STIMULUS GENERALIZATION AND DELAY OF REINFORCEMENT DURING ONE COMPONENT OF A MULTIPLE SCHEDULE¹

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The key pecking of six pigeons was reinforced according to a variable-interval 1-min schedule during each of two successively presented stimuli. When the key was illuminated by a black line on a white background, reinforcement was delayed for 10 sec. When the key was illuminated by a plain white light, reinforcement was not delayed. All subjects responded at a lower rate during the presentation of the black line. A subsequent generalization test along the line-orientation dimension produced a U-shaped gradient, with the nadir located at or near the training stimulus, for each subject. These gradients suggested that the lower rate of response during the stimulus associated with delayed reinforcement may have been due to an inhibition of responding.

The two-component multiple schedule of reinforcement, which requires the successive presentation of two independent schedules of reinforcement, each in the presence of a different exteroceptive stimulus, has frequently been used as a training procedure before testing for stimulus generalization (see, Mostofsky, 1965; Gilbert and Sutherland, 1969; Terrace, 1972a). Depending on the nature of the study, the two stimuli may lie along the same stimulus dimension (e.g., Hanson, 1959; Pierrel and Sherman, 1960; Bloomfield, 1967) or along different and orthogonal stimulus dimensions (e.g., Jenkins and Harrison, 1960; 1962; Honig, Boneau, Burstein, and Pennypacker, 1963; Farthing and Hearst, 1968). Hanson (1959), for example, trained subjects on a multiple variable-interval 1-min extinction schedule with both stimuli lying along the wavelength dimension. Specifically, a 550 nm light was correlated with the variable-interval (VI) 1-min component and a light with a wavelength greater than 550 nm was correlated with the extinction (EXT) component. The subsequent generalization tests produced gradients that peaked at a wavelength less than 550 nm. This displacement of a generalization gradient's peak away from one training stimulus in the direction opposite that of the other training stimulus has been referred to as peak shift. When the training

stimuli of a *mult* VI EXT schedule lie on orthogonal dimensions, generalization tests have yielded (depending along which dimension the generalization test is conducted) either (a) inverted U-shaped gradients, the peak of which occurs at the stimulus correlated with the VI schedule (e.g., Jenkins and Harrison, 1960) or (b) U-shaped gradients, the nadir of which occurs at the stimulus correlated with extinction (e.g., Jenkins and Harrison, 1962; Honig, *et al.*, 1963; Farthing and Hearst, 1968). These gradients have been used by several investigators (e.g., Jenkins, 1965; Terrace, 1966a; 1966b; 1967; 1972a; 1972b) to define excitatory and inhibitory stimulus control, respectively.

Interestingly, neither the peak shift nor the U-shaped gradient seems to be limited to prior training on the special multiple schedule that has extinction as one of the components. For example, prior training on a *mult* VI 1-min VI 5-min schedule has been found to produce a peak shift away from the stimulus correlated with the VI 5-min component (Guttman, 1959; Terrace, 1968) and a U-shaped gradient with the nadir at the stimulus correlated with the VI 5-min component (Weisman, 1969). Peak shift and the U-shaped gradient have also been found following training on a multiple variable-interval differential-reinforcement-of-low-response-rates schedule (Terrace, 1968; Weisman, 1969), and a multiple variable-interval differential-reinforcement-of-other-behavior schedule (Yarczower, Dickson, and Gollub, 1966; Weisman, 1970). Peak shift has also been observed following training on a *mult* VI 1-

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min VI 1-min schedule with different magnitudes of reinforcement correlated with the two components (Mariner and Thomas, 1969).

During the training phase of each of the previous studies, reinforcement was delivered immediately upon completion of the schedules' requirements. The present study examined the generalization gradients produced following training on a *mult* VI 1-min VI 1-min schedule that had reinforcement delayed during one component. Training stimuli were selected from presumably orthogonal dimensions, and the gradient around the stimulus correlated with delayed reinforcement was examined.

METHOD

Subjects

Six adult, female White Carneaux pigeons, obtained from the Palmetto Pigeon Plant, were maintained at approximately 80% of their free-feeding weights. Several weeks before the present study, S-1019, S-266, and S-7812 were trained, in the chamber described below, to peck the all-white center key that was illuminated by the optical system also described below. These subjects received several sessions of continuous and intermittent reinforcement for responding on this key. The remaining subjects were experimentally naive.

