

GENERALIZATION AND DISCRIMINATION OF SHAPE ORIENTATION IN THE PIGEON¹

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Pigeons learned to peck a green key on which parallelogram-shapes were projected; they then received generalization tests in which the orientation of the parallelogram was varied. Nondifferential training produced very little eventual stimulus control along the orientation dimension, but when training included S- trials (absence of the parallelogram) subjects responded consistently more to certain orientations than to others. Unlike typical results for visual generalization (e.g., line-tilt), the tilt gradients obtained for this complex stimulus were bimodal, supporting predictions on the basis of human perceptual data. However, unimodal gradients could be produced by specific discrimination training along the orientation dimension. Other forms of intradimensional training also produced relatively steep gradients, often characterized by unexpected but consistent secondary peaks. An attempt to obtain inhibitory gradients (S+: green key; S-: parallelogram on a green background) resulted in virtually zero responding all along the shape-orientation dimension; therefore, specific inhibitory control could not be evaluated. All these experiments suggest that definition of this complex stimulus dimension in terms of mere "angular orientation" is inappropriate, and alternative interpretations are discussed.

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The form of any gradient of stimulus generalization depends considerably on the spacing and ordering of the stimulus values along the abscissa (Blough, 1965). Problems of this kind seem especially pronounced when complex stimuli, such as visual shapes or patterns, are the object of study. Attneave (1950) commented that although the nature of the appropriate dimensions and the procedures for their quantification may be fairly obvious in

the case of auditory and visual intensity or frequency, the relevant dimensions are utterly obscure when one studies complex visual forms. Consequently, consistent definitions of "similarity", and decisions regarding the "relevant" stimulus dimension, are difficult to establish for such stimuli.

Reynolds (1961) illustrated this type of problem in the study of generalization gradients in the pigeon. He trained pigeons to peck at a key on which an approximately upright isosceles triangle was displayed. The orientation of this triangle was systematically varied by clockwise rotation of the triangle around an axis through its geometrical center. Reynolds found that the subjects pecked more often to stimulus values rotated 160 to 200° from the conditioned stimulus than to some intermediate values (e.g., 90 to 130°). Therefore, the scaling of Reynolds' complex stimulus on the basis of mere "degrees of rotation" did not produce conventional, single-peaked gradients. Reynolds pointed out that since his procedure did not provide differential reinforcement for responding to 160 to 200° of rotation, "the increase in rate there presumably indicates one characteristic of the pigeon's perception of isosceles triangles" (p. 293).

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Reynolds came upon this phenomenon serendipitously; the major focus of his study was on other aspects of stimulus generalization. The present experiments sought to utilize actual experimental data from human studies of visual perception to predict the shape and slope of generalization gradients for rotation of a complex stimulus (parallelogram) in the pigeon. The work of Rausch (1952) provided the human data on which the present studies were based.

Rausch's human observers reported changes not only in the orientation but also in the perceived shape of a given parallelogram when it is rotated around its center. Parallelograms having their diagonals parallel (DP) to the actual horizontal or vertical generally fall into one "similar" group and lead to different constant errors of reproduction (a tendency toward "pointedness" rather than "rectangularity") as compared to parallelograms of the same size but which have two of their four sides parallel (SP) to the actual horizontal or vertical (see Fig. 1). These effects occur in spite of the fact that two DP parallelograms are much further apart (90°) in terms of tilt than are a single DP and a single SP figure. On the basis of this independent definition of "similarity" provided by human observers, pigeons might be expected to respond more frequently to a parallelogram tilted 90° from the training stimulus than to one tilted only 40 to 50° , unlike typical generalization gradients (e.g., Hearst, Koresko, and Poppen, 1964) for the orientation of a single line, where response strength is inversely related to the difference in tilt between training and test stimuli (but see Thomas, Klipec, and Lyons, 1966, and Landau, 1968 for examples of a few situations in which line-tilt gradients were not unimodal).

The first experiment of the present series sought to determine whether pigeons would show effects like those displayed by humans with regard to these complex visual forms and whether differential training would yield more powerful stimulus control than non-differential training, as has repeatedly been found to be true along simpler visual or auditory dimensions (see Terrace, 1966). The second set of experiments examined generalization gradients following intradimensional discrimination training, in which some birds were required to discriminate between the two

stimuli that had been found to generalize the most in the first experiment. Finally, a third experiment attempted to determine the shape and form of inhibitory generalization gradients (Jenkins, 1965) for parallelogram rotation.

Sutherland (1961) has reviewed the literature on shape discrimination in subhuman organisms. Birds have not often served as subjects in these studies, but recent experiments by Ziegler and Schmerler (1965) and Mello (1966), among others, have added new avian data to those summarized by Sutherland. The present experiments also contribute some specific empirical data on the pigeon's capacity to master various shape discriminations and on the extent of transfer of these discriminations to new stimulus values.

METHOD

The following details were the same for all experiments.

Subjects

Experimentally naive female White Carneux pigeons (5 to 6 yr old) were maintained at 75% of their free-feeding weights. Water was continuously available in their home cages.

Apparatus

A standard key-pecking chamber (Grason-Stadler) was used. A transparent plastic response key (0.75-in. in diameter) was located in the center of one wall, about 10 in. above the floor. Stimuli (parallelograms in different orientations) could be projected on the key by a standard miniature display unit. The feeder opening was located directly below the response key, about 3 in. above the floor. A 5-sec presentation of the illuminated hopper containing mixed grain served as reinforcement. Except during blackout periods, the chamber was illuminated by a house light situated about 6 in. to the right of the key.

A white-noise generator in the experimental room and an air blower in the test chamber masked external sounds. In an adjacent room, a system of relays, counters, and timers provided automatic control and tabulated responses, reinforcements, and stimulus presentations.

Stimulus variations involved changes in the orientation of an equal-sided parallelogram

(rhombus), outlined in white (0.125 in. thick), on a green background. One diagonal of this figure was 0.75 in., the other 0.63 in. In the specification of stimulus values, the parallelogram with the longer diagonal in the vertical position was designated as the 0° orientation. Clockwise and counterclockwise rotation of this figure around its geometrical center yielded several additional stimulus values: $\pm 40^\circ$, $\pm 50^\circ$, and 90° (see Fig. 1 for illustrations of each stimulus value). A blank stimulus, the green key with no figure on it, could also be presented. Care was taken to ensure that the geometrical center of the parallelogram and of the key coincided approximately for every stimulus orientation. The brightnesses of different stimulus values were equated as closely as possible at the beginning of the experiment and were rechecked often with a photometer.

