SOME EFFECTS OF DISCRIMINATIVE TRAINING WITH EQUATED FREQUENCY OF REINFORCEMENT¹

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Pigeons were exposed to a multiple schedule which provided equally frequent reinforcement in the presence of two stimuli but which produced markedly different rates of key-pecking. Generalization gradients were displaced away from the stimulus associated with the lower rate of key-pecking. Another group of pigeons had similar training, except that a low rate of key-pecking was established in a stimulus with a much higher frequency of food reinforcement. In this case, the generalization gradients were not affected by the training on the schedule producing a low response rate.

The purpose of the present experiment was to study the generalization gradients of pigeons exposed to a pair of reinforcement schedules that provided equally frequent reinforcement in the presence of two stimuli but which produced markedly different rates of key-pecking. Would the generalization gradients resemble those obtained following discriminative training with differential reinforcement frequencies?

Hanson (1959) and Guttman (1959) gave pigeons discriminative training, alternating one positive reinforcement schedule with extinction (Hanson) or with another positive reinforcement schedule which produced a different frequency of reinforcement (Guttman). In both cases, rates of responding were higher under the schedule associated with more frequent reinforcement. Generalization tests after the discriminative training indicated that proportionately fewer responses were emitted in the region of the stimulus associated with lower rates and lower reinforcement frequencies. In an attempt to evaluate the effects on generalization gradients of various procedures of discriminative training, Yarczower, Dickson, and Gollub (1966) used schedules of reinforcement which varied rates of responding and frequencies of reinforcement somewhat

independently of each other. The discussion of those experiments suggested that if key pecks were reinforced in the presence of one stimulus, and behavior other than key-pecking was reinforced with equal frequency in the presence of a second stimulus, then subsequent generalization gradients would resemble those which follow discriminative training procedures with unequal reinforcement frequencies; *i.e.*, the gradient would primarily reflect the response pattern established during training rather than the reinforcement frequencies.

METHOD

Procedure

The attempt to equate frequency of reinforcement in the presence of two wavelength stimuli (550 and 570 nm) makes use of DRO (differential reinforcement of other behavior) schedules of reinforcement (Reynolds, 1961a). A DRO schedule programmed in a typical pigeon apparatus is one in which the food magazine operates after key-pecking has not occurred for some period of time. For example, under a DRO 50-sec schedule of reinforcement, the reinforcer is presented after every 50-sec period in which no key pecks occur. A response class, the nonemission of which leads to certain consequences, has been termed a "negative operant" (Findley, 1962).

Two different methods were used to expose pigeons to a multiple schedule involving a DRO schedule of reinforcement. A multiple schedule consists of two or more alternating schedules of reinforcement with a different exteroceptive stimulus during each (Ferster

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and Skinner, 1957). One procedure was to introduce the DRO schedule immediately after magazine training. In this case the DRO schedule was in effect before any key-peck training was undertaken. Thus, when this manner of introducing the DRO schedule was used, the multiple schedule was begun after a number of sessions with only the DRO schedule of reinforcement. The second procedure was to introduce the DRO schedule after key-pecking had been established and maintained for some period of time.

Subjects and Apparatus

Twelve experimentally naive Silver King pigeons, 3 to 7 yr old, were maintained at approximately 80% of their free-feeding body weights throughout the experiment. The experimental chamber, made of Plexiglas except for the aluminum response panel, measured 33 cm long, 40 cm wide and 47 cm high. The visual stimuli were programmed with an aluminum disc with 3.8-cm circular openings into which Bausch and Lomb interference filters (44-78 series) and Kodak neutral density filters (No. 96 series) were placed. The illumination source was a GE 18A/T10/2P-6-v microscope illuminator bulb with a ribbon filament. The collimated monochromatic light transilluminated the translucent response key. All wavelength stimuli were equated for brightness with neutral density filters according to data on the pigeon's photopic sensitivity curve (Blough, 1957). The response panel consisted of a Gerbrands pigeon key (1.9-cm diameter) below which was mounted a Lehigh Valley pigeon feeder. It was the same apparatus used in a previous study (Yarczower *et al.*, 1966).

