PEAK SHIFT FOLLOWING SIMULTANEOUS DISCRIMINATIONS¹

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Pigeons were exposed to stimuli presented on two keys. For some birds, the stimuli varied in a dimension of visual flicker-rate, and for others they varied in visual intensity. During differential training, concurrent schedules operated, with one stimulus correlated with one schedule and another stimulus correlated with a second schedule that arranged a lower, or zero, rate of reinforcement. The stimuli were alternated randomly on the two keys. Generalization tests were given in which the original two, and seven other stimuli lying in the same dimension, were presented in pairs on the two keys in various combinations. In the generalization test given after differential training, each bird showed peak shift. The data did not support explanation for peak shift that gave critical emphasis to whether stimuli were presented simultaneously or successively during differential training.

Key words: peak shift, simultaneous discrimination, concurrent schedules, visual flicker-rate continuum, visual-intensity continuum, key peck, pigeons

Discrimination training frequently involves reinforcing responses in the presence of one stimulus, S1, and either not reinforcing responses, or reinforcing them at a lower rate, in the presence of another stimulus, S2. Generalization tests can be used to investigate the control over responding exerted by S1 and S2. The shape of the resultant generalization gradient will depend, in part, on the relationship of S1 and S2 to the stimuli presented during testing. If both S1 and S2 lie in the same physical dimension as the test stimuli, then a gradient showing substantial peak shift is often obtained (Bloomfield, 1967; Hanson, 1959; Terrace, 1966, 1968). In such a gradient, maximum responding occurs to a stimulus away from S1, in a direction away from S2.

The important factors for producing peak shift are not fully understood. For instance, Hearst (1968, 1969, 1971) did not obtain peak shift but Bloomfield (1967) did using similar procedures. One factor that can be crucial is prior discrimination training (Terrace, 1964; Yarczower, 1974). Studies showing peak shift

have presented S1 and S2 successively during discrimination training, according to various schedules of reinforcement (Catania, Silverman, and Stubbs, 1974; Guttman, 1959; Hanson, 1959; Winton and Beale, 1971). Honig (1962) presented S1 and S2 successively with one group of birds and simultaneously with another group and obtained peak shift only after the successive discrimination training. After simultaneous discrimination training, peak responding occurred during S1. Since simultaneous discrimination-training procedures have been distinguished from successive ones by a number of investigators (*e.g.*, Kimble, 1961; Rachlin, 1970; Riley, 1968), presenting S1 and S2 successively during discrimination training might have been crucial for obtaining peak shift. The present study investigated whether peak shift could be obtained following simultaneous discrimination training.

METHOD

Subjects

Seventeen experimentally naive homing pigeons were maintained throughout the experiment at about 80% of free-feeding weights.

Apparatus

A three-key pigeon chamber was used (Grason-Stadler model E6446CA-1). The standard

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operanda were three translucent keys 10 cm apart and 21 cm from the floor. The center key could be removed and replaced by "split keys". These were two independent Plexiglas keys separated by a metal strip running vertically down the middle of the aperture, so that one key occupied the left half of the aperture, and the other the right half. Each of the standard and the split keys could be lit by an independent rear-mounted light source. A force of about 0.2 N was sufficient to operate a switch mounted behind each key. Reinforcement was 3-sec access to wheat in a raised and lighted magazine located through an opening 12 cm below the center key. At all times the house-light was off, and a blower provided ventilation and masking noise. The experiment was controlled by relay circuitry in an adjoining room.

Stimuli projected onto the keys were of two basic types: flashing colored light, or steady white light. Two dimensions of flashing stimuli were used, produced by alternating green light of various durations with either red light of 0.03-sec duration (G/R stimuli), or white light of 0.03-sec duration (G/W stimuli). The nine durations of green light used were 0.08, 0.10, 0.15, 0.20, 0.30, 0.50, 0.75, 1.00, and 1.50 sec. The steady white-light stimuli (W stimuli) were produced by a 24-V, 2.8-W bulb mounted in a translucent holder 2.5 cm behind each key. The electric potential across the bulb could be varied from 12 to 24 V in 1.5-V steps. This provided nine light intensities ranging from a luminance of 35 cd/m² at 12 V to a luminance of 1360 cd/m² at 24 V.