Preliminary Training

On the first two days, subjects were trained to approach and eat from the grain magazine, shaped to peck the response key, and given 30 continuous reinforcements (CRF) per day for two consecutive days. During shaping and CRF the stimulus value to be later used as S+ was projected on the key.

Sessions were conducted seven days a week throughout most of the experiments described here.

EXPERIMENT I

Nondifferential vs. Differential (Interdimensional) Training

Rausch's experiments with humans suggest that if a bird were initially trained to peck at a DP figure (e.g., 0°), it ought to peck more frequently at the other DP figure (90°) than at intermediate tilt values ($\pm 40^\circ$ or $\pm 50^\circ$), even though the 90° figure is further away from the training stimulus in terms of degrees of rota-

tion. Conversely, birds initially trained to peck at an SP figure (e.g., -50°) ought to show greater generalized responding to the relatively distant SP figures (e.g., $+40^\circ$ or $+50^\circ$) than to the relatively close DP figures (0° and 90°).

Two groups were set up specifically to test this prediction. S+ was either 0° or -50° for the respective groups, and S- was the blank green stimulus for both groups. In order to determine whether the same effects would be obtained even without exposure to a specific S-, another group received S+ trials only, in the presence of the 0° parallelogram. Jenkins and Harrison (1960) found that generalization gradients for auditory frequency were much flatter following such nondifferential training than when exposure to an orthogonal S- was included in the procedure.

Procedure

Eighteen subjects, randomly assigned to three groups of six each, served in this experiment.

Group 1 (nondifferential: stimulus orientation = 0°). After CRF training to a key illuminated by the 0° parallelogram, all subjects in this group received seven sessions of reinforcement on a variable-interval (VI) schedule. During these sessions, 30-sec stimulus periods alternated with 10-sec blackouts. The house light came on and the 0° parallelogram was projected on the key during stimulus periods; the key light and house light were both turned out in the blackout periods. Responses to the illuminated key were reinforced on a 1-min VI schedule. Daily experimental sessions lasted 20 min for each bird.

On the day after the seventh VI session, birds were given a 10-min warmup with reinforcement on the same VI procedure as previously, followed by a generalization test in extinction. Six orientations of the parallelogram (see Fig. 1) were presented in each of 12

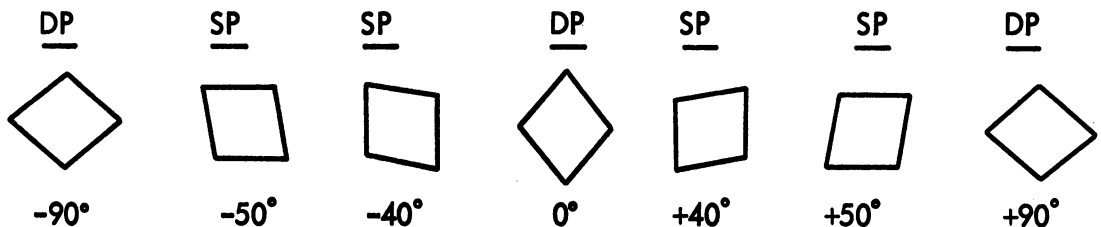


Fig. 1. The parallelogram in its different orientations. DP figures are those with their diagonals parallel to the objective horizontal and vertical; SP figures are those with two of their four sides parallel to the objective horizontal or vertical.

randomized blocks for a total of 72 stimulus periods, separated by 10-sec blackouts. The number of key pecks during each 30-sec stimulus presentation was recorded.

Group 2 (differential: $S+ = 0^\circ$; $S- = \text{blank}$). After CRF training, all subjects in this group received seven sessions of differential training in which $S+$ was the 0° parallelogram and $S-$ was the green key without any figure on it. During these sessions, 30-sec stimulus periods of either $S+$ or $S-$ alternated with 10-sec blackouts. A 1-min VI schedule was in effect in $S+$ periods, and extinction was scheduled in $S-$. Presentations of $S+$ and $S-$ were arranged in a mixed order, with the restriction that neither stimulus could occur on more than

four consecutive trials. $S-$ was presented twice as many times per session as was $S+$. The house light was on during both $S+$ and $S-$.

Daily experimental sessions lasted 60 min for each bird. The latter provision meant that the birds of Group 2 received approximately the same number of $S+$ periods and VI reinforcements throughout training as did the subjects in Group 1.

On the day after the seventh differential-training session, all birds were given a 30-min warmup with reinforcement possible (approximately 10 min of $S+$ and 20 min of $S-$), followed by a generalization test conducted under the same extinction conditions as for Group 1.

