A FURTHER STUDY OF STIMULUS GENERALIZATION FOLLOWING THREE-STIMULUS DISCRIMINATION TRAINING¹

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A group of pigeons was trained in a Skinner box to peck for VI reinforcement when the key was illuminated by a monochromatic light of 540 or 580 m μ but were non-reinforced for responding to 560 m μ . Two control groups, differing in amount of training, received only the two positive stimuli. At the completion of training all Ss received generalization tests under extinction. Both control groups produced bi-modal generalization gradients with the peaks of responding at the S+ values. The post-discrimination gradient revealed peaks displaced from the S+ values in the direction away from the S-, low responding and increased steepness in the region of S- and a general elevation of the gradient.

The present study is one of a series of experiments dealing with the influence of successive discrimination training on the post-discrimination generalization gradient. In the first study in this series Hanson (1959) trained pigeons to respond to one of two successively presented monochromatic stimuli for VI reinforcement. No reinforcement was given for responding to the other stimulus. A generalization test, administered during extinction after completion of discrimination training, revealed a displacement of the mode (peak) of responding from the S+ in the direction away from the S-, an elevation of this peak, an increased steepness of the gradient in the region of S- and a low value of the gradient in this region. These aspects of the post-discrimination gradient have also been reported by others (Honig, 1958; Honig, Thomas and Guttman, 1959; Guttman, 1959; Thomas, Ost and Thomas, 1960; Doris H. Thomas, 1962; D. R. Thomas, 1962).

Hanson (1961) has reported a study involving three-stimulus discrimination training in which pigeons were VI reinforced for responding to a particular monochromatic stimulus and extinguished for responding to two others, one of longer and one of shorter wavelengths. The result was an exceedingly high and steep generalization gradient bounded by the two negative stimulus values.

The present experiment is a further study of generalization following three-stimulus discrimination training and differs from Hanson's in that here a negative stimulus value was surrounded by two positive ones. This study is related to work reported by Doris H. Thomas (1962) which showed that a discrimination between 550 and 570 m μ was equally difficult whichever stimulus was positive, and further, that the post-discrimination peak shift of the generalization gradient was the same for both groups, although in opposite directions on the wavelength dimension.

The present experiment differs from others in this series in two additional ways. First, two different control groups were used, each having a different amount of training. The purpose of this feature was to make certain that differences in generalization gradients following discrimination and non-discrimination procedures could not be attributed to differences in amount of training received. A second innovation was that half of the Ss were naive, and half had been used in previous generalization research. We endeavored to determine whether past training and testing experiences would influence S's performance in the present experimental situation.

METHOD

Subjects

Twenty five homing pigeons were maintained by restricted feeding at approximately 75% of *ad lib.* weight. Twelve of the animals

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had been used in an earlier study on wavelength generalization and 13 were naive.

Apparatus

A Skinner-type automatic key-pecking apparatus equipped with a monochromatic light source was used. This apparatus has been described in detail by Thomas and Lopez (1962).

Procedure

The following indicates the procedure for the 13 naive birds. Upon arrival at the laboratory the pigeons were weighed, individually caged, and allowed free access to food and water. Throughout the experiment, water was available in the home cages. Within seven days a stable weight level was achieved by all birds and food was withheld until 75% of *ad lib.* weight was reached. The pigeons were then adapted, magazine trained, and conditioned to key-peck according to a set schedule covering five days. During this time the box was in complete darkness with the exception of the key light and the magazine light which was on during reinforcement cycles. Following conditioning, the birds were subjected to fixed ratio training, with 30 min sessions of FR 15, FR 25, and FR 50 administered on successive days. On the five following days the Ss were given daily, 30 min sessions of VI₁ training (the mean inter-reinforcement interval was approximately 1 min, the range from 4 sec to 4 min). During the training of all Ss a shutter was used which alternated 30 sec periods of stimulus presentation with 10 sec periods of blackout. Reinforcements were never given during blackout periods. During all training sessions up to this point the stimuli 540 and 580 m μ were used alternately.

At the end of five sessions of VI training, five of the pigeons were selected at random for discrimination training between 540 m μ (S+), 560 m μ (S-), and 580 m μ (S+), successively presented in an irregular order. Positive stimuli were reinforced according to the VI₁ schedule previously used. The negative stimulus was never reinforced. Ninety 30 sec stimulus presentations comprised a session, composed of 30 of each value. Discrimination training was continued until a criterion of three successive daily sessions with less than 10% of the total responses to the negative stimulus was achieved.

