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DISCRIMINATION OF COMPOUND STIMULI INVOLVING THE PRESENCE OR ABSENCE OF A DISTINCTIVE VISUAL FEATURE[1]

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Pigeons learned a free operant, go/no-go discrimination between stimuli produced by rapid alternation of different features on the response key. The 0°—B compound consisted of a vertical black line on a white background (the 0° feature) alternated with a blank white field (the B feature), with successive 0.75-sec feature *on* periods separated by 0.20-sec dark periods. Pecks at the alternating 0° and B features were recorded separately. When pecks at the 0°—B compound were reinforced and pecks at the B—B stimulus (repeated brief presentations of the B feature) were extinguished, the birds pecked more at the 0° feature than at the B feature in the 0°—B compound; subsequently, decremental line-tilt generalization gradients were obtained. When pecks at B—B were reinforced and pecks at 0°—B were extinguished, the rate of pecking at the 0° feature decreased to a low level much more rapidly than did the rate of pecking at the B feature in the 0°—B compound; incremental line-tilt gradients were obtained. Following training with pecks at 0°—B reinforced and pecks at 0°—0° extinguished, incremental line-tilt gradients were obtained, whereas the gradients were decremental following training with 0°—0° reinforced and 0°—B extinguished.

Jenkins and Sainsbury (1969, 1970) studied the performance of pigeons on successive (go/no-go) operant discriminations between visual displays that had certain features in common, but a distinctive feature that occurred only on reinforcement (S+) or nonreinforcement (S—) trials, such that the discrimination could be learned only on the basis of the presence or absence of the distinctive feature on a particular trial. For example, in one experiment, one display consisted of three stars, whereas the other display consisted of two stars and a dot; the stars were the common feature, and the dot was the distinctive feature. A discrimination in which the distinctive feature appeared only on S+ trials was called a feature-positive discrimination, and a discrimination in which the distinctive feature appeared only on S— trials was called a feature-negative discrimination.

Jenkins and Sainsbury were able to record pecks at the distinctive and common features separately, by means of a response key divided into independently operable quadrants. They found that in learning the feature-positive discrimination, in S+ the birds pecked much more at the distinctive feature than at the common feature. In the feature-negative discrimination, in S— the birds pecked much more at the common feature than at the distinctive feature. Furthermore, whereas all of the birds trained on the feature-positive discrimination eventually learned the overall successive discrimination between S+ and S—, none of the birds learned the feature-negative discrimination, since they continued to peck at the common feature in S—.

The purpose of the present study was to replicate and extend the findings of Jenkins and Sainsbury in a different type of training situation. Rather than a simultaneous display of distinctive and common features, the present experiment employed a successive, rapid alternation of the different features on the response key. This type of compound stimulus is here referred to as a successive-com-

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pound, in contrast to Jenkins and Sainsbury's simultaneous-compounds. The experiment sought to determine whether pigeons would respond differentially to the different features within these successive-compound stimuli, in addition to learning the overall discriminations between S+ and S−. Finally, generalization tests were used in order to obtain information about the nature of the stimulus control exerted by the distinctive and common features in both the feature-positive and feature-negative discriminations.

METHOD

Subjects

Eight experimentally naive female White Carneaux pigeons (5 to 7 yr old) were maintained at 75% of their free-feeding body weights.

Apparatus

The birds were trained in a Lehigh Valley Electronics (Model 1519) pigeon test chamber, with the houselight removed. The transparent, 1-in. (2.54-cm) diameter response key was mounted 10 in. (25.4 cm) above the floor and 3.3 in. (8.3 cm) to the right of center of the intelligence panel. An in-line readout projector (Grason-Stadler E4580-168) could trans-illuminate the response key with a blank white field (B), or a plain white field bisected by a 3.2-mm wide black line, oriented either vertically (0°) or 30° or 60° clockwise from vertical. Extraneous noises were masked by an air blower and white noise in the test chamber. Reinforcers consisted of 5-sec access to mixed grain.