Group 3 (differential: $S+ = -50^\circ$; $S- =$

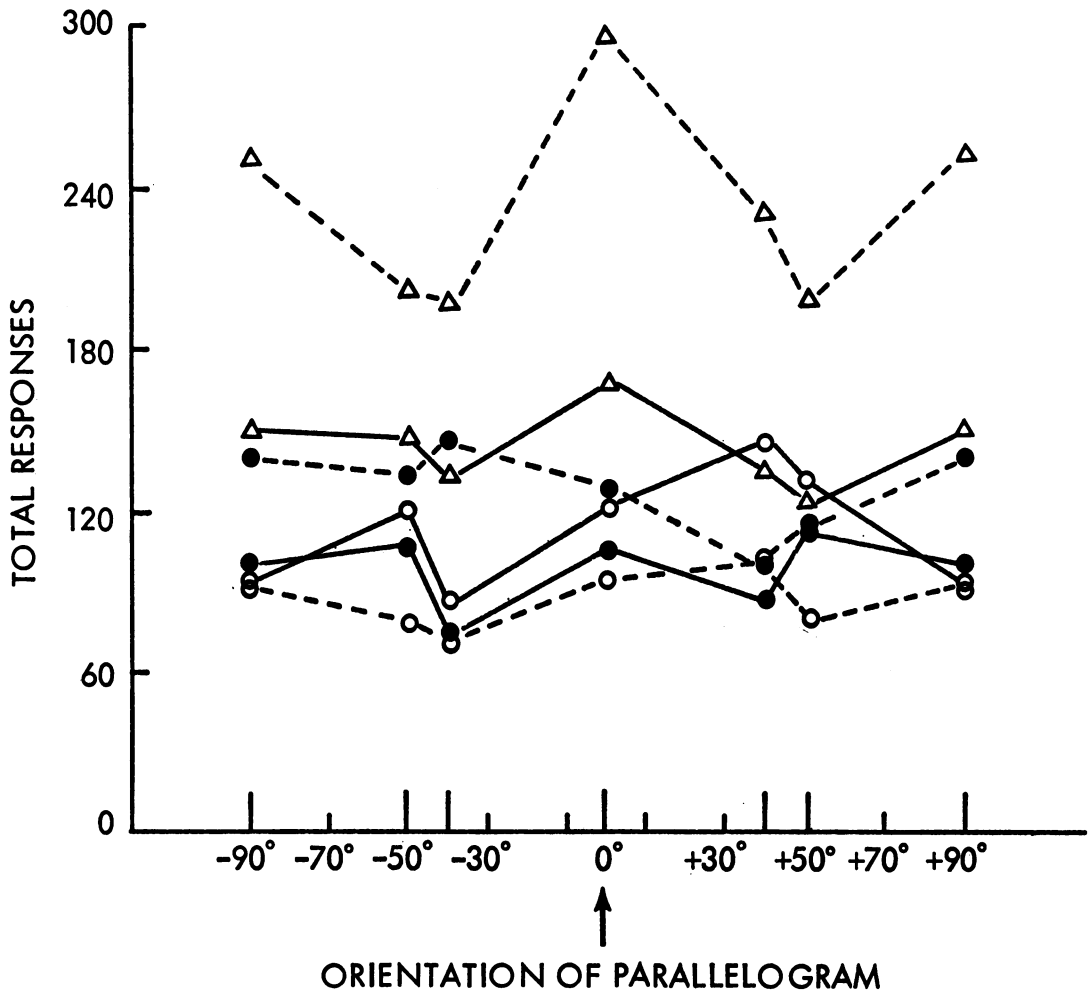


Fig. 2. Absolute generalization gradients for the six individual subjects in the nondifferential group (Group 1; Exp. I). Total responses to each stimulus value throughout the generalization test are plotted for each bird. The training stimulus for all birds was 0° .

blank). This group was treated exactly like Group 2 except that the -50° parallelogram appeared on the key during S+ periods.

RESULTS

Absolute generalization gradients following nondifferential training with the 0° parallelogram are shown in Fig. 2. The designations of the six different test stimulus values correspond to the labels in Fig. 1. In the interests of symmetry, the same data point is plotted at $+90^\circ$ and -90° .

The gradients of Fig. 2 indicate very little specific stimulus control by the parallelogram orientation present during training. Only two of the six subjects had their gradient peak at 0° , and only one subject (the highest re-

sponder) showed a bimodal gradient clearly of the type predicted from Rausch's human findings. Unlike typical gradients following nondifferential training along visual dimensions, such as wavelength or line tilt, most of the Fig. 2 gradients were relatively flat and inconsistent from subject to subject. This result is like that of Jenkins and Harrison (1960), who observed very little stimulus control along an auditory frequency continuum following nondifferential training to one specific tonal frequency.

Absolute gradients following differential training in which S+ was 0° and S- was a blank stimulus are displayed in Fig. 3. All six subjects produced bimodal gradients with peaks at the 0° and 90° test values, the

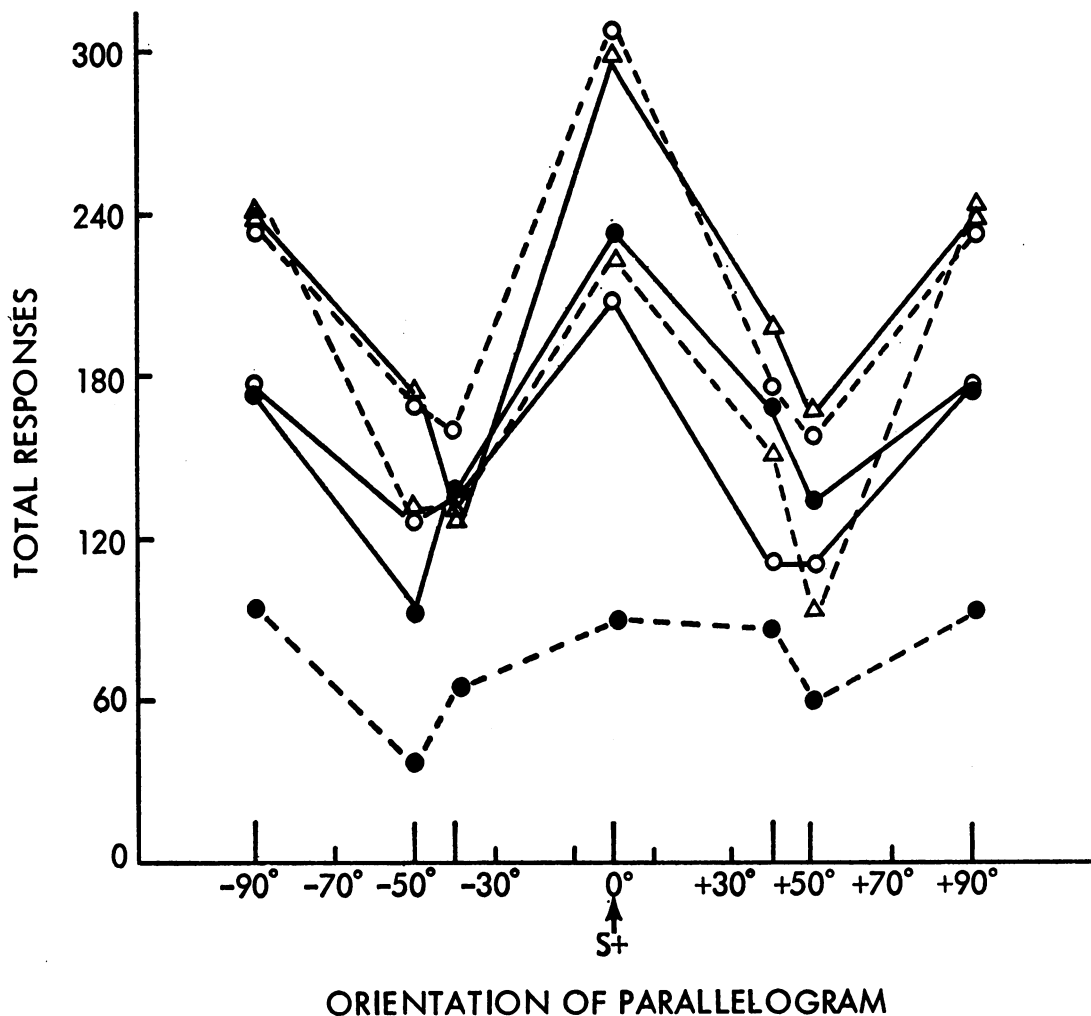


Fig. 3. Absolute generalization gradients for the six individual subjects in the group that received differential training with S+ = 0° (Group 2; Exp. I).

two DP figures according to Rausch's classification. Differences among the $\pm 40^\circ$ and $\pm 50^\circ$ values were not very pronounced or consistent from subject to subject.

