°) line on a green surround correlated with extinction and a blank green surround correlated with reinforcement. Birds that had massed extinction in the presence of the 0° line showed flat gradients. Thus, discrimination training, but not massed extinction, appears to generate inhibitory control. In Exp. II, as in studies of control by a stimulus correlated with punishment, non-differential training across the line-orientation dimension preceded further sessions. Steep inverted gradients about the 0° line were obtained after discrimination training with the 0° line correlated with extinction. Gradients obtained after massed extinction tended to be flat. Again, discrimination training was critical in obtaining negative gradients of stimulus control.

The concept of differential inhibition has played an important role in the theoretical formulations of Pavlov (1927), Hull (1952), and Spence (1937). Yet, relatively few papers in the literature have dealt experimentally with negative or inhibitory stimulus control, especially when compared to the now extensive experimental literature concerned with positive or excitatory stimulus control (Mofsky, 1965; Terrace, 1966a).

Three papers have thus far reported control by a stimulus correlated with extinction in an operant inter-dimensional discrimination (Jenkins and Harrison, 1962; Honig, Boneau, Burstein, and Pennypacker, 1963; Terrace, 1966b). The procedure has been to correlate reinforcement with a stimulus (S+) in a different physical dimension than the stimulus correlated with extinction (S-) in an operant discrimination. Later, S-, various other stimuli in the same dimension as S-, and S+ are presented during a generalization test in extinction. Presumably, stimuli on the same dimension as S- are all at equal distance from S+ in the sense that they are in a dimension not varied during discrimination training.

Prior post-discrimination generalization tests in the S- dimension have yielded gradients in which variations of the stimulus dimension including S-, but not S+, have resulted in progressive increases in responding as the distance between the generalization stimulus and S- increased. Shallow inverted, or U-shaped, gradients about S- have been observed in the dimensions of tone frequency (Jenkins and Harrison, 1962), line orientation (Honig *et al.*, 1963), and wavelength (Terrace, 1966b). Jenkins (1965) suggested that these inverted gradients about a stimulus correlated with extinction be labelled inhibitory gradients. In adopting a conventional label, inhibitory stimulus control, for inverted post-discrimination gradients about S- we do not feel committed to either accepting any particular physiological or psychological model of the effect, or ignoring other sorts of empirical evidence for or against a more general, independent, or primary, inhibitory process (Skinner, 1938; Rescorla, 1967).

Inhibitory stimulus control does develop when a discrimination is trained with interspersed presentations of S+ and S-, and responding occurs to S- (Terrace, 1966b). Is discrimination training a determinant of inhibitory stimulus control or might separate massed extinction have a similar effect on the generalization gradient? The present work was primarily concerned with comparing discrimination training with massed extinction.

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EXPERIMENT I

Experiment I was an extension of the work of Honig *et al.* (1963), and used a two-phase procedure. During the first phase, reinforcement was correlated with both the presence and absence of a white line on a green surround. In a second phase (differential training) extinction was correlated with the line. Resulting post-discrimination generalization gradients were compared with gradients obtained after separate massed extinction. Gradients were also obtained after discrimination training with the line as S+ and after reinforced single-stimulus training.

METHOD

Subjects

Eighteen adult male Silver King pigeons were maintained at about 75% of their free-feeding weight. The birds had not been used in any prior experiment.

Apparatus

The side keys in a Grason-Stadler Model E6446 three-key pigeon chamber were covered by plastic tape. A house light, used only during early training, was mounted in the left rear corner of the chamber. An Industrial Electronics Engineers in-line display cell trans-illuminated the center key. Six orientations of a $\frac{1}{8}$ -in. wide by $\frac{7}{8}$ -in. 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 illuminated during the reinforcement cycle by a 5-w lamp above the hopper. A shield prevented light from the magazine from reaching the response key. An opening 2-in. wide by 2-in. high and 4 in. below the response key provided access to the hopper during the reinforcement cycle. The lamp over the hopper and stimuli projected on the face of the display cell provided the only illumination in the pigeon chamber. 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. During the first phase of the experiment, each bird had eight sessions of non-differential training with 1-min variable-interval reinforcement (VI 1-min) correlated with each of two visual stimuli. A white vertical (0°) line on a green surround and the (blank) green surround alone appeared on the key in an irregular sequence (seven independent Gellerman orders) of approximately 14 presentations of each stimulus. Identical but independent variable-interval tapes, each with an arithmetic mean of 1 min, (VI 1-min) were correlated with the 0° line and blank key. No reinforcements were available during timeout. One session with non-differential VI 30-sec reinforcement preceded the eight sessions of VI 1-min non-differential training just described.