Procedure

Stimuli. The training stimuli are illustrated schematically in Fig. 1. A stimulus presentation consisted of a 30-sec period during which brief (0.75-sec) intervals of keylight *on* were separated by briefer (0.20-sec) intervals of light *off*. The 0°—0° stimulus consisted of a series of brief illuminations of the key by the vertical black line on a white background, whereas the B—B stimulus consisted of a series of brief illuminations of the key by the blank white field. The 0°—B stimulus was a successive-compound in which the 0° and B features were alternated in successive keylight *on* intervals. During the 0°—B stimulus, pecks at the 0° and B features were recorded separately. Pecks occurring during a 0.20-sec dark interval between successive keylight *on* intervals were recorded on the same counter as pecks at the feature that preceded the dark interval, on the assumption that such pecks were actually initiated by the pigeon before the light offset.

There were four different discriminations, with two birds trained on each discrimination. In both of the feature-positive discriminations, 0°—B was the reinforcement stimulus (S+). In the 0°-feature-positive discrimination (Birds 80 and 12), B—B was the non-reinforcement stimulus (S—), whereas in the B-feature-positive discrimination (43 and 22), 0°—0° was S—. In both of the feature-negative discriminations 0°—B was S—. In the 0°-

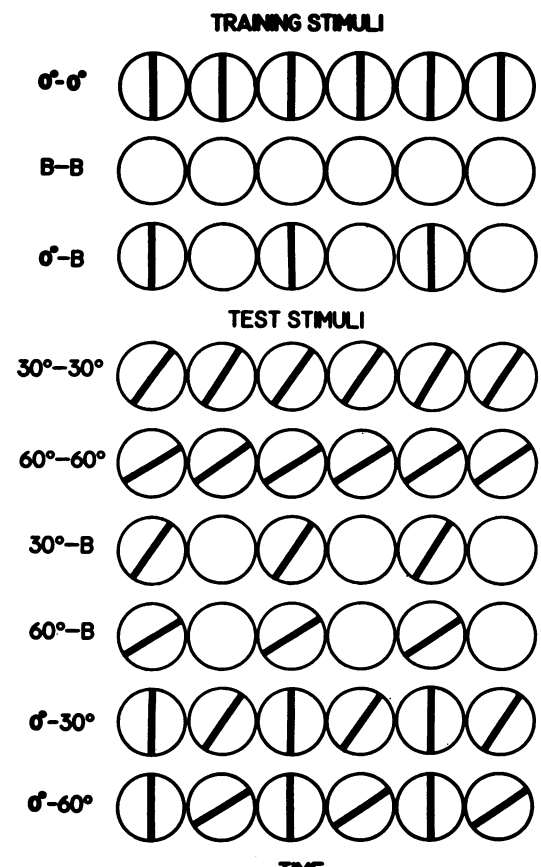

Fig. 1. Schematic illustration of the three stimuli used in discrimination training, and six additional stimuli used during the generalization test only. The different features were rapidly alternated on the response key, with 0.75-sec keylight *on* periods separated by 0.20-sec keylight *off* periods.

feature-negative discrimination (67 and 58) B—B was S+, whereas in the B-feature-negative discrimination (19 and 48) 0°—0° was S+. Thus, in both types of discrimination there was a common feature that appeared in both S+ and S—, and a distinctive feature that appeared in only one of the two stimuli. The feature-positive discriminations could be learned only on the basis of the distinctive feature in S+, whereas the feature-negative discrimination could be learned only on the basis of the distinctive feature in S—.

Preliminary training. In the first preliminary session, the key-peck response was shaped by the method of successive approximations, and every peck was reinforced until 30 reinforcers had been collected. In the second session, every peck was reinforced until another 30 reinforcers had been collected. During the third and fourth preliminary sessions, pecks were reinforced on a variable-interval schedule in which the mean interval between reinforcers was 1 min (VI 1-min). These VI sessions consisted of 60 stimulus periods, each of 30-sec duration, and alternated with 10-sec blackouts during which the keylight was off, the chamber was dark, and pecks could not be reinforced. During the four preliminary training sessions, the only stimulus presented on the key was S+.