Procedure

Sessions were scheduled six days a week, one session each day. The study was conducted in the form of two consecutive experiments, each using three groups of birds. Groups 3, 4, and 5 were used in the first experiment, and Groups 6, 7, and 8 in the second. (Groups 1 and 2 were composed of birds used in an earlier unpublished study). Three birds were assigned to each group, but one bird in Group 4 became ill during the experiment and had to be discarded. Each bird was designated by the letter 'B' followed by two numerals, the first numeral being the number of the group to which the bird was assigned.

Differences in the procedure used with the various groups are summarized in Table 1.

Table 1

Group	Stimuli	Keys	Schedules	Test Values
3	G/R	Standard	VI 2 VI 10 VI 2 EXT	Apart
4	G/W	Standard	VI 2 VI 10 VI 2 EXT	Apart
5	G/W	Standard	VI 2 VI 10 VI 2 EXT	Same and adjacent
6	W	Standard	VI 1 EXT	Apart
7	W	Standard	VI 2 EXT	Apart
8	W	Split	VI 2 EXT	Apart

They consist of: the dimensions in which the stimuli lay (Stimuli); whether the standard or split keys were used (Keys); what concurrent schedules operated during differential training (Schedules); whether the pairs of stimuli presented during generalization testing had the same or adjacent value with respect to the physical dimensions in which they lay, or had values wider apart (Test Values). Two schedules are shown for Groups 3, 4, and 5 because, for some birds in each of these groups, the schedule with which S2 was correlated was changed during the differential training (See Results).

Preliminary training. The birds were trained to eat from the magazine and then to raise it by emitting behaviors successively approximating a peck on either of two keys. These keys were lit by white light, which, for Groups 6, 7, and 8, was of 16.5-V intensity. The keys were the split keys for Group 8, and the two side keys for all other groups. In the next session, reinforcement followed each peck made alternately to the two keys. Sixty reinforcements were delivered in this session.

Nondifferential training. From the following session, pecks on the two keys were reinforced on concurrent schedules, with independent variable-interval (VI) schedules arranged on each key. Each schedule made reinforcement available on the average every 2 min (*conc* VI 2-min VI 2-min). A session consisted of 60, 30-sec trials during which each key displayed a stimulus of identical value, S1. The S1 was the G/R stimulus of 0.5-sec duration for Group 3, the G/W stimulus of 0.5-sec duration for Groups 4 and 5, and the W stimulus of 16.5 V for Groups 6, 7, and 8. For 10 sec between trials, blackouts occurred in which the keys were dark and ineffective and the reinforcement tapes stopped. Groups 3, 4, and 5

birds received 10 training sessions and Groups 6, 7, and 8 received 12.

A 1.5-sec changeover delay was in effect during these and all later sessions. The changeover delay began with each peck on either key that followed a peck on the other key, the start of a trial, or a reinforcement. Only after the changeover delay had elapsed, could a scheduled reinforcement occur.

Differential training. During the differential training that followed, S1 was presented on one key correlated with a VI 1-min schedule of reinforcement for Group 6, or VI 2-min for all other groups. A different stimulus value, S2, which was in the same dimension as S1, was simultaneously displayed on the other key, and was correlated with a VI 10-min schedule of reinforcement (for Groups 3, 4, and 5), or (for Groups 6, 7, and 8) no reinforcement (EXT). Each session consisted of 60, 30-sec trials in which S1 and S2 were always both present, one on each key. The key on which each stimulus was displayed varied irregularly from trial to trial. Trials were separated by 10-sec blackout periods. Training continued until the relative number of responses made in the presence of S1 during a session was at least 0.83, *i.e.*, they equalled or exceeded the relative number of reinforcements scheduled for responses made during S1 by Groups 3, 4, and 5.