Apparatus

A Kodak Ektagraphic slide projector model B, equipped with a 3-in. (7.5 cm) lens and mounted 10 in. (25.4 cm) behind the center key of a standard three-key operant conditioning chamber (Lehigh Valley Electronics) was used to project the training and test stimuli. During training, the key was illuminated by either a homogeneous white light (S1) or by a black line ($\frac{1}{16}$ in. thick) on a white surround (S2). The orientation of this line was horizontal for three subjects and vertical for three subjects. Test stimuli included S1, S2, and five other orientations of this black line (departures of $+30^\circ$, $+60^\circ$, -30° , -60° , and $\pm 90^\circ$ from S2) on the white surround.

Overall illumination of the chamber was provided by the standard houselight (CM 1820) and two pilot lights (GE 1819), which were mounted slightly above the covered side keys. A red pilot light (CM 1829), mounted on the chamber's back wall, was illuminated during the 10-sec timeouts of S1 and 10-sec delay

periods of S2. The reinforcer was 1.5-sec access to mixed grain. The timing of this interval began when the subject placed its head into the illuminated food aperture, thus interrupting a light beam focused on a photocell. Responses on the illuminated key during the reinforcer's presentation had no scheduled consequences.

Standard scheduling and recording equipment was housed in an adjacent room. The chamber's ventilation fan and the projector's cooling fan provided the only masking noise.

Procedure

After the key-peck response was established, by using the shaping technique with the naive subjects and by delivering several free reinforcers to the experienced subjects, the response requirement was gradually increased over several sessions until a fixed-ratio 20 schedule was attained. Subjects then received two sessions of training on a VI 1-min schedule. During this preliminary training, only S1 was presented.

During the next 15 sessions, each of which contained 120 stimulus presentations, responding was reinforced according to a *mult* VI 1-min VI 1-min schedule with reinforcement delayed for 10 sec during S2. During S1, reinforcement was never delayed. However, 10-sec timeouts were scheduled according to an independent, but identical, VI 1-min schedule. The red pilot light provided the chamber's only illumination during the delay and timeout periods; responses during these periods had no scheduled consequences. If a reinforcement and timeout were "set up" concurrently during S1, the first response produced the reinforcer and the next response produced the timeout. Reinforcements and timeouts "set up", but not received during one stimulus presentation, carried over to the next presentation of that stimulus. The order of stimulus presentations was mixed with the restriction that no stimulus could occur more than three times in succession. This procedure of scheduling the illumination of the pilot light with equal frequency during S1 and S2 controls for any possible effects of the pilot light, *per se*. Thus, if all scheduled timeouts and reinforcements are obtained, the only difference between the components would be S1's association with immediate reinforcement and S2's association with delayed reinforcement.

Throughout training, responding was non-

Fig. 1. Response rates to S1 (closed circles) and S2 (open circles) over the 15 sessions of *mult* VI 1-min VI 1-min reinforcement. During S1, reinforcement was not delayed, but during S2, reinforcement was delayed for 10 sec. The denominator for all rate calculations excluded the time that the food magazine was accessible and the pilot light illuminated.

functional during the 1-sec blackouts that separated successive 30-sec stimulus presentations. This 30-sec duration excluded delay, timeout, and reinforcement time.

The session following the completion of training on the multiple schedule began with a period of additional training (50 stimulus presentations) and ended with a test for generalization. The red pilot light was never illuminated during the generalization test that was conducted during extinction. Each of the seven generalization test stimuli were presented in random order within each of 10 blocks. A different random sequence was used

for each bird. As in training, 30-sec stimulus presentations were separated by 1-sec blackouts.

RESULTS

Figure 1 shows that all subjects maintained responding during S2 (open circles), the component associated with delayed reinforcement, but at a lower rate than during S1 (closed circles), the component associated with immediate reinforcement. Subject 266 also key pecked during the illumination of the pilot light irrespective of which component was in

Fig. 2. Reinforcement rates during S1 (open circles) and S2 (open triangles) and timeout rates during S1 (closed circles) over the 15 sessions of *mult* VI 1-min VI 1-min reinforcement. The mean rates over the 15 sessions are indicated at M. During S1, reinforcement was not delayed, but during S2, reinforcement was delayed for 10 sec. The denominator for all rate calculations excluded the time that the food magazine was accessible and the pilot light illuminated.

effect. Casual observation failed to show any consistent behavior during these periods for most of the remaining subjects. In all figures, the S2 for subjects in the left column was a horizontal line on a white surround; the S2 for subjects in the right column was a vertical line on a white surround. Since all results were essentially the same irrespective of the line orientation associated with S2, no further comparisons between columns will be mentioned.