Discrimination training. After preliminary training, all subjects were given 36 sessions of discrimination training. Discrimination sessions consisted of a random mixture of 30 S+ (VI 1-min reinforcement) and 30 S— (extinction) periods, each of 30-sec duration, with successive stimulus periods separated by 10-sec blackouts. The VI tape puller ran during S+ periods only. A reinforcer arranged by the VI schedule could be collected by the next peck in S+, regardless of the stage of the feature alternation cycle (thus, pecks during the 0.20-sec dark intervals could be reinforced).

Generalization testing. On the day after the last discrimination session, all birds were given a brief (10 S+ and 10 S—) warmup of additional discrimination training, followed by a generalization test in extinction. The test included the three training stimuli (0°—0°, B—B, and 0°—B) shown at the top of Fig. 1, plus the six additional stimuli shown in the lower part of Fig. 1. Two new line orientations (30° and 60°) were presented, either in alternation with themselves (30°—30° and 60°—60°), with the vertical line (0°—30° and 0°—60°), or with the blank feature (30°—B and 60°—B). The nine test stimuli were presented once in each of 12 randomized blocks, and the number of pecks at each feature in each stimulus was recorded during each 30-sec test stimulus period. Pecks occurring during a 0.20-sec dark interval within a stimulus period were counted on the same counter as pecks at the feature that preceded the dark interval. Thus, pecks at each feature of a successive-compound stimulus were recorded during 15 sec of each of twelve 30-sec stimulus periods, for a total of 180 sec. Pecks at stimuli consisting of features alternated with themselves (*i.e.*, the 0°—0°, 30°—30°, 60°—60°, and B—B stimuli) were recorded during twelve 30-sec stimulus periods, for a total of 360 sec. As during acquisition, test stimulus periods were separated by 10-sec blackouts.

RESULTS

Discrimination learning. Acquisition data for the feature-positive discriminations are shown in Fig. 2 and 3. The dashed lines indicate rates of pecking at the 0° and B features (filled and open circles, respectively) of the 0°—B, S+, compound. The solid lines indicate rates of pecking at S— (B—B or 0°—0°). In order to compare the overall rates of pecking at S+ and S—, it must be remembered that pecks at each of the separate features of the 0°—B compound could occur only during 15 sec of each 30-sec stimulus periods (counting the 0.20-sec dark intervals as part of the preceding feature interval). Thus, the actual overall rate of pecking at the 0°—B stimulus is equal to the average of the separate rates of pecking at the 0° and B features in 0°—B.

In all four birds trained on feature-positive discriminations, the rate of pecking during S— initially increased, and then decreased to a low level in later training sessions. In S+, the rate of pecking at the distinctive feature increased to an asymptotic level. During the first four to seven sessions, the rate of pecking at the common feature in S+ increased in parallel with the rate of pecking at the distinctive feature, but then decreased with further training. With occasional exceptions in Bird 43, the rate of pecking at the common feature in S+ was always greater than the rate of pecking at that feature in S—. Bird 22's rate of