Generalization tests. In a generalization test, nine stimuli were presented in pairs on the two keys. For each group, S1, S2, and the other seven stimuli lying in the same dimension were used. Except for Group 5, all combinations of pairs of the nine stimuli were presented, except for pairs of the same, or immediately adjacent value, and the pair consisting of the smallest and largest value. This provided 27 different stimulus pairs, with each stimulus occurring three times on each key. The pairs were arranged in a mixed sequence, with each stimulus occurring twice in each group of nine pairs. By presenting each stimulus in the same sequence, but on the opposite key, a further 27 stimulus pairs could be arranged, providing a total of 54 trials. For Group 5, tests consisted of presenting pairs of stimuli of the same, or immediately adjacent value. This provided 17 different stimulus pairs. During a generalization test, this sequence was presented three times. In the second sequence, each stimulus was presented on the key opposite to that during the first and third sequences. Two extra

stimulus presentations were made at the end of the first two sequences, which provided a total of 55 trials. One presentation was the stimulus of longest duration on both keys, and the other presentation was the stimulus of shortest duration on both keys. For all groups, a test ended after all scheduled trials were presented, or sooner if no more than two stimuli were responded to in any five consecutive trials. No reinforcement was provided during a test. All trials were separated by 10-sec blackouts.

A baseline generalization test, G1, was given in a session between nondifferential and differential training. A second generalization test, G2, was given following differential training.

RESULTS

During nondifferential training, total responses on the two keys increased, each bird making at least 1100 responses in the last session. Two birds (B51, B52) showed consistent but slight preferences for one key. During differential training, the relative number of responses during S1 increased, although several birds showed some transitory reversals in this trend. After Session 13 with Groups 3, 4, and 5, there was an apparatus failure. In Session 14, the five birds that had not reached the criterion for giving G2, all made about 50% of their responses during S1. From Session 21, the schedule for these birds was changed to *conc* VI 2-min EXT, by discontinuing all reinforcement for responses during S2. The number of days of differential training required to reach criterion, and the total number of responses made in the presence of S2 during differential training are shown in Table 2.

Data from the two generalization tests are shown in Figure 1. Each gradient shows the total number of responses the bird made to each of the nine test stimuli. The gradients of Group 5 were corrected for the extra presentations of the stimulus of longest duration and the stimulus of shortest duration. For this group, component gradients are shown based on responding during presentations of pairs of the same stimulus value (single-value gradients) and of different stimulus values (double-value gradients). With the W stimuli, S1 was made dimmer than S2 to prevent the possibility of producing a peak to stimuli in the test dimension beyond S1, in a direction away from

Table 2

<i>Subject</i>	<i>Number of Days of Differential Training</i>	<i>Total Responses Made to S2</i>
B31	11	5658
B32	31	22631
B33	25	26812
B41	12	5560
B42	26	40387
B51	45	59929
B52	9	6915
B53	59	58867
B61	7	5255
B62	8	5402
B63	6	4063
B71	5	4496
B72	3	1525
B73	8	4584
B81	23	8307
B82	23	19214
B83	13	8363

S2, by a "stimulus-intensity dynamism" effect (Hull, 1949). The number to the right of each gradient shows the total number of presentations of each stimulus on the two keys. If the scheduled generalization test sequence was completed, each stimulus was presented a total of 12 times. No number is shown for the Group 5 gradients because of the unequal number of presentations of the stimuli of shortest and longest duration. All birds in this group maintained responding and so were given the scheduled 55 trials.

The baseline (G1) gradients did not have the same form for each bird. Most gradients were fairly shallow, although some (*e.g.*, those of B42, B51, B71) were quite steep. For several birds, responding peaked during S1 (B41, B52, B71) or during a stimulus near S1 (B51, B62, B63, B73, B82) and generally decreased to either side of the peak. The single-value and double-value gradients of Group 5 resembled the composite gradients.