The form of the gradients is quite different from those usually obtained for orientation of a single line (e.g., Hearst *et al.*, 1964), since a value far from the S+ in terms of angular rotation produced more generalized responding than closer values. A comparison of Fig. 2 and 3 reveals that differential training with an orthogonal S- produces much greater

stimulus control by S+ than does nondifferential training.

Figure 4 presents absolute gradients for subjects given differential training with $S+ = -50^\circ$, an SP figure. In general, gradients for these birds showed clear and consistent stimulus control by S+ and resembled up-down mirror images of the Fig. 3 gradients. Besides displaying a peak at the S+ value, all subjects exhibited other peaks at $+40^\circ$ or $+50^\circ$. Most of the birds responded the least to either the 0° or 90° stimulus. Somewhat inconsistent with the other conclusions from Fig. 3 and 4 was the relatively low response level at the -40° value, which was the SP figure closest to S+ in degrees of orientation (but see the discussion of Fig. 6). Although the

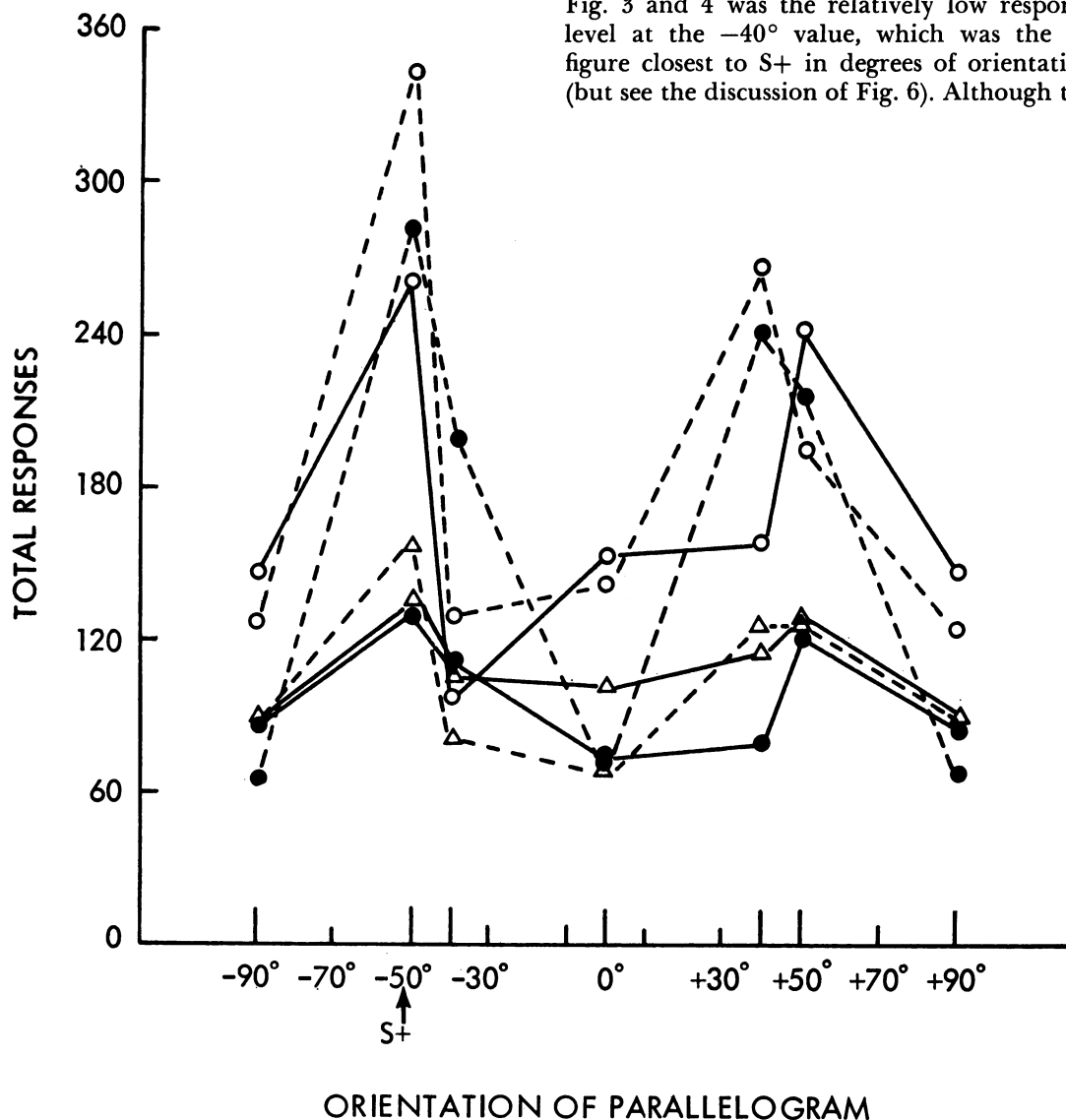


Fig. 4. Absolute generalization gradients for the six individual subjects in the group that received differential training with $S+ = -50^\circ$ (Group 3; Exp. I).

gradients of Fig. 4 appear more variable from subject to subject than those of Fig. 3, both of these differentially-trained groups showed much more stimulus control than the non-differentially-trained group of Fig. 2, an additional corroboration of Jenkins and Harrison's original finding.

A frequent result in studies of stimulus generalization is a systematic steepening of relative gradients as generalization testing

progresses during extinction, in the complete absence of any differential reinforcement (see Hearst, 1968, for a summary of such results). Figures 5 and 6 permit an analysis of this effect for the differentially-trained groups of the present experiment. In these figures, "relative generalization" was scaled in a conventional manner by dividing response output for the entire group of subjects at each test value by response output at S+ for the entire group.