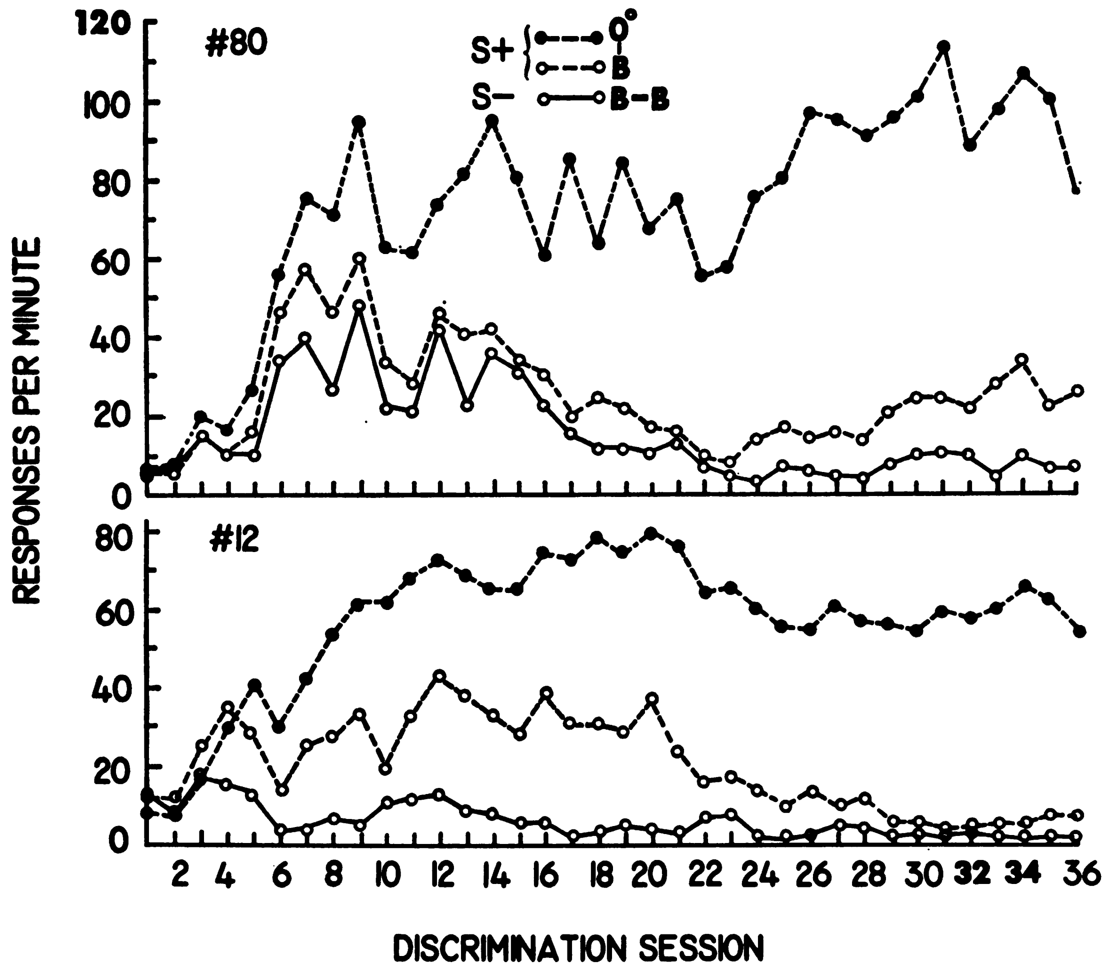

Fig. 2. Acquisition data for the two birds trained on the 0°-feature-positive discrimination, S+ (0°—B) *vs.* S— (B—B). The distinctive feature was 0° and the common feature was B.

pecking at the common (0°) feature in S+ decreased to its lowest level in the seventeenth session, and then slowly increased again, but never reached the level of pecking at the distinctive feature.

Acquisition data for the feature-negative discriminations are shown in Fig. 4 and 5. In all four birds, as training progressed the rate of pecking during S+ increased to a high level, while the rate of pecking at the distinctive feature in S— decreased to a relatively low level. The rate of pecking at the common feature in S— was as high as (or in Bird 48, higher than) the rate of pecking at that same feature in S+ for several (eight to 28) sessions, until eventually the rate of pecking at the common feature in S— decreased to a relatively low level, though never to a level as low as for the distinctive feature.

