Two-way generalization peak shift after two-key training in the pigeon*

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Thirteen pigeons were reinforced on a 1-min variable-interval schedule (VI 1 min) for pecking at a key illuminated by a 550-nm light. All birds were tested for generalization to 550 nm and 10 other wavelengths, following three variations of training as follows: Group 1 received only single-stimulus training to 550 nm before the test. Group 2 received successive single-key discrimination training between 550 nm as S+ and 559 nm as S- (extinction) before the test. Group 3 received successive training, but 559 nm was not associated with extinction; rather, in the presence of 559 nm, the birds were reinforced on VI 1 min for pecking a second key. In agreement with previous results, Group 1 yielded generalization gradients peaked at 550 nm, and Group 2 produced peaks shifted away from S-. For Group 3 a separate gradient was obtained for responses to each key, and each of these gradients was shifted away from the wavelength that signaled reinforcement on the other key. The results suggest that peak shift can result from the interaction of stimulus control from each of two "excitatory" stimuli, if each controls a response that interferes with the response controlled by the other. A general description of the conditions for peak shift and peak-shift failure is briefly suggested.

Under some circumstances, a pigeon will peck more rapidly at a novel stimulus than at a stimulus to which pecking has been reinforced. This result is commonly seen after single-key discrimination training, in which the reinforced stimulus (S+) is alternated with a relatively less reinforced or punished stimulus (S-) that lies close to the S+ along some stimulus dimension (e.g., Hanson, 1959; Guttman, 1959; Grusec, 1968; Terrace, 1968; Mariner & Thomas, 1969). The subsequent generalization gradient, generated by measuring the response to a number of stimuli along the dimension, reaches its peak at a stimulus value beyond S+, in the direction away from S-. However, this "peak shift" is not produced by certain other discrimination conditions. Reported among these, for example, are massed extinction at S-, simultaneous discrimination training, increasing relative rate of reinforcement at S+, and "errorless" discrimination training (Honig, Thomas, & Guttman, 1959; Honig, 1962; Terrace, 1964, 1966).

What causes peak shift? One trend in the literature emphasizes variables that induce, along with peak shift, such phenomena as response suppression, emotionality, and escape behavior (cf. Terrace, 1968, 1971; Bloomfield, 1969). These variables certainly often induce peak shift, but the precursors of peak shift may be more general: It may only be necessary that a stimulus close to "S+" on the tested dimension be made to set the occasion for any process—perhaps another operant—that interferes with the response recorded in a generalization test. This view lies behind the present study, which provides two incompatible responses (pecking at two keys) and measures generalization after responses to one key have been reinforced in the

presence of one wavelength and responses to the other key have been reinforced in the presence of the other wavelength.

METHOD

Subjects

Thirteen male domestic pigeons (white Carneaux and Silver King) served as Ss. All were maintained at approximately 80% of free-feeding weight during the experiments by feeding after the experimental sessions when necessary.

Apparatus

The birds worked in a Lehigh Valley two-key pigeon chamber, with the two keys 10½ in. from the floor and 1½ in. apart. When the left key was used, it was dimly illuminated from behind by an incandescent lamp, such that a white diamond, ¼ in. on a side and approximately 3 mL in luminance, appeared on the key. The right key was illuminated through a hole cut in the box by light from a Farrand No. 101866 grating monochromator, supplied with 2-mm slits. Selected wavelengths, uncorrected for luminance, were supplied by this instrument. The approximate luminance of the training stimuli (550 and 559 nm) was 1.3 mL. A shielded houselight faintly illuminated the bird's chamber. A two-way stepping device changed the stimulus wavelength up or down in 9-nm steps. Standard relay equipment controlled the presentation of stimuli and reinforcements. Responses were recorded on electromagnetic counters and cumulative recorders.

Procedure

All birds were magazine trained with a 550-nm stimulus present on the right key and the left key dark. The keys were then illuminated singly, and several reinforcements were given on each until a total of 30 reinforcements had been received for pecks on each key. During right-key training, that key was illuminated by 550 nm from the monochromator and the left key was dark. During left-key training, the white diamond was illuminated and the right key was dark.

For further training, the birds were divided into three groups. The first group (two birds) was exposed to the right key, illuminated by a 550-nm light, for a series of 1-min trials separated by 4-sec blackouts. Responses to the illuminated key

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Fig. 1. Mean generalization gradients from Group 1, given single-stimulus training at 550 nm, and Group 2, given successive single-key discrimination training with 550 nm as S+ and 559 nm as S-.

produced reinforcement (3 sec access to mixed grain) on a 1-min variable-interval schedule (VI 1 min). The birds were run on alternate days for a total of 10 1-h sessions. A generalization test followed on the 11th session. During this test, each bird received one reinforcement for pecking at the training wavelength (550 nm) and then received blocks of test wavelengths in extinction for 30-sec trials, with 11 wavelengths randomized within each block. Testing continued for 10 blocks of 11 wavelengths, or until the bird had not responded during one full block.