Most postdiscrimination training (G2) gradients were orderly, particularly those obtained with the W stimuli. Responding was minimal in the presence of stimuli away from S2, in the direction away from S1, and increased fairly systematically, reaching a peak during a stimulus away from S1, in the direction away from S2. For all but four birds (B32, B51, B52, B81) responding declined during stimulus values beyond that to which the peak occurred. Compared with the G1 gradients, there was a steep-

ening in the slope of all the G2 gradients, and for most birds this was marked. Again, the single-value and double-value gradients of Group 5 were similar to the composite gradients. Peak responding occurred during the same stimulus away from S1 as in the composite gradient, except for the single-value gradient of B52, where peak responding occurred during S1.

DISCUSSION

Peak shift was reliably obtained following discrimination training in which the training stimuli were presented simultaneously. Every bird responded maximally during a stimulus displaced from S1 in a direction away from S2.

Peak shift was found with both visual flicker-rate and visual-intensity dimensions. Sloane (1964, 1966) obtained peak shift using stimuli differing in flicker rate, although he alternated white light with periods of no light, usually varying the rate of flicker by varying the period of no light. Ernst, Enberg, and Thomas (1971) obtained peak shift with white-light stimuli that varied in visual intensity. The data from Groups 6, 7, and 8 support their contention that peak shift can be obtained using stimuli lying in this dimension. Heinemann and Chase (1970) suggested that a sigmoidal form of gradient, where responding increased during stimuli away from S1 in a direction away from S2, but did not decline during stimuli still further away, was the usual finding after discrimination training with stimuli varying in visual intensity. Only one bird (B81) in Groups 6, 7, and 8 did not show a decline in responding during one or more stimuli beyond that during which peak responding occurred. Also, these gradients cannot be explained in terms of Hull's (1949) suggestion that animals may respond faster during more-intense stimuli, since the stimuli in the region of peak responding were of lowest intensity. Peak shift was obtained after correlating S2 with a low rate of reinforcement, thereby supporting other findings that one stimulus does not have to be correlated with extinction to obtain the effect (Guttman, 1959; Terrace, 1968; Winton and Beale, 1971).

The present results showed that peak shift could be obtained following simultaneous discrimination training. Honig (1962) obtained peak shift following successive discrimination training, but not following simultaneous dis-

Fig. 1. Individual generalization gradients showing the number of responses made to each stimulus during the generalization test given before differential training, G1, and following differential training, G2. The abscissa shows the duration of colored light that produced variations in the flicker-rate stimuli (Groups 3, 4, and 5), and the electrical potential across the bulbs that produced the white-light stimuli (Groups 6, 7, and 8). The stimuli presented during the training sessions, S1 and S2, are indicated by arrows. The number of times each stimulus was presented during the generalization test is shown to the right of each gradient, except for Group 5 (see text).

crimination training. While the present study does not isolate the essential differences between the present procedure and Honig's, it is relevant to explanations of why peak shift did not occur in Honig's study.

Some explanations have emphasized the greater choice between S1 and S2 available in the simultaneous discrimination training. Catania (1966, p. 247) suggested that the availability of changeover responses between S1 and S2 may be crucial; Bloomfield (1969, p. 229) emphasized the importance of continuous availability of both stimuli. In the present study, both stimuli were continuously available, and changeover responses could always be made. The finding of peak shift supports the contention of Winton and Beale (1971) that these factors were not responsible for Honig's failure to obtain peak shift.

A number of explanations for Honig's results have referred to the control over responding exerted by S2 following discrimination training. They suggested that peak shift occurred after the successive discrimination training because, unlike after the simultaneous discrimination training, S2 became a cue for not responding (Honig, 1962), became aversive because of unreinforced responding during it (Grusec, 1968), or exerted inhibitory control over responding (Bloomfield, 1969; Macphail, 1972). A problem with this type of explanation is that, even if correct, it is not clear what essential features of the successive discrimination training produced this type of control by S2. Finding peak shift in the present study, suggests that it could not have been the successive discrimination training, as such, that was crucial.