For the overall successive discrimination, a discrimination ratio (total pecks at S— divided by total pecks at S+) of 0.25 or less was reached in an average of 12.5 sessions by the feature-positive birds, and in an average of 22.0 sessions by the feature-negative birds. Although this difference is in the direction predicted from Jenkins and Sainsbury's (1969, 1970) experiments, it does not quite reach statistical significance ($U = 2$, $p < 0.06$ by a one-tailed test.) By the final discrimination session, discrimination ratios for the feature-positive and feature-negative discriminations were almost identical (means of 0.16 and 0.13, respectively).

Generalization test. Generalization test data are shown in Fig. 6 and 7. The average rate of pecking at each feature is expressed as a relative generalization score, which is a per cent of the reference value shown in parentheses for each bird. For birds trained on feature-positive discriminations (Fig. 6), the reference value is the average rate of pecking at the distinctive feature in the test stimulus in which it alternated with itself (*i.e.,* the 0°—0° stimulus for Birds 80 and 12, and the B—B stimulus for Birds 43 and 22). For birds trained on feature-negative discriminations (Fig. 7) the reference value is the average rate of pecking in S+ during the test (*i.e.,* the B—B stimulus for Birds 67 and 58, and the 0°—0° stimulus for Birds 19 and 48).

The top panel indicates relative peck rates as a function of the feature pecked at, with the feature that alternated with it as the parameter (*i.e.,* the feature being pecked at was alternated with either 0°, B or itself). (Of course, the birds pecked at both features in the successive-compounds. The phrase "feature-pecked at" means the feature under consideration at the moment.) The bottom panel indicates rates of pecking at the 0° and B features, as a function of the feature with which they were alternated. Thus, for example, the filled circle over 30° in the top panel