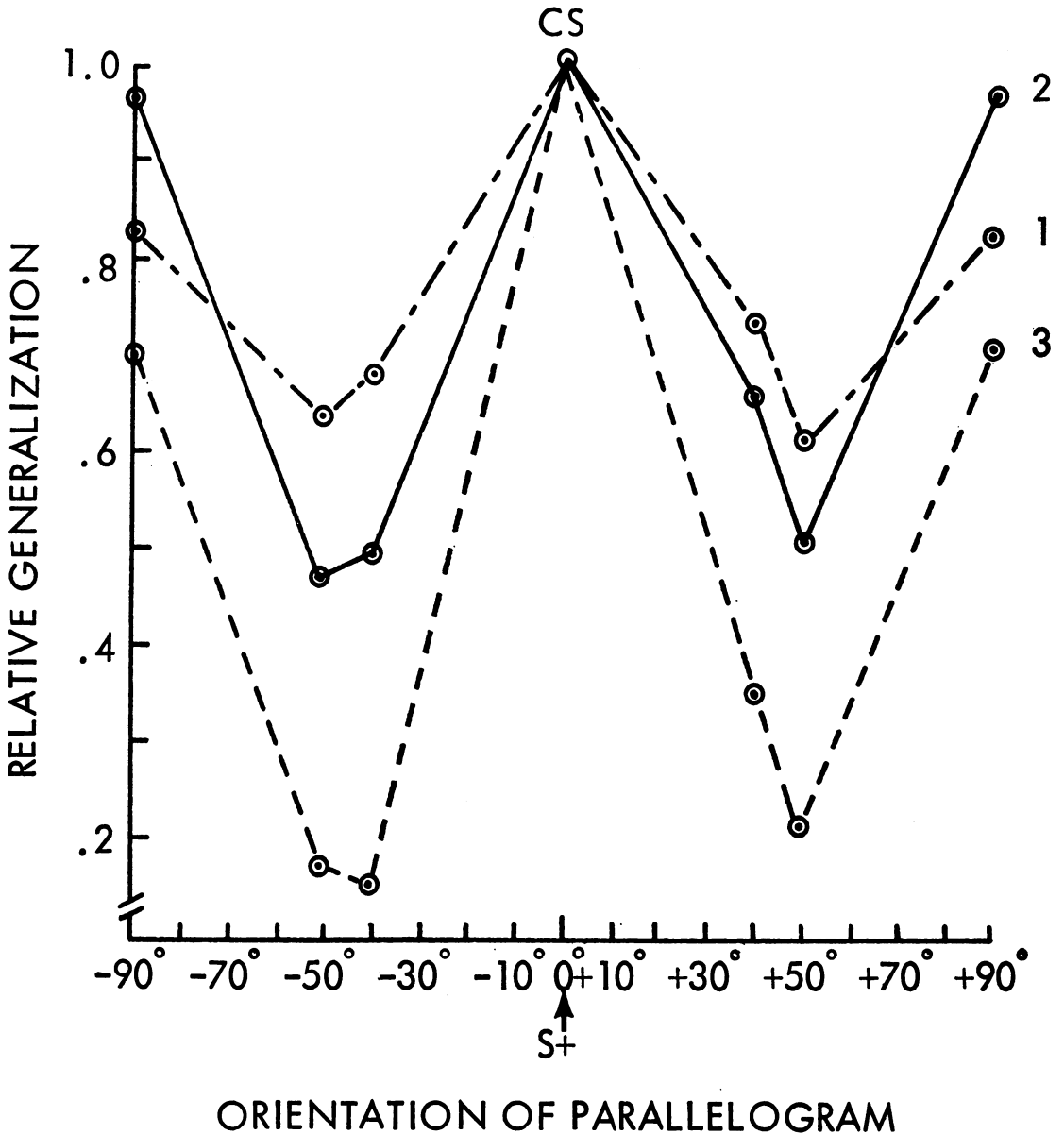


Fig. 5. Relative generalization gradients over successive thirds of the generalization test. Data were combined for all subjects in the group that received differential training with $S+ = 0^\circ$ (Group 2, Exp. I).

