BEHAVIORAL CONTRAST WITH MULTIPLE POSITIVE AND NEGATIVE STIMULI ON A CONTINUUM¹

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After an initial period of nondifferential training, six pigeons were trained on a go/no-go discrimination involving 12 line tilts from vertical clockwise to horizontal. Responses to the first six tilts (positive stimuli) were reinforced on a variable-interval one-minute schedule, whereas responses to the other six tilts (negative stimuli) were extinguished. During the first several discrimination sessions, the highest response rate was typically to one of the positive stimuli that was relatively close to the negative stimuli or at an intermediate distance, rather than to one of the positive stimuli most distant from the negative stimuli. This effect decreased with extended training up to 50 or 80 sessions.

Behavioral contrast is a change in response rate in one component of a multiple schedule in a direction opposite to the direction of change in response rate in another component, where the schedule of reinforcement in the presence of the first component has remained constant. One fundamental question regarding behavioral contrast concerns the functional relation between the magnitude of the physical difference between the component stimuli and the amount of behavioral contrast. This question is closely related to that of the relation between the difficulty of the discrimination and the amount of behavioral contrast. These questions are of particular interest because of their implications for theories of discrimination learning.

Either a between-subjects or a within-subjects experimental design might be used to study the effect of the difference between the stimulus in the presence of which responses are reinforced (S+) and the stimulus in the presence of which responses are extinguished (S-) on positive behavioral contrast. At present, there have been no completely satisfactory experiments on this topic employing a between-subjects design. Mackintosh, Little, and

Lord (1972, Experiment 1, massed-practice groups) found higher response rates to S+ in a group of pigeons trained on a line-tilt discrimination involving a 90° stimulus difference than in a group with 15° stimulus difference. Unfortunately, their experiment involved only two levels of discrimination difficulty, and it did not provide a baseline of nondifferential training, before discrimination training, from which to measure the actual magnitude of behavioral contrast.

Different groups of pigeons were trained on discriminations involving different amounts of physical separation between S+ and S-, before a generalization test, in experiments by Hanson (1959) on the wavelength continuum, and Hearst (1969) on the line-tilt continuum. Unfortunately, these experiments provided little information about the relation between contrast and the S+/S- difference. Neither experiment provided an adequate baseline of nondifferential training, and in both experiments the groups with the more difficult discriminations had more training before the test than the groups with the easier discriminations.

A within-subjects experimental design to study the effects of S+/S- difference on behavioral contrast would require several S+ values on a continuum, and one or more S- values at one end of the continuum. Such a procedure would enable the experimenter to plot response rate as a function of the stimulus value (such a plot is called a rate/stimulus function in this paper). The rate/stimulus function at various stages of discrimination

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training could be compared with a baseline rate/stimulus function from prior nondifferential training, to determine the amount of behavioral contrast in the presence of S+ values at various distances from S—.

In a variation of this within-subjects design, Catania and Gill (1964) trained three pigeons on a discrimination between eight S+ values and eight S— values on a linear spatial dimension. When one of the top eight in a vertical row of 16 miniature lamps was lit, key pecks were reinforced on a fixed-interval one-minute schedule (FI 1-min), whereas pecks were never reinforced when one of the bottom eight lamps was lit. After about a week of training, the birds typically responded more to the S+ lamp closest to the S— region than to the other S+ values. This experiment suggests greater behavioral contrast with a smaller S+/S— difference, though unfortunately the authors provided no baseline of nondifferential training.

The present study examined the relation between the magnitude of the S+/S— difference and the amount of positive behavioral contrast, using a within-subjects design. The experiment was similar to the Catania and Gill (1964) experiment in that it involved several values of both S+ and S— on a continuum (line tilt). However, the present study employed a relatively large number of subjects, and the procedure included extensive nondifferential training before a long period of discrimination training.

METHOD

Subjects

Six female Silver King pigeons (5 to 8 yr old) were maintained at $75\% \pm 15$ g of their free-feeding body weights. Birds 1, 2, 3, and 4 had previously been used in an auditory discrimination experiment that involved variable-interval reinforcement for pecks at a red response key. Birds 5 and 6 were experimentally naive.

Apparatus

The birds were trained in a Lehigh Valley Electronics (Model 1519) pigeon test chamber, which included a transparent plastic key mounted behind a 2.5-cm diameter circular opening above the food hopper opening (the two side keys were covered with cardboard). An in-line digital display cell (Grason-Stadler pattern No. E4580-186) was mounted behind

the key. This miniature projector could transilluminate the key with a white line (25 mm by 3 mm) at any of 12 different degrees of tilt, ranging from vertical (Tilt 1) clockwise through horizontal (Tilt 12) in 8.18° steps. Stimulus switching was accomplished by a stepper relay that arranged four different randomized blocks of stimuli; this sequence of 48 stimulus presentations was repeated three and one-fourth times during each training session. A dim houselight was mounted above the key. External noises were masked by an air blower and a white-noise generator. Reinforcers consisted of mixed grain (2-sec access).