The three birds in Group 2 received single-key discrimination training on the right key, with 550 nm as S+ and 559 nm as S-. The trials were like those of the first group of birds, except that the two wavelengths appeared in a semirandom sequence, such that neither stimulus appeared for more than three consecutive intervals. A VI 1-min schedule was in effect during the S+ trials, extinction during the S- trials. Training continued in 2-h sessions until the bird met a criterion such that total responding in S- during a session was 10% or less of responding in S+. For Group 2, as for Group 1, the left key was never lighted after the initial key training. Generalization testing followed the same course as in Group 1.

Group 3 (eight birds) was trained and tested on the same 550-559 nm discrimination as Group 2, except that a form of concurrent two-key training was used instead of successive go/no-go training. During discrimination training trials for Group 3, the left key was always illuminated by a white diamond. As with the single-key group, 550 and 559 nm appeared on the right key in semirandom order, and pecks at 550 nm were reinforced on VI 1 min. However, reinforcement was also available at 559 nm. When 559 nm illuminated the right key, pecks at the left key (i.e., pecks at the white diamond) were reinforced on VI 1 min. For three birds in Group 3, a change-over delay was instituted after four sessions; for the remainder of the birds, this delay was in effect from the beginning of training. The delay was such that no peck on a key was reinforced until at least 2 sec had elapsed after the first peck to that key, following a switch from the other key. Discrimination training continued until S- responding in a single session fell below 10% of S+ responding. Generalization testing followed the same course as in the other groups, except that the left key was illuminated with the white diamond, while the various test wavelengths appeared on the right key. The birds were reinforced once on each key, during the appropriate stimulus, at the beginning of the testing session.

RESULTS

Group 2 birds met their single-key discrimination criterion in either four or five sessions. Two of the Group 3 (two-key) birds failed to meet criterion in 17 days, and their results were discarded. The remaining six

birds reached criterion in from 5 to 11 sessions.

Figure 1 shows the mean generalization gradients from Groups 1 and 2. Both of the birds trained at 550 nm alone yielded gradients peaking at this wavelength, and all birds given single-key discrimination between 550 nm (VI 1 min) and 559 nm (extinction) showed the usual peak shift away from the S- wavelength. The mean curves for both groups resemble closely the data that Hanson (1959) obtained under similar conditions.

The data from Group 3 (two keys) appears in Figs. 2 and 3. All six of these birds gave their maximum number of left-key responses not at the S+ for the left key (559 nm) but at a longer wavelength (Fig. 2). Five of them also produced the opposite peak shift, responding maximally not at the S- for the right key (550 nm) but at a shorter wavelength (Fig. 3). (Bird 4 pecked little at the right key during the generalization test; the resulting small gradient peaked at 550 nm—see Fig. 3.) The left-key gradients of Birds 5 and 6 showed large secondary response peaks at short wavelengths (Fig. 2), but none of the right-key gradients showed such peaks.

DISCUSSION

The two-way peak shifts recorded in this experiment (Group 3) are consistent with the hypothesis that peak shift results when two stimuli, close together on the tested dimension, control incompatible behaviors. Since, as a general rule, the behaviors controlled by one stimulus will be to some extent incompatible with the

Fig. 2. Left-key generalization gradients from individual birds in Group 3. These birds were trained with VI 1-min reinforcement for pecks at 550 nm, when this wavelength appeared on the right key, and with VI 1-min reinforcement for pecks at the left key, when 559 nm appeared on the right key.

behaviors controlled by the other (and may, of course, include "suppression" or "not responding"), this hypothesis suggests that peak shift may be predicted if the conditions leading to stimulus control are understood.

Unfortunately, most peak-shift experiments have not measured control by each stimulus explicitly, because only one response is recorded. An exception is provided by Bowen and Nevin (1971), whose method was much like that used in the present study. These investigators gave their pigeons an infrequently reinforced alternate key to peck, while the birds learned a discrimination between S+ and S- wavelengths on a primary key. The alternate key measured some of the bird's behavior when it was not pecking the primary key, and this measure gauged control by S-. The conditions of Bowen and Nevin failed to produce a peak shift on the primary key, and it is interesting to note that the alternate-key gradients collected simultaneously showed no sign of specific control by S-. The birds pecked the alternate key no more for S- than for other wavelengths that were "not S+." Group 3 birds in the present study also had two keys, but these were equally reinforced and reinforcement on the "alternate" (left) key was correlated with just one of the training stimuli. Group 3 gradients show control by both stimuli, but the bimodal gradients of two birds suggest some weakness in control of left-key responses by 550 nm, as if these birds (Birds 5 and 6, Fig. 2) sometimes pecked the left key simply because "not 550 nm" was on the right key.