The 12 pigeons were divided into three groups of four birds each. All birds were trained to approach the raised magazine in one day. Group 1 was then trained to peck the response key and was exposed, one session each day for 10 days, to a tandem two-component schedule of reinforcement with the key illuminated by a 550-nm light. Each session consisted of ten 4-min trials, each trial followed by a 10-sec timeout period during which the key was not illuminated and reinforcements were not available. A tandem schedule is one in which a reinforcement is programmed by two schedules in succession without correlated exteroceptive stimuli (Fer-

ster and Skinner, 1957). Thus, in this schedule a reinforcement is available at variable intervals with a mean of 30 sec (VI 30-sec). Once the reinforcement becomes available a response starts a timer which runs for 4 sec and the first response after 4 sec operates the feeder. If the bird responds during the 4-sec period the timer resets and begins timing again. This schedule is called "differential reinforcement of low rates" (DRL). The *tand* VI 30-sec DRL 4-sec was used in this experiment to facilitate comparisons with previous experiments which had used the same schedule of reinforcement (Yarczower *et al.*, 1966).

After 10 days under a *tand* VI 30-sec DRL 4-sec schedule of reinforcement, Group 1 was given nine days of a *multiple (mult)* *tand* VI 30-sec DRL 4-sec — DRO 10-sec schedule of reinforcement. The *tand* VI 30-sec DRL 4-sec was associated with a key light of 550 nm and the DRO 10-sec schedule was associated with a 570-nm key light. The 550-nm key light, in the presence of which responses were reinforced according to a *tand* VI 30-sec DRL 4-sec schedule, was presented for 10 trials, during which the key light was on for 4 min and off for 10 sec. The 570-nm key light was also on for 4 min and off for 10 sec, but only five trials were given. The order of presentation was 550, 550, 570 nm, *etc.*

Group 2, after magazine training, was key trained and given one session each day for 18 days of VI 1-min training with the key illuminated by a 550-nm light. Each session consisted of 10 trials during which the key light was on for 4 min. There was a 10-sec timeout period between trials.

Group 3, after magazine training, was given one session each day for eight days of DRO 50-sec training with the key illuminated by a 570-nm light. Each session consisted of 10 trials during which the key light was on for 4 min. There was a 10-sec timeout period between trials. After the eighth day, three of the four birds received one day's training which included some shaping (reinforcement of behavior which successively approximated the response of pecking the key) and about 50 reinforcements in which each key peck in the presence of 550 nm was reinforced. The fourth bird received 200 reinforcements in which each key peck in the presence of 550 nm was reinforced. The *mult* VI 1-min — DRO 50-sec schedule of reinforcement began on the day

after the last trial in which each key peck was reinforced.

Discriminative training thus consisted of a *mult* VI 1-min – DRO 50-sec schedule of reinforcement in the presence of 550 and 570 nm respectively. Group 3 was exposed to the multiple schedule for one session each day for 18 days. Each session consisted of ten 4-min trials at each of the two wavelength stimuli for a total of 20 trials, each trial separated by a 10-sec timeout. Generalization tests began on the day after the last session of the multiple schedule for Groups 1 and 3 and after the last session of VI 1-min training for Group 2. Group 1 began the test day with two 4-min trials of 550 nm followed by one 570-nm trial under the same reinforcement schedule programmed as during training. Groups 2 and 3 received two 4-min trials of 550 nm under the same reinforcement schedule as during training.

Generalization tests consisted of random

presentations of seven test stimuli (520 to 580 nm in 10-nm steps) for 30 sec with a 10-sec timeout between trials. There were 56 test trials, eight presentations of the seven test stimuli. Food reinforcers were not available during tests.

RESULTS

The training data for the individual birds of Group 1 are presented in Fig. 1. It is quite apparent that the introduction of the *mult tand* VI 30-sec DRL 4-sec – DRO 10-sec following exposure only to the *tand* VI 30-sec DRL 4-sec schedule for 10 sessions did not produce a rate increase in the presence of the discriminative stimulus (S^D) associated with the *tand* VI 30-sec DRL 4-sec schedule of reinforcement (550 nm). If anything, the response rates of Birds Y107 and Y109 decreased. Rate of responding under the DRO 10-sec compo-

Fig. 1. Rates of responding in each component of the multiple schedule of reinforcement, *mult tand* VI 30-sec DRL 4-sec – DRO 10-sec. Each graph shows data for a single pigeon.

nent decreased during continued training and by the last day of training few key pecks were emitted in the presence of 570 nm. The ratio of the number of reinforcements received in the presence of 550 nm to the number received in the presence of 570 nm was 1:1.36 for Bird Y107; 1:1.55 for Bird Y108; 1:1.20 for Bird Y109; and 1:1.59 for Bird Y110. Thus, the number of reinforcements received in the presence of 570 nm was about 1.5 times that received in the presence of 550 nm. Because the pigeons were exposed to 570 nm for half as much time as they were to 550 nm, the temporal frequency of reinforcement in the presence of 570 was about triple that in the presence of 550 nm.