Figure 2 shows the reinforcement rates during S1 (open circles) and S2 (open triangles), as well as the timeout rates during S1 (closed circles). These rates are approximately equal for all birds.

The results of the generalization test are shown in Figure 3. The gradient for each subject is U-shaped with the nadir located at or near S2. There are, however, large differences in the regularity, slope, and symmetry of these individual gradients, as can readily be seen by comparing the gradients of S-157 and S-2591.

DISCUSSION

To the extent that a U-shaped gradient is indicative of inhibition (as suggested by Jenkins, 1965; Terrace, 1966a; 1966b; 1967; 1972a; 1972b), the present experiment suggests that a stimulus associated with delayed reinforcement exerts inhibitory control over responding, when alternated with a stimulus associated with immediate reinforcement. The validity of the U-shaped gradient as such an index has, however, been recently questioned by Hearst and his colleagues (Farthing and Hearst, 1968; Hearst, Besley, and Farthing, 1970; Hearst, 1972). These investigators suggest that a distinction be made between the terms *inhibitory stimulus* and *inhibitory dimensional control*. Their suggestion is that procedures other than the generalization test (such as the resistance-to-reinforcement and stimulus-compounding techniques) are necessary to classify a stimulus as inhibitory, and

Fig. 3. Relative generalization gradients for each bird. For the sake of symmetry, the per cent of responses to the vertical line has been plotted at both $+90^\circ$ and -90° for subjects shown in the left column. Similarly, the per cent of responses to the horizontal line has been plotted at both $+90^\circ$ and -90° for subjects shown in the right column. Only the responses emitted to the six line-orientations were used in computing the per cent of responses to each specific line-orientation (*i.e.*, the denominator in these calculations did not include the responses emitted to the all-white key). The first number in parenthesis above each gradient is the total number of responses emitted to the six line-orientations during the generalization test; the second number is the total number of responses emitted to the all-white key.

that the term inhibitory dimensional control should be applied only after a U-shaped gradient has been generated around a stimulus, independently established as inhibitory.² While the value of this distinction is unclear at the present time, as Terrace (1972*a*, 1972*b*) also

²It should be noted that while these comments were made regarding a stimulus paired with nonreinforcement, they also seem relevant to stimuli paired with other schedules of reinforcement, as in the present study and in the series of experiments by Weisman (1969, 1970).

noted, it would, in any event, be useful to examine delayed reinforcement via the procedures suggested by Hearst. The generalization test, thus, might best be viewed as only one method of gaining information on the nature and functioning of a particular stimulus.

Two specific assumptions regarding the usefulness of the line-orientation dimension in generalization tests for inhibition should be mentioned. First, it is generally assumed that all of the line-orientations are of equal similarity to the other training stimulus, which in the present study was a plain white key (this, of course, is the assumption of orthogonality). It is, also, assumed that the shape of the gradient is not due to preferences for various line-orientations, irrespective of the specific training procedures employed. While the present study was not designed to test these assumptions directly, the consistency in overall shape of the generalization gradients, regardless of whether a horizontal or vertical line was associated with delayed reinforcement, seems to demonstrate their validity, at least in the present study.

The present study, in conjunction with the recent demonstration (Wilkie, 1972) of a peak shift away from a stimulus correlated with delayed reinforcement, supports the idea (e.g., Thomas and Williams, 1963; Terrace, 1966a; 1972a; 1972b; Hearst, 1968; Weisman, 1969) of a close relationship between peak shift and the U-shaped gradient. The present study also provides another demonstration (cf. Weisman, 1969; 1970) that a lower frequency of reinforcement during one component of a multiple schedule is not necessary to the production of a U-shaped gradient.

While delayed reinforcement during one component of a multiple schedule has been shown to produce behavioral contrast (Keller, 1970; Wilkie, 1971; Richards, 1972), the experimental design prevented the assessment of behavioral contrast in the present study. It would, however, be beneficial to replicate Richards' parametric work on reinforcement delay and behavioral contrast with the inclusion of a generalization test following training. Such work would be most informative, given the assertion (e.g., Terrace, 1966a; 1972a) that behavioral contrast, peak shift, and the U-shaped gradient are produced by identical training conditions (except for selection of training stimuli) and the previous demonstra-

tion (Wilkie, 1971; Richards, 1972) that behavioral contrast may occur without a reduction in response rate during the delay component.

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