That stimulus control is the crux of peak shift has been recognized previously. For example, Terrace (1968) attributed peak-shift failure after errorless

training to failure of control by S-. Thus, after training *with* errors, Ss follow the rule "respond to S1 and not to S2," while after training *without* errors, they follow the rule "respond to S1 and not to its absence" (cf. Jenkins, 1965). It is apparent that the difference between these rules is a matter of "attention to S2." Indeed, if peak shift is a matter of stimulus control, it is by definition a matter of attention and might well be reviewed in light of the attention literature. Lack of attention to S2 might, for example, result from "overshadowing" or "blocking." Errorless training could have its effect by making the S2 relatively uninformative, not "surprising," as Kamin (1968) has suggested. Other instances of peak-shift failure, such as that after massed extinction, might be understood in a similar fashion.

However, even were an attentional account of peak shift substantially correct, it would probably not subsume all instances of peak-shift failure. For example, as Hearst (1969) suggested, gradients of control around two stimuli may become so steep after prolonged training that they cease to overlap, and their associated responses then should no longer interfere. Likewise, if separately controlled responses are not recorded separately, an apparent failure of peak shift may result. Honig (1962) suggested essentially this explanation of peak-shift failure in his simultaneous discrimination situation, where the response "peck the other key," controlled by one stimulus, may have been confounded with the response "peck this key," controlled by the other stimulus.

In summary, the experiments reported here are consistent with the notion that generalization peak shift arises from the control of incompatible responses by two or more stimulus classes that overlap along some dimension. If this is the case, peak shift should generally be a function of those variables that control attention to the two stimuli, and systematic analysis of this possibility may prove fruitful.

REFERENCES

- Bloomfield, T. M. Behavioral contrast and peak shift. In R. M. Gilbert and N. S. Sutherland (Eds.), *Animal discrimination learning*. New York: Academic Press, 1969.
- Bowen, R. W., & Nevin, J. A. Discrimination and generalization with an alternative response. Proceedings of the 79th Annual Convention. American Psychological Association, 1971. 681-682.
- Grusec, T. The peak shift in stimulus generalization: Equivalent effects of errors and non-contingent shock. *Journal of the Experimental Analysis of Behavior*. 1968, 11, 39-49.
- Guttman, N. Generalization gradients around stimuli associated with different reinforcement schedules. *Journal of Experimental Psychology*. 1959, 58, 335-340.
- Hanson, H. M. Effects of discrimination training on stimulus generalization. *Journal of Experimental Psychology*. 1959, 58, 321-334.
- Hearst, E. Excitation, inhibition, and discrimination learning. In N. J. Mackintosh and W. K. Honig (Eds.), *Fundamental issues in associative learning*. Halifax: Dalhousie University Press, 1969.

Fig. 3. Right-key generalization gradients from individual birds in Group 3, collected during the same sessions as the data in Fig. 2.

- Honig, W. K. Prediction of preference, transposition, and transposition-reversal from the generalization gradient. *Journal of Experimental Psychology*, 1962, 64, 239-248.
- Honig, W. K., Thomas, D. R., & Guttman, N. Differential effects of continuous extinction and discrimination training on the generalization gradient. *Journal of Experimental Psychology*, 1959, 58, 145-152.
- Jenkins, H. M. Generalization gradients and the concept of inhibition. In D. I. Mostofsky (Ed.), *Stimulus generalization*. Stanford: Stanford University Press, 1965.
- Kamin, L. J. "Attention-like" processes in classical conditioning. In M. R. Jones (Eds.), *Miami symposium on the prediction of behavior: Aversive stimulation*. Miami: University of Miami Press, 1968.
- Mariner, R. W., & Thomas, D. R. Reinforcement duration and peak shift in post-discrimination gradients. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 759-766.
- Terrace, H. S. Wavelength generalization after discrimination learning with and without errors. *Science*, 1964, 144, 78-80.
- Terrace, H. S. Stimulus control. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application*. New York: Appleton-Century-Crofts, 1966.
- Terrace, H. S. Discrimination learning, the peak shift, and behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 727-741.
- Terrace, H. S. Escape from S-. *Learning & Motivation*, 1971, 2, 148-163.

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