Procedure

Preliminary training. The experimentally naive birds were initially trained to peck at a key illuminated by white light, and every peck was reinforced until 30 reinforcements had accumulated. All six birds were then given two sessions in which all 12 line-tilt stimuli were presented in three different randomized blocks. Each peck was reinforced, and the stimulus was changed after each peck, for 36 total reinforcements per session.

Nondifferential VI training. In order to establish a baseline response rate from which to measure subsequent behavioral contrast, each bird was then given 30 to 36 sessions of nondifferential training, during which all 12 line tilts were presented. Reinforcement opportunities were scheduled with a single tape timer, which set up reinforcements on a variable-interval 30-sec (VI 30-sec) schedule in a predetermined "random" half of the presentations of each stimulus. Thus, the overall effective schedule of reinforcement was VI 1-min for each stimulus.

In each training session, each of the 12 line-tilts was presented once in each of 13 randomized blocks. The first block was a warm-up period; data were collected only during the final 12 blocks. The stimulus presentations were of 30-sec duration, separated by 5-sec blackouts, during which both the key stimulus and the houselight were off and pecks could not be reinforced. Training sessions were conducted once every day, except occasionally when a bird was not at the proper weight.

Discrimination training. Following nondifferential training, Birds 1, 2, 3, and 4 were given 80 sessions of discrimination training. Birds 5 and 6, which were introduced into the

experiment later, had 50 sessions of discrimination training. Discrimination sessions were identical to nondifferential training sessions, except that the six tilts at one end of the line-tilt continuum were S+s (VI 1-min reinforcement), while the other six tilts were S-s (extinction). Tilts 1 to 6 were S+s for Birds 1, 4, and 6, whereas Tilts 7 to 12 were S+s for Birds 2, 3, and 5.

RESULTS

Figure 1 shows each bird's mean response rate to each line tilt for the last three nondifferential VI training sessions, and for the second, fourth, and sixth discrimination sessions. During nondifferential training, individual birds sometimes had a maximum or a minimum response rate to one stimulus or another for several sessions in a row. However, there were no consistent, long-term maximum or minimum response rates at any particular line tilt (or tilts), either within any individual subject or for the group as a whole.

Behavioral contrast occurred in at least some of the S+ values by the sixth discrimination session, or sooner, in all birds except Bird 1. In the sixth discrimination session, the peak of the rate/stimulus function was at Tilt 6 in Bird 5 and Tilt 7 in Bird 6: these tilts were the S+ values closest to the S- region. In Birds 2, 3, and 4 in the sixth discrimination session, the peak of the rate/stimulus function was at an intermediate S+ value. In no case, except Bird 1, during the fourth or sixth discrimination sessions was the peak of the rate/stimulus function at either of the two S+ values furthest from the S- region.

Figures 2 and 3 show mean rate/stimulus functions for blocks of discrimination sessions for individual birds. The dashed line on each graph indicates that bird's overall mean response rate during the last three sessions of nondifferential VI training; this mean can be used as a baseline from which to measure behavioral contrast effects. For all birds, the function for Sessions 6 to 10 is indicated at the bottom of the graph. Succeeding blocks of

Fig. 1. Response rates to each stimulus for the mean of the last three sessions of nondifferential VI training, and for the second, fourth, and sixth discrimination sessions, for individual subjects. During discrimination training, Tilts 7 to 12 were S+ values for the birds in the top row, whereas Tilts 1 to 6 were S+ values for the birds in the bottom row.

Fig. 2. Mean response rates to each stimulus for blocks of discrimination sessions for birds with Tilts 1 to 6 as S+ values. The figures beside each function indicate the sessions included in that function. The functions for successive blocks of sessions are displaced upward by 20 (or 40) responses per minute. The dashed horizontal lines indicate each bird's overall mean response rate during the last three sessions of nondifferential VI training.

five or 10 sessions are displaced upwards by 20 (in some cases 40) responses per minute. In all cases, the lowest actual response rate in each block is at or just above zero responses per minute. (Thus, the actual rate to any stimulus in any block can be determined by subtracting the zero reference level from the indicated ordinate value for that stimulus. For example, for Bird 1, in Sessions 21 to 30, the zero reference level is 60; the actual response rate to Tilt 9 is 110 minus 60 equals 50 responses per minute.)