Figure 2 shows the generalization gradients obtained from each of the birds in Group 1.

Also shown is the mean gradient obtained from birds exposed to a *tand* VI 30-sec DRL 4-sec schedule in the presence of 550 nm in a previous experiment under comparable conditions (Yarczower *et al.*, 1966). The gradients obtained from birds of Group 1 do not differ substantially from the comparison gradient of birds exposed only to the response contingent schedule in one stimulus with no DRO schedule training. There is little evidence of any modification of exteroceptive stimulus control due to discriminative training. This result is consistent with an unpublished study by Nevin (personal communication) which suggested that there was no inhibitory control by an exteroceptive stimulus paired with a DRO schedule of reinforcement when the frequency of DRO reinforcements exceeded that

Fig. 2. Generalization gradients for each pigeon given discriminative training under a *mult tand* VI 30-sec DRL 4-sec—DRO 10-sec schedule of reinforcement. Comparison data are taken from a previous study performed under comparable conditions (Yarczower *et al.*, 1966).

under a VI component in a multiple schedule. Thus, training under the DRO component of the multiple schedule did not markedly affect generalization gradients even though differential responding was maintained throughout discriminative training. It is possible to interpret these data in the following way. The discriminative training procedure provided a situation such that "... the removal of S+ seemed to be a signal not to respond, independently of what value of S- represented the removal of S+. Thus, the control over not responding to S- seemed to depend mainly upon the absence of S+ and not on a particular value of S-" (Terrace, 1966, p. 339; cf. Jenkins, 1965). It is possible that generalization gradients obtained after errorless discrimination (Terrace, 1964, 1966) and separate extinction (Honig, Thomas, and Guttman, 1959; Yarczower and Switalski, 1967) procedures reflect a similar lack of stimulus control by the specific value of S- used.

The training data for Groups 2 and 3 are shown in Fig. 3. The mean rate of responding in the VI 1-min component for birds trained under multiple schedule (Group 3) is lower

during the first four sessions of discriminative training than the rate for birds exposed only to the VI 1-min schedule (Group 2). However, after five days the mean VI rate in the multiple schedule rises above the mean rate in the VI schedule and continues at a higher level throughout the remainder of discriminative training. An analysis of variance indicated that this interaction is statistically significant ($p < 0.01$), but the difference in response rates between the two groups through Sessions 6 to 18 did not achieve statistical significance ($p > 0.05$). Figure 4 shows the total number of key pecks emitted in each session under the DRO 50-sec component of the multiple schedule. Also shown is the total number of reinforcements obtained under the VI 1-min and DRO 50-sec components of the multiple schedule.

The individual generalization gradients for Groups 2 and 3 are shown in Fig. 5. Three of the four birds tested after exposure to only a VI 1-min schedule of reinforcement showed a nearly equal percentage of responses to stimuli on either side of 550 nm. The fourth bird, Z 8, showed some asymmetry, with more

Fig. 3. Mean rates of responding under the VI 1-min schedule of reinforcement for the group exposed only to a VI 1-min schedule or exposed to a *mult* VI 1-min - DRO 50-sec.

Fig. 4. Number of reinforcements in each component of the multiple schedule of reinforcement, *mult* VI 1-min — DRO 50-sec. Also shown is the number of responses emitted under the DRO 50-sec component. Each graph shows data for a single pigeon.

responses emitted in the presence of wavelengths longer than 550 nm. All of the birds previously exposed to the multiple schedule of reinforcement emitted fewer responses in the presence of wavelengths longer than 550 nm than they did in the presence of wavelengths shorter than 550 nm. This difference in the percent of responses to stimuli shorter and longer than 550 nm is statistically significant ($p = 0.025$, Mann-Whitney U test). Thus, the group exposed to the multiple schedule (Group 3) showed a significant redistribution of responding along the stimulus dimension compared with a group given training with only a single wavelength stimulus.

DISCUSSION

The purpose of the present study was to examine the generalization gradients of pigeons

exposed to a pair of reinforcement schedules that provided equally frequent reinforcement in the presence of two stimuli but which produced markedly different rates of key-pecking. Did the generalization gradients resemble those obtained following discriminative training with unequal reinforcement frequencies? To answer this question we must first identify the specific effect on the generalization gradient with which we are concerned. Almost all studies that have investigated the effects on generalization gradients of discriminative training have used a multiple schedule consisting of components with unequal reinforcement frequencies (Ames and Yarczower, 1965; Bloomfield, 1967; Guttman, 1959; Hanson, 1959; Honig, 1962; Honig *et al.*, 1959; Jenkins and Harrison, 1962; Pierrel and Sherman, 1960; Riccio, Urda, and Thomas, 1966;

Fig. 5. Generalization gradients for each of the pigeons given either discriminative training with 550 nm or 570 nm (*mult* VI 1-min – DRO 50-sec) or exposed only to 550 nm (VI 1-min). Percent of responses to stimuli of shorter and longer wavelengths than 550 nm are shown for each subject.