Another explanation for Honig's results has been offered by R. Rudolph (cited in Riley, 1968, pp. 81-84). He emphasized that during the generalization testing, Honig sometimes presented pairs of stimuli of different values, and sometimes only a single stimulus. He proposed that the simultaneous discrimination training produced strong control by the relation between the two training stimuli, and that had only pairs of stimuli been presented during the generalization test, then peak shift would have occurred. The single-stimulus presentations, he argued, gradually overcame the control by the relation between the training stimuli, until maximum control was exerted by S1, and hence no peak shift occurred. If

Rudolph's explanation was correct, it should apply to the Group-5 birds, which were presented with pairs of stimuli of the same value, as well as pairs of different values, during the generalization test. However, peak shift was obtained from all birds in this group. In addition, while they tended to be less orderly than their composite gradients, in both component gradients of these birds, except the single-value gradient of B52, maximum responding occurred during a stimulus away from S1, in a direction away from S2.

White's (1972) explanation for Honig's results emphasized the simultaneous presentation of S1 and S2 during discrimination training. He suggested that a necessary condition for producing peak shift is the "absence of a comparator" when a training stimulus is presented. White found that after subjects were trained to choose S1, when both S1 and S2 were present, they chose S1 most frequently when it was presented in pairs with other stimulus values in a subsequent test. He argued that because the S1 and S2 were not simultaneously presented in the Winton and Beale (1971) study, there was the absence of a comparator, which may have been why peak shift was obtained. However, peak shift was found in the present study, where both training stimuli were always displayed together. Further, the use of the split keys allowed subjects in Group 8 more nearly to make a truly simultaneous comparison of the two stimuli, yet clear peak shift was obtained from all these birds.

Honig (1962) reported that the group given successive discrimination training (which showed peak shift) required more differential training to reach his criterion for giving a post-discrimination generalization test, than the group given simultaneous discrimination training (which did not show peak shift). Further, the successive group made seven times more responses in the presence of S2 during differential training than the simultaneous group. Terrace (1966, 1968) emphasized that high rates of responding during S2 often occur with subjects that show peak shift after successive discrimination training. Grusec (1968) suggested that peak shift may not have followed Honig's simultaneous discrimination training, because few responses were made during S2. Direct comparison with Honig's data is not possible because he did not report the actual

number of responses during S2. Further, Honig reported only group results. It is possible that some subjects given simultaneous discrimination training did produce peak shift. If the number of responses during S2 and the occurrence of peak shift are related, peak shift might have been obtained from the two subjects he discarded which continued to respond during S2 in the simultaneous discrimination training.

Table 2 shows a fairly close correlation between the number of days taken to reach criterion and the number of responses made during S2. However, peak shift did not correlate directly with either of these measures. For instance, some of the birds that took the longest times to reach the criterion, and that made the greatest number of responses during S2 (e.g., B42, B53), showed less-convincing peak shift than some of the birds that took the shortest times, and that made the least number of responses during S2 (e.g., B71, B73). Terrace (1972, p. 114) also found no direct correlation between the number of responses made during S2 and amount of peak shift. Some general correlation may exist between the number of responses during S2 and peak shift since, in the present study, only two birds (B71, B72) reached the criterion for G2 in five days or less, the period in which all the subjects given simultaneous discrimination training in the Honig study reached a more-stringent criterion. However, even if such a correlation exists, it still remains necessary to isolate which aspects of the procedure are important for producing greater responding during S2, and for producing peak shift. Again, the present data show that it is not simply a function of whether S1 and S2 are presented simultaneously.