In general, the mean rate/stimulus functions are smoother than the usual single-session functions. However, the mean functions fairly represent the general shape of the majority of the single-session functions within each block of sessions, particularly with regard to whether the peak of the function was at one of the S+ values closest to the S-

region, at an intermediate distance, or furthest from the S- region.

During discrimination Sessions 6 to 15, the peak of the rate/stimulus function was typically at one of the two S+ values closest to the S- region (Birds 2, 5, and 6) or at one of the middle two S+ values (Birds 3 and 4). Bird 1 had essentially equal response rates to all six S+ values during Sessions 6 to 15. No bird had a clear peak response rate at one of the two S+ values farthest from the S- region in Sessions 6 to 15.

As training progressed, the relative response rates to the various S+ values changed in all birds. By the last block of sessions, the peak of the rate/stimulus function was clearly at the S+ value farthest from the S- region in Birds 2 and 5. During the course of extended discrimination training, from Sessions 6 to 10 to

Fig. 3. Mean response rates to each stimulus for blocks of discrimination sessions for birds with Tilts 7 to 12 as S+ values. The figures beside each function indicate the sessions included in that function. The functions for successive blocks of sessions are displaced upward by 20 (or 40) responses per minute. The dashed horizontal lines indicate each bird's overall mean response rate during the last three sessions of nondifferential VI training.

41 to 50 (or 71 to 80), the mean response rate at the S+ value closest to the S- region decreased relative to the rate at the farthest S+ value, in all birds except Bird 1.

Bird 1 was unique in that it did not show behavioral contrast during the first 30 discrimination sessions. When contrast finally occurred in the later sessions, the peak of the rate/stimulus function was typically at an S+ value at an intermediate distance from the S- region.

In general, the data were more systematic for the birds trained with Tilts 1 to 6 as S+ (Birds 2, 3, and 5) than for the birds trained with Tilts 7 to 12 as S+. The former group showed more initial behavioral contrast, and a more regular shift in the peak of the response rate function from an S+ at a short or intermediate distance from the S- region early in discrimination training to an S+ far from the S- region later in training.

DISCUSSION

What is the relation between the magnitude of the physical difference between S+ and S-

and the amount of positive behavioral contrast? The present experiment suggests that during the first several discrimination sessions, the amount of contrast is usually greater with a relatively small or moderate S+/S- difference than with a relatively large S+/S- difference. This conclusion is indicated by the fact that during the first several discrimination sessions, the peak of the rate/stimulus function was usually at an S+ value at a relatively small or intermediate distance from the S- region. In no case was the initial behavioral contrast greatest at one of the two S+ values farthest from the S- region. However, during later discrimination sessions, the tendency to respond more to the S+s near the S- region decreased, and the peak of the rate/stimulus function was often at the S+s farthest from the S- region.

One puzzlement in this study is that the bird's with Tilts 1 to 6 as S+s (Birds 2, 3, and 5; Figure 2) showed more behavioral contrast than the birds trained with Tilts 7 to 12 as S+s (Figure 3). A possible cause of this difference concerns the specific stimulus sequence employed during discrimination training. The

same sequence was used in each session, for each subject, with the two groups differing only in the designation of either Tilts 1 to 6 or 7 to 12, as S+s. An analysis of the stimulus sequence after the experiment revealed that for the birds with Tilts 1 to 6 as S+ values, the S+ tilts were preceded by S- tilts about one-third more often than for the birds with Tilts 7 to 12 as S+. Malone and Staddon (1973) showed that the response rate to a particular stimulus in a multiple schedule will be temporarily greater if it is immediately preceded by a lower-rate-producing stimulus than if it is preceded by a higher-rate-producing stimulus.

Different theoretical viewpoints would make different predictions about the relation between the magnitude of the S+/S- difference and the amount of behavioral contrast. Spence's (1937) excitation-inhibition theory of discrimination learning does not account for contrast *per se*. However, if one assumes that the mechanism causing contrast is independent of the S+/S- difference, then Spence's theory would predict that the measured amount of contrast would be greater with a larger S+/S- difference, since inhibition generalized from S- would presumably reduce the response strength to S+ values relatively close to S- more than it would reduce the response strength to S+ values relatively far from S-.

A line of reasoning consistent with Terrace's work (e.g., 1972) would predict that behavioral contrast would be greater with a smaller S+/S- difference. Terrace believes that behavioral contrast is a result of some sort of emotional reaction to the discrimination situation, this reaction being caused by the suppression of responding to S-. If one further assumes that the emotional reaction to a difficult discrimination is greater than the reaction to a relatively easy discrimination (e.g., as a result of greater conflict in the difficult discrimination), then one can deduce that contrast should be greater with more difficult discriminations. The present results are more consistent with this line of reasoning than with the derivation from Spence's (1937) theory, in that initial contrast was greater at S+ values close to the S- region or at an intermediate distance, rather than at the S+ value farthest from the S- region. However, the line of reasoning derived from Terrace's work does not account for the fact that even though contrast was

still occurring after extended discrimination training in all subjects, the peak of the rate/stimulus functions in later discrimination sessions was often at the S+ values farthest from the S- region.