After non-differential training, each of 10 birds had six sessions of discrimination training. Discrimination training sessions were identical to prior non-differential training sessions (*mult* VI 1-min VI 1-min), except that responses to one of the visual stimuli were not reinforced (*mult* VI 1-min EXT). For five birds, the 0° on a green surround was correlated with VI 1-min and the blank green key with EXT; the remaining five birds had the blank green key correlated with VI 1-min and the 0° line on a green surround correlated with EXT.

An additional eight birds each had six single stimulus sessions of only 14 periods with the 0° line on a green surround as the visual stimulus following non-differential training with two stimuli. Reinforcement was discontinued and massed extinction (Hearst and Poppen, 1965) given to four birds, while VI 1-min reinforcement continued for four birds.

Thus, five birds had reinforcement correlated with the 0° line during discrimination sessions and four birds during single-stimulus sessions. The remaining nine birds had the 0° line correlated with non-reinforcement: five birds during discrimination sessions, four birds during

single-stimulus sessions (massed extinction).

Each bird had a generalization test in extinction. The birds given discrimination training began the session in which the test was conducted with four reinforced presentations of S+ (S- was not presented during this "warm up"). The birds given single-stimulus, instead of discrimination, sessions continued during the four warm-up trials under the same conditions as in the six previous sessions. Presented during the generalization test were six orientations of the white line: $\pm 90^\circ$, -60° , -30° , 0° , $+30^\circ$, and $+60^\circ$ departures from vertical, each on the 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

Figure 1 shows the rate of responding during each session of non-differential and differential reinforcement for four birds. Results for two birds, which had the 0° line as S+, are shown in the left-hand panels, results for two birds trained with the blank key as S+ are shown in the right-hand panels. These rate functions show results typical for all birds receiving discrimination training in Exp. I, as well as in other experiments with similar training conditions (*mult* VI 1-min EXT) in our laboratory.

Fig. 1. Rates of responding during non-differential and differential training for four birds in Exp. I.

During discrimination training (Fig. 1) the rate of responding increased in the presence of S+ as the rate of responding in the presence of S- decreased. The extinction of responding to S-, or error reduction, was gradual but nearly complete by Session 6 of discrimination training.

The rate of responding for four birds that had single-stimulus sessions following non-differential training is shown in Fig. 2. The left-hand panels summarize the results for two birds whose responses were reinforced during single-stimulus sessions. The apparent increase in the rate of responding in single-stimulus sessions by Bird 1799 is not atypical. Other birds, including 1473, run under these conditions showed similar increases. If the rate of responding during single-stimulus training (14 trials) is compared with the rate during only the first 14 trials of prior non-differential sessions, most of the "increase" disappears. Gradual increases in the rate of responding over sessions probably account for any remaining rate change.

Rate functions for two birds given sessions of massed extinction following non-differential reinforcement are presented in the right-hand panels of Fig. 2. Extinction was complete by Session 5 with the massed-extinction procedure: none of the birds responded during the final massed extinction session.

Figure 3 shows gradients obtained after massed extinction in the presence of the 0° line. Few responses were emitted in the presence of any line orientation in these tests. Gradients obtained after discrimination training with the 0° line as S- are shown in Fig. 4. A

Fig. 2. Rates of responding during non-differential training and subsequent single-stimulus reinforcement or massed-extinction sessions for four birds in Exp. I.

shallow U-shaped inhibitory gradient was obtained from each bird: the maximum increase from 0° to ±90° line orientation was 100 responses (Bird 1487), the minimum increase only 21 responses (Bird 1767). Comparison between Fig. 3 and 4 shows that gradients of inhibitory stimulus control were obtained after discrimination training but not massed extinction.