Sloane, 1964; Stevenson, 1966; Terrace, 1964; Thomas and Caronite, 1964; Thomas, Ost, and Thomas, 1960; Yarczower *et al.*, 1966). Fewer experiments have been completed using other discriminative training procedures, but two investigations used multiple schedules which alternated two positive reinforcement components, one containing a shorter magazine duration (Dickson and Thomas, 1963) or an unavoidable shock (Hoffman and Fleshler, 1964).

In all of the studies cited, there was a characteristic difference in the distribution of responses during the generalization test of subjects given discriminative training compared to the distribution of responses of subjects exposed to only a single training stimulus. Proportionately more responses were emitted in the presence of stimuli on the side of the discriminative stimulus opposite the stimulus associated with lower response rates and a less favorable reinforcement schedule. For exam-

ple, if visual wavelengths were used such that 550 nm was a "positive" and 570 nm a "negative" stimulus, then during generalization tests, proportionately more responses were emitted in the presence of wavelengths shorter than 550 nm than were emitted by a group exposed to only the positive 550-nm stimulus. This "displacement away from the negative stimulus in the direction of the positive" (Hanson, 1959 p. 333) has been termed an "area-shift" (Terrace, 1964). The amount of shift is inversely related to the difference between S+ and S– (Hanson, 1959), and directly related to the number of "negative" stimuli used in discriminative training (Sloane, 1964). Did the gradients of the present experiment yield an "area-shift"? Yes, for the group exposed to the discriminative training schedule in which reinforcement frequencies in the presence of the two discriminative stimuli were equal (Group 3). No, for the group (Group 1) exposed to the discriminative train-

ing schedule in which food reinforcement, contingent on non-key-pecking behavior, occurred three times as frequently as food reinforcement, contingent on key pecks.

Any one or a combination of procedural differences between the two groups given discriminative training may have been responsible for the different effects. Besides the difference in relative frequency of reinforcement under the DRO schedule, the order of introduction, the temporal durations, and the schedule of reinforcement correlated with 550 nm differed between the groups. Recent work by Nevin (personal communication), however, suggests that when the frequency of reinforcement contingent on non-key-pecking behavior is higher than the frequency of reinforcement contingent on key pecks the stimulus projected on the key exerts little control of non-key-pecking behavior. Apparently if the difference in reinforcement frequency is great enough, non-key-pecking behavior is emitted with equal frequency in the presence of all of the exteroceptive stimuli on the generalization test dimension. When behavior is emitted with equal frequency in the presence of all stimuli, stimulus control of that behavior by that stimulus dimension is said to be absent. If the probability of some component of non-key-pecking behavior in the presence of a generalization test stimulus affects the probability of key-pecking behavior in the presence of that stimulus, then a generalization gradient which reflects this interaction will differ from a gradient in which no interaction occurs. We are suggesting that stimulus control of key-pecking behavior established by a variable-interval schedule of reinforcement during exposure to a particular discriminative stimulus can be modified by a discriminative training procedure which provides equally frequent reinforcements contingent on non-key-pecking behavior. Further, modification of stimulus control of key-pecking behavior is apparently not produced by a discriminative training procedure in which the frequency of reinforcement contingent on non-key-pecking behavior is substantially greater than that for key-pecking behavior.

Modification of stimulus control of key-pecking behavior by exteroceptive stimuli as shown in subsequent stimulus generalization tests is apparently produced by those discriminative training procedures which (a) yield be-

havioral contrast or (b) produce differential responding with stimuli interspersed during discriminative training.

Modification of stimulus control of key-pecking behavior by exteroceptive stimuli is apparently not produced by: (a) "errorless discrimination" procedures (Terrace, 1964), (b) separate extinction procedures (Honig *et al.*, 1959), or (c) procedures which produce differential responding but under which a higher reinforcement frequency is associated with a lower response rate. It is possible that in all three cases, other cues correlated with differences in the reinforcement schedules successfully compete for control of non-key-pecking behavior during what has been termed "discrimination" training.

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