Recently, Gamzu and Schwartz (1973; also see Redford and Perkins, 1974) have suggested that the additional responses involved in the response-rate increase during positive behavioral contrast are "autopecks" (cf. Brown and Jenkins, 1968). That is, the extra responses are a direct result of the differential stimulus-food contingencies during discrimination training, independent of the response-food contingencies. The notion that contrast depends entirely on the differential signalling value of the stimuli would seem to imply that contrast should be greater, the more easily discriminable a stimulus paired with food is from a stimulus paired with extinction. In other words, it would be predicted that contrast would be greatest at the S+ values furthest from the S- region in the present experiment. The data from the early discrimination sessions are clearly not in conformity with this prediction.

Results similar to those of the early discrimination sessions in the present study (higher response rates to S+ values near the S- region than to S+ values far from the S- region) have also been obtained by Catania and Gill (1964), Taus (1972), and Blough (1973, personal communication). These authors all pointed out an analogy between the behavioral contrast data from experiments with multiple S+s and contrast effects in sensory systems that arise from lateral neural inhibition (e.g., Békésy, 1969). This analogy may have heuristic value for the study of discrimination learning, and it raises the question of whether the shapes of the rate/stimulus functions in experiments of the present type are affected by perceptual processes as well as learning and motivational processes.

Apparently similar results have also been obtained by Reynolds (1961) in an experiment that involved eight S+ values and two S- values on a circular continuum of isosceles triangle orientation. In this experiment, the response rates were higher to S+ triangle orientations at an intermediate distance from the S- orientations than to the S+ orientations that were most distant from the S- orientations. However, the interpretation of Reyn-

olds' data is complicated by the fact that the S+ triangles that were most distant from the S- triangles in terms of the angular orientation of the apex were identical to the S- triangles in terms of the angle of the long axis.

In any study of the relation between the magnitude of the S+/S- difference and behavioral contrast, the results might be affected by several factors, including stimulus sequences, the number of stimuli, stimulus spacing, and the size of the minimum S+/S- difference relative to the subjects' differential threshold at that point on the continuum. The possibility of perceptual contrast effects, and other complex interactions between the stimuli in the within-subjects design, makes it particularly important to compare the results of between-subjects and within-subjects experimental designs in future research on the relation between the S+/S- difference and behavioral contrast. Such a comparison is also important because the transfer-along-a-continuum effect (e.g., Riley, 1968, pp. 103-115) may make it easier to learn to discriminate a small S+/S- difference in a within-subjects design than in a between-subjects design.

REFERENCES

- Békésy, G. v. Similarities of inhibition in the different sense organs. *American Psychologist*, 1969, **24**, 707-719.
- Brown, P. L. and Jenkins, H. M. Auto-shaping of the pigeon's keypeck. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 1-8.
- Catania, A. C. and Gill, C. A. Inhibition and behavioral contrast. *Psychonomic Science*, 1964, **1**, 257-258.
- Gamzu, E. and Schwartz, B. The maintenance of key pecking by stimulus-contingent and response-independent food presentations. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 65-72.
- 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, Canada: Dalhousie University Press, 1969. Pp. 1-41.
- Mackintosh, N. J., Little, L., and Lord, J. Some determinants of behavioral contrast in pigeons and rats. *Learning and Motivation*, 1972, **3**, 148-161.
- Malone, J. C., Jr. and Staddon, J. E. R. Contrast effects in maintained generalization gradients. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 167-179.
- Redford, M. E. and Perkins, C. C., Jr. The role of autopecking in behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1974, **21**, 145-150.
- Reynolds, G. S. Contrast, generalization, and the process of discrimination. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 289-294.
- Riley, D. A. *Discrimination learning*. Boston: Allyn and Bacon, 1968.
- Spence, K. W. The differential response in animals to stimuli varying within a single dimension. *Psychological Review*, 1937, **44**, 430-444.
- Taus, S. E. *Behavioral contrast in a multiple-stimulus discrimination*. Unpublished doctoral dissertation, University of Missouri, Columbia, 1972.
- Terrace, H. S. By-products of discrimination learning. In G. H. Bower and J. T. Spence (Eds.), *Psychology of learning and motivation, Volume 5*. New York: Academic Press, 1972. Pp. 195-265.

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