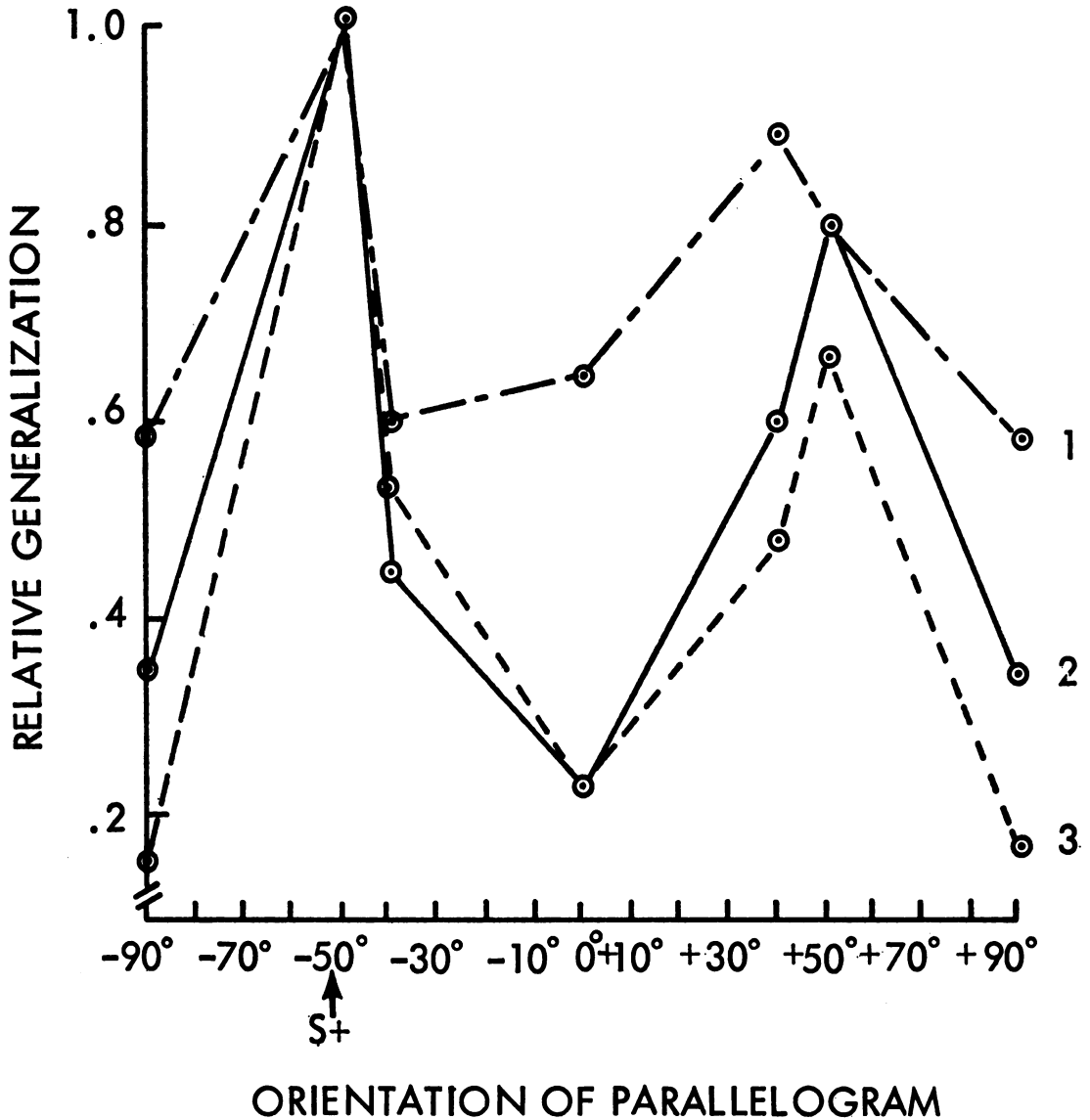


Fig. 6. Relative generalization gradients over successive thirds of the generalization test. Data were combined for all subjects in the group that received differential training with $S+ = -50^\circ$ (Group 3; Exp. I).

Separate gradients were calculated for the first third of the generalization test (Blocks 1 to 4), second third (Blocks 5 to 8), and final third (Blocks 9 to 12) for each group.

Figures 5 and 6 reveal the usual steepening-in-extinction effect, even though the stimulus dimension in the present experiment is presumably more complex than for prior findings of this kind. The steepest gradients around $S+$ occurred in the third block of trials for both groups. An examination of these third-block gradients points up most clearly the

differences previously discussed between the SP-trained and DP-trained groups: subjects trained with the DP figure (0°) showed maximal generalized responding to the other DP figure (90°) and much less responding to the SP figures, whereas subjects trained with the SP figure (-50°) showed minimal generalized responding to the two DP figures (0° and 90°) and appreciably more responding to all the SP figures.

The nondifferentially-trained subjects of Group 1 also showed some steepening of rela-

tive gradients during extinction, but this effect was far less pronounced than for the other two groups. These results are not presented in the figures, but during the final four blocks the nondifferential group produced a gradient roughly equivalent to that obtained from Group 2 in the first four blocks.

EXPERIMENT II

Intradimensional Discrimination Training

In Exp. I, birds typically generalized most to the other DP figure after they had been trained on a DP figure, and generalized most to other SP figures after they had been trained on an SP figure. This finding meant that generalization gradients plotted in terms of degrees of rotational proximity to the CS were bimodal, in contrast to the single-peaked visual gradients typically encountered in the literature on stimulus generalization. Perhaps this bimodality could be eliminated by specific prior training to discriminate between the two peak values. One group in Exp. II was trained in this way ($S+ = 0^\circ$; $S- = 90^\circ$), whereas subjects in three other groups were given discrimination training between other values of parallelogram orientation before generalization testing. The relative difficulty of learning the different intradimensional discriminations, and the form of subsequent generalization gradients, could possibly help isolate the specific stimulus properties that control complex discriminations of this kind.

Procedure

Twelve naive subjects, randomly assigned to four groups of three birds each, served. Each group learned to discriminate between two different values of parallelogram orientation. For the first group, the 0° parallelogram was $S+$ and the 90° parallelogram was $S-$, for the second group $S+$ was 0° and $S-$ was -50° , for the third group $S+$ was $+40^\circ$ and $S-$ was $+50^\circ$, and for the fourth group $S+$ was -40° and $S-$ was -50° .

The procedure was essentially the same as for the differential-training groups of Exp. I except that no blank stimulus was used; both $S+$ and $S-$ involved a parallelogram projected on the key. Because these intradimensional discriminations were much more difficult than the interdimensional procedures of Exp. I, seven sessions of discrimination training usually

proved insufficient for the subjects of Exp. II to achieve good performance on the discrimination. Therefore, we established a discrimination criterion which had to be met before the generalization tests were given: a subject was given the discrimination procedure for a minimum of seven days and then was given the generalization test on the eighth day only if its response rate in $S-$ had been less than 25% of its response rate in $S+$ on the seventh day of discrimination training. Otherwise, the subject continued on the discrimination task until it had achieved the 25% criterion on two successive days. It was then given the generalization test on the following day.

The generalization test was conducted in a manner similar to that of Exp. I, except that the blank stimulus was included among the test values to see how much generalized responding would occur to a stimulus value without any parallelogram on it. Therefore, generalization tests comprised seven test values, each presented 12 times for a total of 84 stimulus periods.

RESULTS

Although the intradimensional discriminations of this experiment proved uniformly more difficult than the interdimensional discriminations of Exp. I, the number of training sessions required to reach criterion did not differ greatly among the separate groups. All four groups averaged 10 to 12 days of training before reaching the criterion. By contrast, all subjects in the differentially trained groups of Exp. I had attained the same performance level on the very first day of training. Thus, pigeons were certainly able to master the subtle shape discriminations required in Exp. II, even though these tasks were more difficult than the discriminations of Exp. I. One might have expected that the 0° vs 90° discrimination would have proven more difficult than the 0° vs -50° discrimination on the basis of generalization data of Fig. 3, but no such difference was observed between these groups. Terrace (1966, p. 302-303) also provides evidence that gradient slope is sometimes an inaccurate predictor of the difficulty of a discrimination.

The absolute generalization gradients displayed in the left-hand panel of Fig. 7 show the effect of prior discrimination training be-

tween the two DP figures, 0° and 90° . The bimodality which characterized all the gradients of Fig. 3 is completely absent in the functions of Fig. 7; all subjects produced gradients with a single peak at S+. The gradients were not very different from those typically observed for angular rotation of a single vertical line (Hearst *et al.*, 1964). Apparently subjects show highly selective control by "angular rotation" in our situation only after that behavior has been specifically reinforced (0° vs 90°).

The righthand panel of Fig. 7 summarizes the effects of specific discrimination training between two stimulus values, 0° and -50° , that had produced quite different response outputs even without specific prior training (Fig. 3). Compared to Fig. 3, explicit discrimination training between these values did lead to a higher absolute level of responding to S+ during the generalization test, as well as to a much lower absolute level of responding at the S- value, but the general form of the gradients following intradimensional training was not too much different from that of Fig. 3; peak responding still occurred at the two DP values, 0° and 90° .