Generalization gradients obtained from birds with reinforced single-stimulus training are shown in Fig. 5. All four birds showed gradients that peaked at either the 0° or a line orientation adjacent (±30°) to the training stimulus. Although these gradients are rather flat, examination of responding over blocks of generalization stimuli (not shown) gave evidence that some gradual steepening, typical for generalization tests conducted in extinction, occurred in gradients obtained from Birds 1977, 1698, and 1473. Gradients obtained from birds trained with the 0° line as S+ in discrimination training are shown in Fig. 6. The gradient obtained from each of the five birds peaked at S+ and those obtained from Birds 1998, 2310, and 1424 were steep and convex.

Fig. 3. Generalization gradients of line orientation obtained after massed extinction in the presence of the 0° line in Exp. I.

Fig. 4. Generalization gradients of line orientation obtained after discrimination training with the 0° line as S- in Exp. I.

Fig. 5. Generalization gradients of line orientation obtained after non-differential training with the 0° line in Exp. I.

Included at the extreme right with each gradient in Fig. 3, 4, 5, and 6 is the number of responses obtained during presentation of the blank green key. The increase in responding from ±90° to the blank green key after discrimination training with the 0° line as S- (Fig. 4) ranged from 169 (Bird 2154) to 670 (Bird 1487) responses. Birds given massed-extinction (Fig. 3), rather than discrimination training, responded much less frequently to the blank green key, but still generally more than to any other line orientation. Among birds that had the 0° line as S+ (Fig. 6), the decrease in responding from ±90° to the blank

Fig. 6. Generalization gradients of line orientation obtained after discrimination training with the 0° line as S+ in Exp. I.

green key (S-) ranged from 42 (Bird 1663) to 122 (Bird 2587) responses. Birds given single-stimulus training sessions (Fig. 5) responded as frequently in the presence of the blank green key as in the presence of $\pm 90^\circ$. Thus, not only did birds with prior discrimination training respond more to S+ than S- during the generalization test, but also prior discrimination training was reflected in the level of responding in the line-orientation dimension and to the blank green key.

DISCUSSION

Massed extinction in the present experiment reduced the level of responding in the line-orientation dimension but gave no evidence of inhibitory control. This might be because the birds had ceased to orient toward the key. Since the birds did respond occasionally to the blank green key (Fig. 3) early in the test, some other explanation for the flat gradients obtained would seem necessary. Inhibitory gradients about the 0° line were obtained from birds with discrimination training (Fig. 4). The level of responding in the inhibitory gradient was lower than in the positive gradients obtained after either single-stimulus or discrimination training (Fig. 5 and 6). This asymmetry had been observed in previous studies of the inhibitory gradient (Jenkins and Harrison, 1962; Honig *et al.*, 1963; and Terrace, 1966b). Thus, both massed-extinction and discrimination training reduced the level of responding in the line-orientation dimension but only discrimination training yielded inhibitory stimulus control.

Peak shift (Hanson, 1959), a shift in the peak of the gradient away from S+ in a direction opposite from S-, has been observed during post-discrimination generalization tests across a dimension including both S+ and S-. Tests obtained after massed extinction, without discrimination training, have yielded only a reduction in the level of responding in the dimension without peak shift (Honig, Thomas, and Guttman, 1959). Terrace (1966a) proposed that S- becomes an aversive stimulus as a result of discrimination training involving many non-reinforced responses to S-, and that the peak shift is a symptom of this "aversive or inhibitory" control. The results of Exp. I support this prediction, since inhibitory

stimulus control was obtained after discrimination training but not after massed extinction.

No change in the reinforcement schedule correlated with S+ accompanied the shift from non-differential reinforcement to discrimination training in Exp. I. Increases in the rate of responding to S+ over the rate of responding to the same stimulus during non-differential training, as shown in Fig. 1, have been defined as behavioral contrast (Reynolds, 1961). Positive behavioral contrast is observed when the rate of response to S+ increases (contrasts) with the decreasing rate of responding to S- (Terrace, 1966a). Behavioral contrast has been observed, with some variation, during the acquisition of multiple-schedule discriminations employing several training procedures (Reynolds, 1961; Terrace, 1963; Bloomfield, 1966), including one (Bloomfield, 1966), somewhat similar to the procedure used here.