After the five days of VI training, four control pigeons continued with further VI training to a total of 10 sessions and four others continued to a total of 22 sessions. This latter was the median number of sessions required by the Ss (both naive and experienced) in the discrimination group. On the last day of VI training prior to the generalization test the stimuli 540 and 580 m μ were successively presented in an irregular order during the 30 sec stimulus-on periods and both were reinforced according to the VI schedule previously used. Note that no S- was used with either of the two control groups.

On the day following the last day of discrimination training (or VI training for the control groups) a generalization test during extinction was administered to all Ss. Thirteen stimuli were randomized within a series and eight different random series were presented to each S. The stimuli were 500 m μ through 620 m μ in 10 m μ steps. Each stimulus was presented for a period of 30 sec followed by a 10 sec blackout during which the stimulus was changed and the number of responses made in the previous period was recorded.

The treatment of the 12 pigeons which had been used in previous experimentation was identical to the above with the exception that the magazine training, conditioning, and fixed ratio sessions were omitted. Four of the experienced pigeons were tested in the experimental group and four in each of the control groups.

RESULTS AND DISCUSSION

The mean generalization gradients of the experimental and the control groups are presented in Fig. 1. These curves were constructed by plotting the mean number of responses made by each group to each stimulus presented during the generalization test against the wavelength of that stimulus. Control Group 1 received 10 daily sessions of VI training whereas Control Group 2 had 22. The control gradients indicate that the result of equal training to the two stimuli 540 m μ and 580 m μ is to produce a peak of responding at each S+ value, a decrease in responding to stimuli "outside" of the S+ values (*i.e.*, wavelengths shorter than 540 m μ and longer than 580 m μ) as well as a decrease in responding between the two reinforced values. The

Fig. 1. The mean generalization gradients of the experimental and the control groups.

group gradients can be considered accurate representations of individual performance, as is shown in Fig. 2 and 3 where the gradients of the individual animals in Control Groups 1 and 2, respectively, are presented.

Fig. 2. Gradients of the individual pigeons in Control Group 1.

Comparison of the individual gradients in these figures reveals that it is impossible to distinguish the naive *Ss* from the previously trained ones. In Fig. 2 pigeons No. 17, 18, 20 and 21 had had no previous training. In Fig. 3 *Ss* No. 213, 217, 218 and 220 were naive. The assumption that the effects of earlier training would be nullified by the procedure used in this study would appear justified, at least as far as the control groups are concerned.

The experimental group in Fig. 1 shows a displacement of the gradient in both directions away from the negative stimulus value of 560 $m\mu$. The gradient of this group shows minimal responding in the 560 $m\mu$ region and a flattened (and elevated) gradient to the "outside" of each modal value. As can be seen in Fig. 4 each pigeon in this group shows the displacement of both modes from the positive stimulus values in a direction away from *S*—. The naive *Ss* in this group were No. 133, 143, 152, 155 and 157. As was true of the control groups, the performance of the naive and the experienced pigeons was indistinguishable.

Before proceeding with comparisons between experimental and control conditions, the differences between the two control groups will be considered. As shown in Fig. 1, the

Fig. 3. Gradients of the individual pigeons in Control Group 2.

Fig. 4. Gradients of the individual pigeons in the experimental group.

two control gradients are very similar in form but differ somewhat in height, with the group having less training giving more responses during the test. Three separate analysis of variance were used to compare the two control groups. One treated the total number of responses made during the generalization test and may be considered an index of resistance to extinction. A second analysis dealt with the number of responses emitted on the first test

series, a measure of response rate. The third measure was the proportion of total responses given during the first stimulus series of the generalization test, the greater this proportion the more rapid the progress of extinction. In all three, analysis of variance of the naive-experienced distinction provided a second dimension. In none was there a significant effect, either of the amount of VI training or of the naive-experienced difference.