The difference in absolute output to S+ (the 0° orientation) between Fig. 2 and Fig. 7 provides a clear example of the presence of "behavioral contrast" (Reynolds, 1961) brought about by differential training. Inter-

dimensional differential training (Fig. 3) produced generally higher response outputs to S+ during the generalization test than did non-differential training (Fig. 2)—a mean of 227.8 responses vs 152.0 responses respectively—whereas intradimensional differential training (Fig. 7) produced much higher response outputs to S+ than did interdimensional training: a mean of 597.8 responses for the six birds in Fig. 7 vs 227.8 responses for the six birds in Fig. 3. These comparisons of the relative amounts of contrast following inter- vs intradimensional training ought, however, to be regarded as tentative; they are based on between-subject comparisons with a relatively small number in each group, and the number of days of discrimination training before generalization testing differed between the two groups.

Discrimination training between two SP figures that are very close in terms of angular rotation (40° vs 50°) resulted in the gradients shown in Fig. 8. These gradients are not directly comparable to those in Fig. 4, since a different S+, -50° , was used in the earlier experiment. Nevertheless, one unexpected and rather consistent aspect of the Fig. 8 gradients seems to merit comment. When S+ was $+40^\circ$ and S- was $+50^\circ$ (lefthand panel), two of the three birds displayed a second peak at -50° , whereas when S+ was -40° and S- was -50°

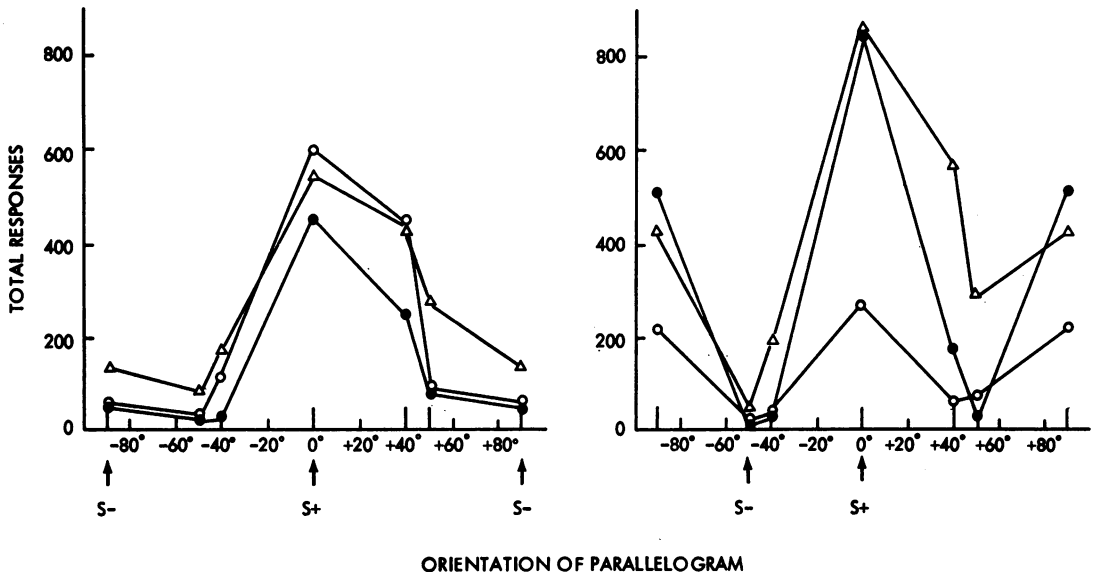


Fig. 7. Absolute generalization gradients for individual subjects receiving specific intradimensional training before the generalization test. The S+ and S- values are indicated on the abscissa of each set of curves (Exp. II).

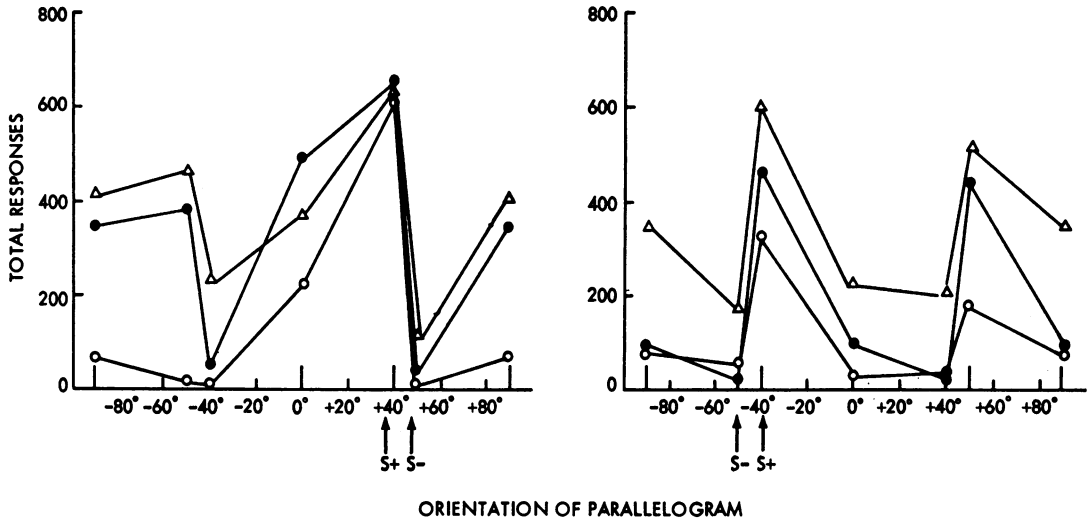


Fig. 8. Absolute generalization gradients for individual subjects receiving specific intradimensional training before the generalization test. The S+ and S- values are indicated on the abscissa of each set of curves (Exp. II).

all three birds displayed a second peak at $+50^\circ$. This interesting finding does not appear to have any simple explanation, either in terms of mirror-image effects (Mello, 1966) or on the assumption that subjects attended to a specific feature of the complex shapes (Sutherland, 1961, p. 58; Jenkins and Sainsbury, 1967).

It will be remembered that the blank stimulus was included among the generalization test values for subjects in this experiment. There was very little generalized responding to this orthogonal stimulus. Response rates to the blank averaged less than 5% of response rates to S+ in all four experimental groups.

EXPERIMENT III

Generalization Gradients of Inhibition

In Exp. I, gradients of excitation around S+ were obtained following differential training with an S- that was orthogonal to the S+ dimension. In a final experiment, we wanted to find out whether generalization gradients of inhibition, *i.e.*, gradients with a minimum at S-, could be obtained by using the reverse procedure (S+ = blank; S- = a parallelogram of a given orientation). Several recent studies (see Jenkins, 1965) have used an analogous procedure to secure inhibitory gradients along relatively simple dimensions like line-tilt or auditory frequency. Would inhibitory gradients appear at all with the complex stimuli

employed in the present work and, if they did appear, would they have two minima, a result which might be predictable from the bimodal excitatory gradients of Exp. I?