Terrace (1966a) proposed that behavioral contrast, along with the peak shift, be considered correlates of inhibitory control. Although Terrace has provided considerable evidence for this view (1963, 1966a, 1966b) the single-stimulus reinforcement and massed-extinction procedures of Exp. I provide a further test. Since neither procedure yielded a gradient of inhibitory stimulus control, neither procedure should result in behavioral contrast. Of course, the single-stimulus reinforcement procedure did not involve extinction and it is therefore not surprising that no "contrast" was observed. The only opportunity to evaluate response strength to the blank green key after massed extinction occurred during the generalization test. Massed extinction did not produce a higher rate of responding to the blank key during its first presentation in the test than during prior non-differential training. Discrimination training uniformly resulted in an increase over the rate observed during prior non-differential training. In support of the theoretical analysis of the aversive properties of S- which was proposed by Terrace (1966a, 1966b), behavioral contrast and inhibitory stimulus control were correlated in the present experiment.

Single-stimulus training after non-differential training with two stimuli was included in Exp. I for comparison with inter-dimensional discrimination training. Steeper and more orderly gradients were obtained after

discrimination training (Fig. 6) than as a result of single-stimulus reinforcement (Fig. 5). This agrees with the findings of other investigators concerned with the sharpening of positive stimulus control following inter-dimensional discrimination training (Jenkins and Harrison, 1960; Newman and Baron, 1965; Switalski, Lyons, and Thomas, 1966).

EXPERIMENT II

Some investigators (Terrace, 1963; Weisman and Premack, 1966; Azrin, Hutchinson, and Hake, 1966; Rilling, Ahlskog, and Askew, 1968) have suggested that as a result of extinction, especially gradual extinction during discrimination training, the stimulus correlated with extinction, S—, acquires aversive properties. If this suggestion is taken seriously, then studies (Hoffman and Fleshler, 1961; Honig and Slivka, 1964; Honig, 1966) generally cited in the context of aversive control may also be relevant in the context of inhibitory control.

These studies share common ground in at least four respects: (a) Reinforced training occurred at several points in the dimension later examined in a generalization test. (b) Training involving the correlation of a discriminative stimulus with an aversive event; either response-contingent punishment or conditioned suppression training, preceded the generalization test. (c) A gradual and discriminated decrease in responding in the presence of the punished stimulus was observed. (d) Inverted generalization gradients of responding similar in appearance to the gradients of inhibition obtained in Exp. I, but generally much steeper, were observed.

In Exp. II, a procedure similar in some respects to that used in the study of stimulus control by discriminated response-contingent punishment (Honig, 1966), and the stimulus generalization of conditioned suppression (Hoffman and Fleshler, 1961), was employed. As in Exp. I, generalization tests were obtained after reinforcement or extinction in the presence of the 0° line either in a discrimination or single-stimulus procedure. Unlike Exp. I, but as in studies of stimulus generalization of the effects of punishment, during the first phase of Exp. II responding in the presence of all of the stimuli later presented in the generalization test was reinforced.

METHOD

Subjects

As in Exp. I, 18 adult male, experimentally naive Silver King pigeons were maintained at about 75% of their free-feeding weight.

Procedure

The procedure in Exp. II was identical to that in Exp. I with two exceptions: during non-differential training seven, rather than two, visual stimuli were presented. These were the seven stimuli presented in the generalization test in Exp. I. Six orientations of the white line on the green surround and the blank green surround were presented in four randomized blocks in each non-differential training session in Exp. II. The reinforcement procedure also differed slightly in that the two VI 1-min reinforcement tapes, rather than being correlated with specific stimuli, were simply alternated with succeeding trials independently of the randomized series of stimuli presented on the key. Other details of non-differential training, later discrimination or single-stimulus sessions, and generalization test were the same as in Exp. I.

RESULTS

Rate functions for discrimination and single-stimulus sessions are shown in Fig. 7 and Fig. 8 respectively. The similarity between these functions and those obtained in Exp. I (see Fig. 1 and Fig. 2) is clear. Comments relevant to the rate functions of Exp. I would seem to apply to Exp. II as well.