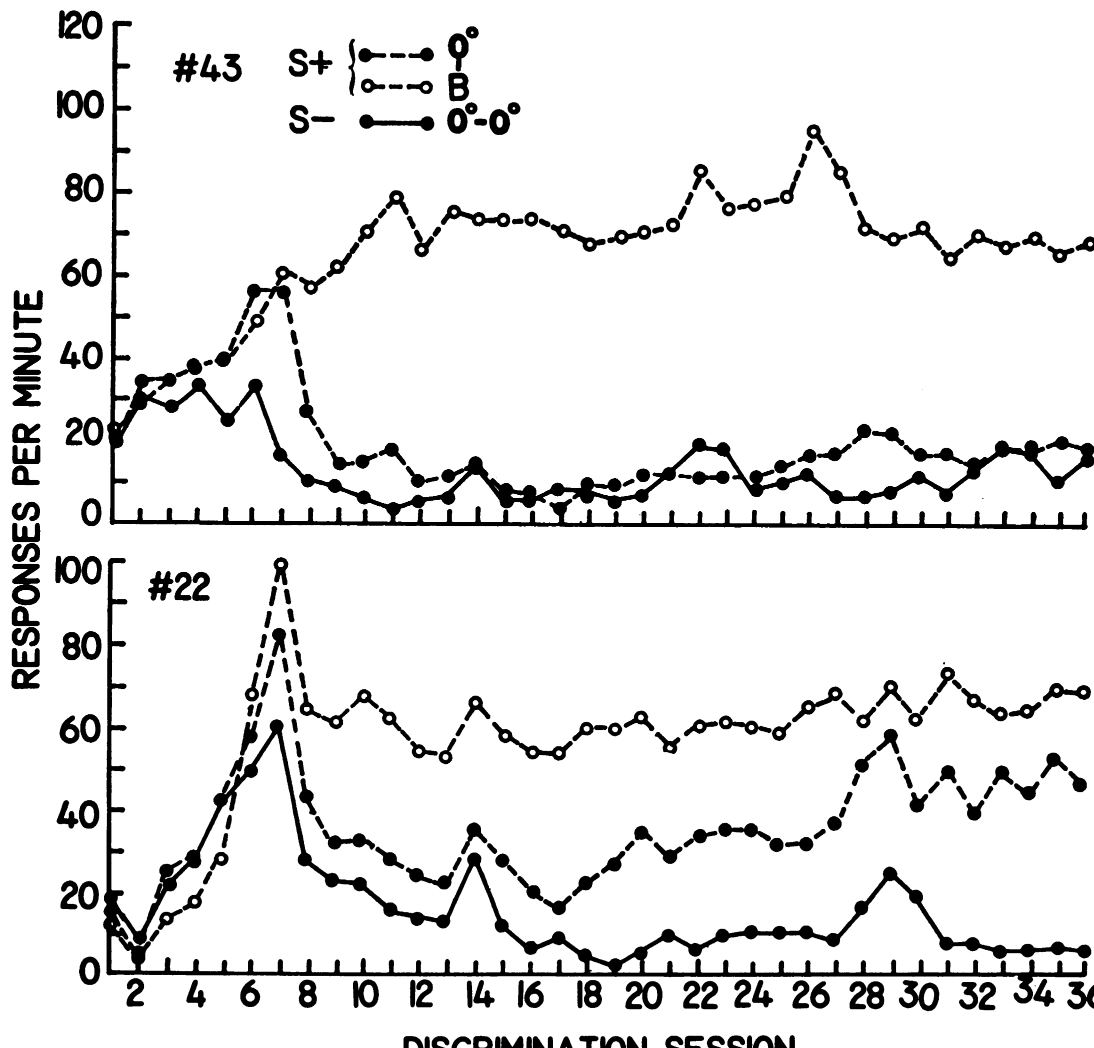

Fig. 3. Acquisition data for the two birds trained on the B-feature-positive discrimination, S+ (0°—B) *vs.* S— (0°—0°). The distinctive feature was B, and the common feature was 0°.