In the comparisons between experimental and control groups, Control Group 2, which had the same amount of training as the experimental group, was used. Parallel analyses using Control Group 1 yielded comparable results. The experimental group made significantly more responses during the generalization test than did the control group ($t=3.83$, 15 df, $p<.01$). The experimental and control groups differed even more strikingly in the location of responses along the stimulus dimension. The number of responses made to 560 $m\mu$ is significantly lower for the experimental than for the control group ($t=8.52$, 15 df, $p<.01$). A separate analysis of the number of responses to 530 $m\mu$ and stimuli of shorter wavelength and 590 $m\mu$ and stimuli of longer wavelength shows significantly more responding by the experimental group ($t=6.08$, 15 df, $p<.01$, $t=5.10$, 15 df, $p<.01$). Neither the experimental nor the control group responded significantly more often to stimuli of 570 $m\mu$ and longer wavelengths than to stimuli of 550 $m\mu$ and shorter wavelengths. In agreement with Doris H. Thomas (1962), there was no evidence that the displacement of the mode of responding was any greater in one direction than in another.

Despite the fact that the control Ss in the above comparison received as much training as the experimental Ss and therefore received even more reinforcements, the experimental gradient was reliably higher than the control. To determine whether this difference in the gradients is due to a difference in rate or only in resistance to extinction, an analysis of the number of responses made during the first series of stimulus presentations was performed. Analysis of variance employing the dimensions experimental *vs.* control and naive *vs.* experienced revealed a significant F for the former ($F=14.16$, 1/12 df, $p<.01$) but not for the latter ($F=0.12$, 1/12 df). Thus, the experimental and the control groups differed reliably in response rate at the start of generalization testing. Analysis of variance of the proportion of the total number of responses emitted during the first series of stimulus presentations revealed no significant difference attributable to experimental *vs.* control ($F=2.84$, 1/12 df) or to naive *vs.* experienced ($F=1.01$, 1/12 df) conditions. This indicates that the relative rate at which extinction was taking place was the same for experimental

and control groups. Despite the fact that the experimental group would in all probability have given more responses to the completion of extinction, there is reason to believe that it would not have taken any more time to do so. The failure of the measure of time to extinction to correlate with other indices of response strength has been noted before. Estes reported in 1944 that punishment may reduce the number of responses made to a criterion of extinction without altering the time required. More recently, Thomas (1961) found that the number of responses made to S— in discrimination learning could be predicted on the basis of the steepness of a previously obtained generalization gradient; however, the time required for the mastery of the discrimination could not be predicted on this basis. In two separate studies Thomas (1962) and Hiss (1962) have obtained evidence that following single stimulus training the measure of number of responses to extinction provides a reliable generalization gradient but the measure of time to extinction does not. Time to extinction does not seem to be subject to the influence of the same variables as are measures of responding.

The data obtained in the present study may be evaluated with regard to an application of Spence's (1936, 1937) theory of discrimination learning to the operant free responding situation. The algebraic summation of gradients of excitation and inhibition would account for many of our findings: the peak shifts, the increased steepness of the gradient and the low value in the region of S—, *etc.* The main point of disagreement with this type of analysis is the fact that the post-discrimination gradient is higher than the control gradient, rather than a fractional part thereof. This finding is typical of this entire series of investigations and suggests that Spence's theory errs in failing to consider that extinction has excitatory as well as inhibitory effects.

It has been shown (Guttman, 1959; Reynolds, 1961a, 1961b) that the increase in responding to the positive stimulus as a result of discrimination training does not require that responding to the "negative" stimulus be extinguished. Reynolds (1961a, 1961b) has demonstrated in a number of situations that when a condition involving fewer reinforcements is alternated with one involving more, response rate to the richer schedule is in-

creased as if to compensate for the decrease in rate to the poorer schedule. This phenomenon, called "behavioral contrast" by Reynolds, is an extension of the Pavlovian concept of "positive induction". Such a contrast effect may be observed during successive discrimination learning of the sort used in this experiment and is reflected in the elevation of the post-discrimination generalization gradient. It should be noted, however, that the elevation occurs at values other than CS. The interpretation of this finding requires a combination of behavioral contrast (which accounts for the elevation in the gradient) and the generalization of inhibition (to account for the peak shift).

In conclusion, the effect of equal training to two monochromatic stimuli is to produce a by-modal generalization gradient with peaks of responding at the two S+ values and a gradual decrease of responding on either side of these values. Within the limits tested (10 sessions and 22 sessions) amount of VI training has no effect on the resulting gradient. The effect of successive discrimination training involving three stimuli, one S- surrounded by two S+'s, is to produce a post-discrimination generalization gradient with both peaks displaced from the S+ values in the direction away from S-, low responding and increased steepness in the region of S- and a general elevation of the gradient. A combination of the concepts of behavioral contrast and generalized inhibition may be employed to account for these results.

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