Gradients obtained from birds given massed extinction during single-stimulus sessions are shown in Fig. 9. Only Bird 1542 showed variation in responding during the generalization test suggestive of inhibitory control. The other gradients are about as flat as those obtained after massed extinction in Exp. I. Evaluation of the gradient obtained from Bird 1542 is complicated by the small number of responses emitted during presentations of the +60° line. Figure 10 presents gradients obtained from birds given discrimination training with the 0° line as S—. Steep inverted post-discrimination gradients of stimulus control about S— were obtained. As in Exp. I, U-shaped gradients were observed after discrimination but not massed extinction.

Figure 11 presents generalization gradients obtained after single-stimulus training for four birds in Exp. II. Gradients obtained from birds with prior non-differential training across the line-orientation dimension are

Fig. 7. Rates of responding during non-differential and differential training for four birds in Exp. II.

Fig. 8. Rates of responding during non-differential training and subsequent single-stimulus reinforcement or massed extinction for four birds in Exp. II.

Fig. 9. Generalization gradients of line orientation obtained after massed extinction in the presence of the 0° line in Exp. II.

Fig. 10. Generalization gradients of line orientation obtained after discrimination training with the 0° line as S- in Exp. II.

nearly flat. The level of responding in the line-orientation dimension was somewhat lower than in Exp. I. Generalization gradients obtained from birds given differential training with the 0° line as S+ after non-differential reinforcement across the line-orientation dimension are shown in Fig. 12. These gradients varied considerably in steepness, but each gradient peaked at S+.

The number of responses emitted during presentations of the blank green key are shown at the right of each gradient in Fig. 9, 10, 11, and 12. Birds with prior discrimination training during Exp. II showed differences between the level of responding in the line-orientation

Fig. 11. Generalization gradients of line orientation obtained after non-differential training with the 0° line in Exp. II.

Fig. 12. Generalization gradients of line orientation obtained after discrimination training with the 0° line as S+ in Exp. II.

dimension and to the blank key. When the blank key had been S—, the difference in the number of responses to $\pm 90^\circ$ and the blank key was greater than in Exp. I. When the blank key had served as S+, the difference between $\pm 90^\circ$ and the blank key was not as great as in Exp. I. These differences probably reflect the effect of non-differential training across the line-orientation dimension on responding during a post-discrimination generalization test. Gradients obtained from birds with single-stimulus sessions in Exp. II (Fig. 9 and 11) showed approximately the same relationship between the level of responding in the line-orientation dimension and to the blank key as was observed after single-stimulus sessions during Exp. I (Fig. 3 and 5).

DISCUSSION

Jenkins (1965, p. 61) suggested that "should it turn out that simple extinction does not yield inhibitory stimulus control while at least some forms of discriminative training do, the prevalent view that discrimination is simply a case of combined conditioning and extinction would come in for a thoroughgoing revision." The present results showed that inhibitory stimulus control is absent after simple (massed) extinction but present after discrimination. Terrace (1966b) found that errorless discrimination learning did not yield in-

hibitory stimulus control. Thus, neither non-reinforcement alone during discrimination training, nor non-reinforcement plus extinction but without discrimination training, as in the present work, are sufficient to generate inhibitory stimulus control.

Perhaps, as suggested in the introduction to Exp. II, the results of the present experiments are best viewed in another context. Honig (1966) compared gradients obtained after discriminated punishment with gradients obtained after punishment without interspersed presentations of an unpunished stimulus. He found U-shaped gradients of aversive control after discrimination training but only flat gradients without prior discrimination. In Exp. II, Honig's pre-discrimination procedure (non-differential training across the line-orientation dimension) was used, but extinction, rather than response-contingent electric shock, was correlated with the 0° line orientation. The present results paralleled those obtained by Honig (1966) in that discrimination was a critical antecedent of steep gradients of negative control. This parallel may be used to support the hypotheses that an S— correlated with extinction, like a discriminative stimulus for response-contingent electric shock, acquires not only inhibitory but also aversive properties (Terrace, 1963). This analysis of the effects of S— has been strengthened by a recent finding. Grusec (1968) has shown that the addition of electric shock to a previously established errorless discrimination resulted in a peak shift in the post-discrimination gradient. Electric shock also increased the peak shift obtained with a procedure that involved errors. It would appear that the effects of extinction and electric shock combine in the direction predicted by Terrace's (1963) hypothesis.

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