The variations in experimental procedure used in the present study did not isolate factors crucial for producing peak shift. However, obtaining the effect from all birds provides strong evidence against distinguishing between simultaneous and successive discrimination procedures, when peak shift is used as a dependent measure. Simultaneous discrimination training involves concurrent schedules of reinforcement. Concurrent schedules can also be arranged using a changeover-key procedure, where only S1 or S2 is present at any time, but the other stimulus is continuously available, and can be produced by a changeover response

being made at another locus (Findley, 1958). The two methods of concurrent scheduling have produced similar responding (Catania, 1966). Producing peak shift with a changeover-key procedure (Winton and Beale, 1971), as well as with a simultaneous discrimination procedure (present study), provides further support for treating the two types of procedure as similar.

REFERENCES

- Bloomfield, T. M. A peak shift on a line-tilt continuum. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 361-366.
- Bloomfield, T. M. Behavioural contrast and the peak shift. In R. M. Gilbert and N. S. Sutherland (Eds.), *Animal discrimination learning*. New York: Academic Press, 1969. Pp. 215-241.
- Catania, A. C. Concurrent operants. In W. K. Honig (Ed.), *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 213-270.
- Catania, A. C., Silverman, P. J., and Stubbs, D. A. Concurrent performances: stimulus-control gradients during schedules of signalled and unsignalled concurrent reinforcement. *Journal of the Experimental Analysis of Behavior*, 1974, 21, 99-107.
- Ernst, A. J., Enberg, L., and Thomas, D. R. On the form of stimulus generalization curves for visual intensity. *Journal of the Experimental Analysis of Behavior*, 1971, 16, 177-180.
- Findley, J. D. Preference and switching under concurrent scheduling. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 123-144.
- Grusec, T. The peak shift in stimulus generalization: equivalent effects of errors and noncontingent shock. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 239-249.
- 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. Discrimination learning as the summation of excitation and inhibition. *Science*, 1968, 162, 1303-1306.
- Hearst, E. Excitation, inhibition, and discrimination learning. In N. J. Mackintosh and W. K. Honig (Eds.), *Fundamental issues in associative learning*. Halifax, Nova Scotia: Dalhousie University Press, 1969. Pp. 1-41.
- Hearst, E. Contrast and stimulus generalization following prolonged discrimination training. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 355-363.
- Heinemann, E. G. and Chase, S. On the form of stimulus generalization curves for auditory intensity. *Journal of Experimental Psychology*, 1970, 84, 483-486.
- Honig, W. K. Prediction of preference, transposition and transposition reversal from the generalization

- gradient. *Journal of Experimental Psychology*, 1962, **64**, 239-248.
- Hull, C. L. Stimulus intensity dynamism (V) and stimulus generalization. *Psychological Review*, 1949, **56**, 67-76.
- Kimble, G. A. *Hilgard and Marquis' conditioning and learning*. New York: Appleton-Century-Crofts, 1961.
- Macphail, E. M. Inhibition in the acquisition and reversal of simultaneous discriminations. In R. A. Boakes and M. S. Halliday (Eds.), *Inhibition and learning*. New York: Academic Press, 1972. Pp. 121-151.
- Rachlin, H. *Introduction to modern behaviorism*. San Francisco: W. H. Freeman, 1970.
- Riley, D. A. *Discrimination learning*. Boston: Allyn and Bacon, 1968.
- Sloane, H. N. Stimulus generalization along a light flicker-rate continuum after discrimination training with several S's. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 217-222.
- Sloane, H. N. Some effects of light flicker rate on the pigeon. *Psychonomic Science*, 1966, **4**, 119-120.
- 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. Pp. 271-344.
- 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. Conditioned inhibition in successive discrimination learning. In R. A. Boakes and M. S. Halliday (Eds.), *Inhibition and learning*. New York: Academic Press, 1972. Pp. 99-119.
- White, K. G. Choice and frequency measures of stimulus control following simultaneous discrimination. *Psychonomic Science*, 1972, **27**, 15-17.
- Winton, A. S. W. and Beale, I. L. Peak shift in concurrent schedules. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 73-81.
- Yarczower, M. Discriminative effects of massed extinction. *Journal of the Experimental Analysis of Behavior*, 1974, **22**, 161-168.

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