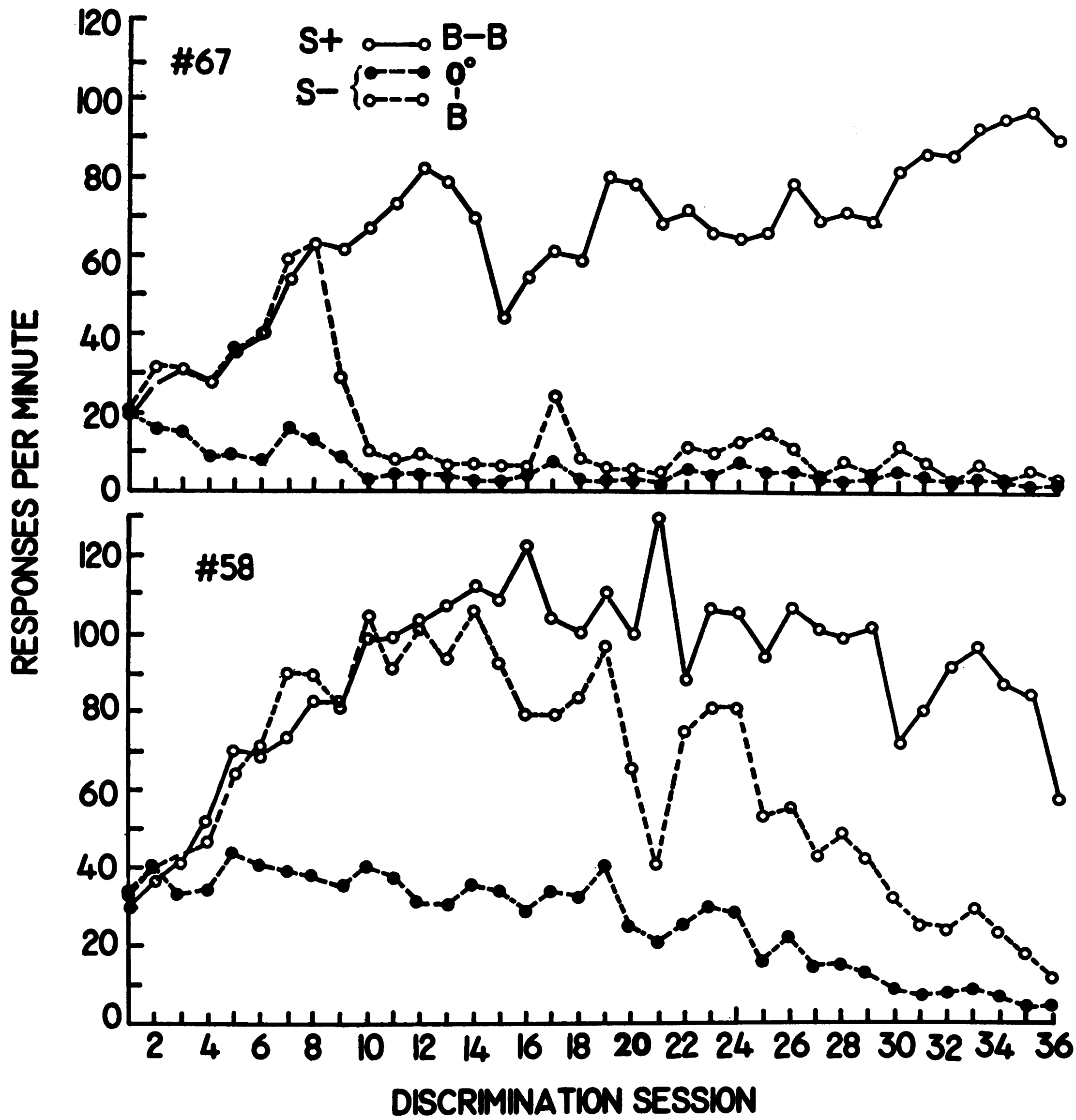

Fig. 4. Acquisition data for the two birds trained on the 0°-feature-negative discrimination, S+ (B—B) *vs.* S— (0°—B). The distinctive feature was 0°, and the common feature was B.

indicates pecks at the 30° feature when it alternated with the 0° feature, whereas the filled circle over 30° in the bottom panel indicates pecks at the 0° feature when it alternated with the 30° feature; both of these data points come from pecking at the 0°—30° successive-compound test stimulus. The open circle over 30° in the top panel indicates pecks at the 30° feature when it alternated with the B feature, whereas the open circle over 30° in the bottom panel indicates pecks at the B feature when it alternated with the 30° feature; both of these data points come from pecking at the 30°—B test stimulus. In the top panel, the small triangle over 30° indicates pecks at the 30° feature when it alternated with itself in the 30°—30° stimulus.

The large symbols around some data points indicate points directly comparable between the two pairs of birds trained on the two different forms of each type of discrimination. Data points surrounded by a square indicate pecks at the distinctive feature when it alternated with the common feature, whereas points surrounded by a large circle indicate pecks at the ditsinctive feature when it alternated with itself. Similarly, points surrounded by a diamond indicate pecks at the common feature when it alternated with the distinctive feature, and points surrounded by a large triangle indicate pecks at the common feature when it alternated with itself.

After training on the 0°-feature-positive discrimination (Fig. 6, Birds 80 and 12, top panel), decremental line-tilt gradients were obtained, with pecking at the line feature decreasing as the line was tilted further away from vertical. Decremental gradients were obtained regardless of which feature alternated with the feature pecked at. (Bird 12 actually pecked more at 30° than at 0°. This asymmetry of the line-tilt gradient has previously been observed in a few of the birds trained and tested by the author with more conventional procedures, but the cause of this occasional failure of the peak of the gradient to be at the training value is not known.) Also, pecking at the common feature, B (open circles, bottom panel), decreased as the line feature that alternated with it was tilted further away from vertical. However, between the two birds there were no consistent changes in pecking at the distinctive feature, 0° (filled circles, bottom panel) as a function of the orientation of the line feature that alternated with it.