Procedure

Six naive subjects, randomly assigned to two groups of three birds each, served. They were treated the same way as the differential training groups of Exp. I, except that S+ was the blank stimulus and S- was a parallelogram of a specific orientation. For one of the two groups, S- was the 0° parallelogram; for the other group, S- was the $+50^\circ$ parallelogram.

All other aspects of training and generalization testing were like those of Groups 2 and 3 in Exp. I, except for the inclusion of the blank stimulus among the generalization test values. Just as for the birds in Exp. II, seven test values (six orientations of the parallelogram and the blank) were presented during the generalization test.

RESULTS

All six subjects in this experiment rapidly learned the interdimensional discrimination (S+ = blank; S- = tilted parallelogram); five birds actually performed below a 25% criterion on the first day of differential training following CRF. Therefore, this discrimination, in which a parallelogram was present on S- trials, was learned about as rapidly as the discrimination of Groups 2 and 3 in Exp. I,

which involved presentations of the parallelogram on S+ trials.

In contrast to the clear excitatory control exerted by S+ with the reverse procedure in Exp. I, the generalization test data of Exp. III provided no evidence of specific inhibitory control by the S- value. No bird trained with an S- of $+50^\circ$ responded to any of the six parallelogram orientations during generalization testing. Two of the three birds trained with an S- of 0° made either 0 or 1 total responses to all six parallelogram stimuli, whereas the other subject made a total of 79 responses to these six stimuli, without any evidence of specific inhibitory control by S- (the minimum of this bird's gradient, nine responses, occurred at 90° and -40° , and the maximum, 20 responses, at $+40^\circ$). As Farthing and Hearst (1968) have pointed out, inhibitory gradients which involve virtually zero responding along the stimulus continuum do not really permit any clear conclusions about inhibitory control, since there is no way to determine whether responding is more "inhibited" at S- than at zero values far from S-.

Responses to the blank were frequent during the generalization test and subjects averaged 300 to 325 total responses to it over the 12 blocks of trials.

GENERAL DISCUSSION

This set of experiments involved an analysis of generalization gradients following training in the presence of relatively complex visual stimuli. Despite the dimensional complexity of the parallelogram-shapes, a number of findings from prior studies which employed simpler visual or auditory continua (see Terrace, 1966) were strongly confirmed: differential training which included an orthogonal (blank) S- produced much better stimulus control than training to S+ alone; intradimensional training between two values on the parallelogram-orientation dimension yielded better control by S+ and more pronounced evidence of "behavioral contrast" than did interdimensional training, when both these procedures are compared to nondifferential training; and a progressive steepening of group relative gradients around S+ was observed during generalization testing.

In addition to these results, we found that pigeons responded most to the other DP figure

following original training to a DP figure, and generally responded more to all SP figures than to any DP figure following training to peck at an SP figure. These findings support predictions from Rausch's (1952) studies, in which human subjects usually classified SP and DP figures into separate categories and displayed different types of constant errors when asked to draw SP or DP figures immediately after viewing them (DP figures are reproduced as more "pointed" than the original stimulus, whereas for SP figures there is a "tendency toward rectangularity" in their reproduction). Although no attempt was made in the present experiments to secure analogous data on constant errors of reproduction in pigeons, it was clear from Exp. I and II that, like humans, pigeons do tend to respond more similarly to values within either the SP or DP category than to values between the different categories. To enable a more complete analysis of this phenomenon, it would be valuable to test birds with parallelogram orientations (*e.g.*, $\pm 20^\circ$, $\pm 70^\circ$) that do not fall precisely into either of the two categories.

Despite the high degree of generalization between stimuli of the same class that was shown in the gradients of Exp. I, pigeons were able to reach criterion on intradimensional discriminations between members of the same class within 10 to 12 training sessions (Exp. II). The bimodality of gradients following DP training with a 0° stimulus (Fig. 3) disappeared after subjects had been initially trained to discriminate a DP figure of 0° from one of 90° . Thus, pigeons are capable of learning shape-orientation discriminations that might have been predicted to be difficult on the basis of the Exp. I gradients following interdimensional training.

As in Reynolds' experiment (1961), the generalization gradients of the present study indicated that definition of the stimulus "dimension" in terms of mere degrees of angular rotation from the training stimulus is an insufficient or inappropriate designation of the "relevant" stimulus continuum. Workers with a Gestalt point of view (*e.g.*, Rausch) tend to interpret results with complex stimuli of this sort as indicating the strong influence of "organizational" factors or "structuring" in the perception of such shapes. Experiment I certainly does tell us that other features of the parallelogram stimulus are more likely to be

initially attended to than simply its orientation, and Exp. II showed that specific discrimination training (e.g., 0° vs 90° , Fig. 7) is necessary to produce selective control by the "rotation" dimension. A possibly fruitful method for further isolating the variables responsible for the bimodalities observed in Exp. I and II might be in terms of the ratio between the major and minor diagonals of the stimulus figures. As the length of the minor diagonal of the standard parallelogram becomes shorter and shorter relative to the long diagonal, the bimodality exhibited in Fig. 3 and 4 ought to disappear and gradients of angular rotation ought to be obtained which are more and more like the standard unimodal gradients for tilt of a single line. (A line may be considered as a parallelogram with one diagonal equal to zero.) On the other hand, when the two diagonals are equal (a square), "bimodality" will obviously occur, since the 0° and 90° figures are exactly the same.

One way of analyzing some of the present effects is based on fragmentary data (Skinner, 1965) concerning the location of a pigeon's pecks at a triangular stimulus pattern. Birds tended to peck at the vertices of such patterns, rather than at the sides or open spaces. Skinner attributed this effect to the specific prior training of his birds, but if a similar phenomenon occurs in naive birds that peck at the parallelograms of Fig. 1, then a 0° -trained bird would be expected to respond more to a 90° figure than to any of the SP figures, since the vertices are in the same relative position on the key for both 0° and 90° . To check on this possibility, one must monitor the location of a bird's key pecks during initial training to a particular parallelogram and determine whether the bird pecks consistently at a specific part of the stimulus pattern. If birds do consistently peck at a specific feature (e.g., a vertex at the bottom of the key), then variation of the orientation of the parallelogram during generalization testing may indirectly bring about its decremental effects (e.g., Fig. 3 and 4) because of the inevitable changes in the location of this particular feature in relation to the place on the key where the bird habitually pecks. An analysis of this sort would be relevant to Jenkins and Sainsbury's recent observation (1967) that birds specifically peck at the feature of S+ (e.g., a dot on the key) that distinguishes S+ from S-.

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