After training on the B-feature-positive discrimination (Fig. 6, Birds 43 and 22, top

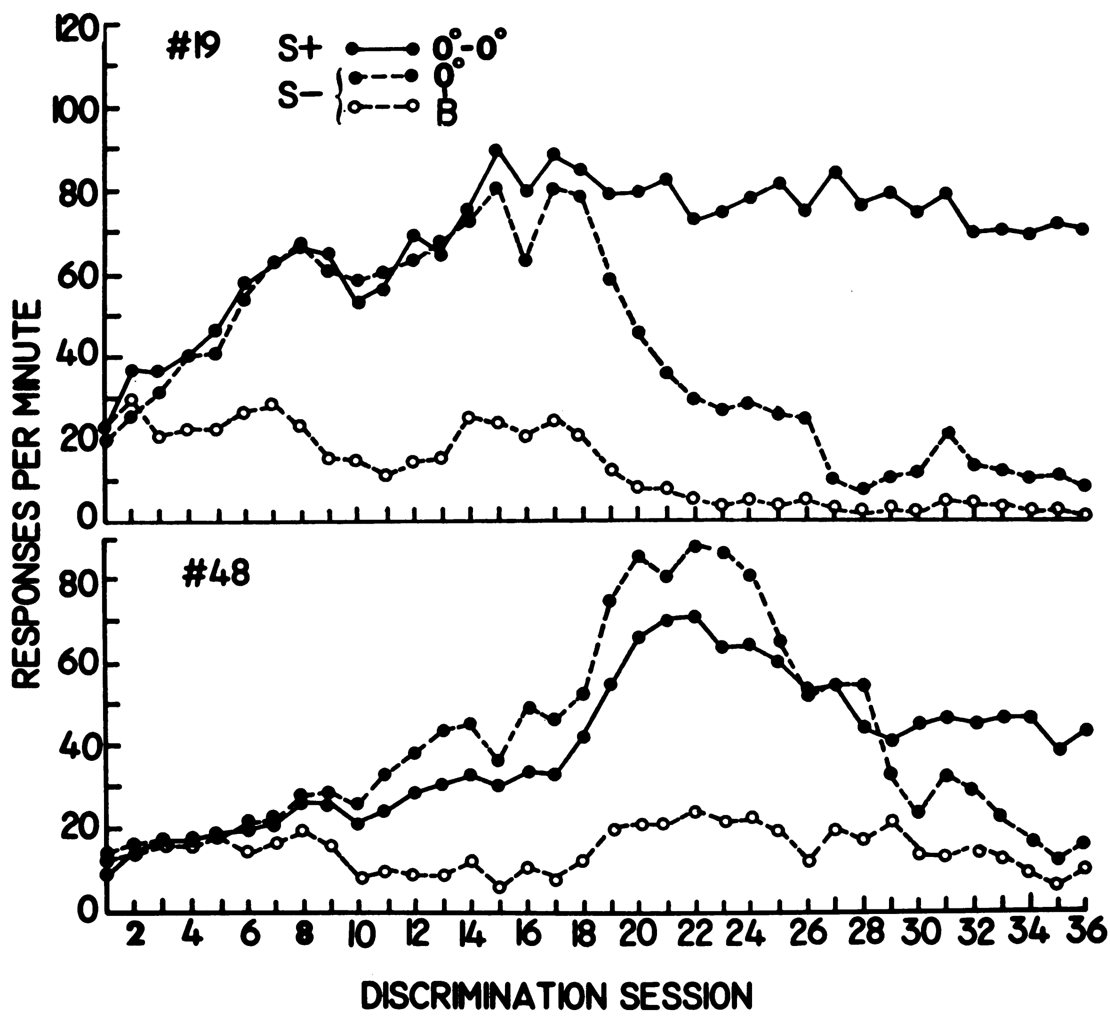

Fig. 5. Acquisition data for the two birds trained on the B-feature-negative discrimination, S+ (0°—0°) *vs.* S— (0°—B). The distinctive feature was B, and the common feature was 0°.

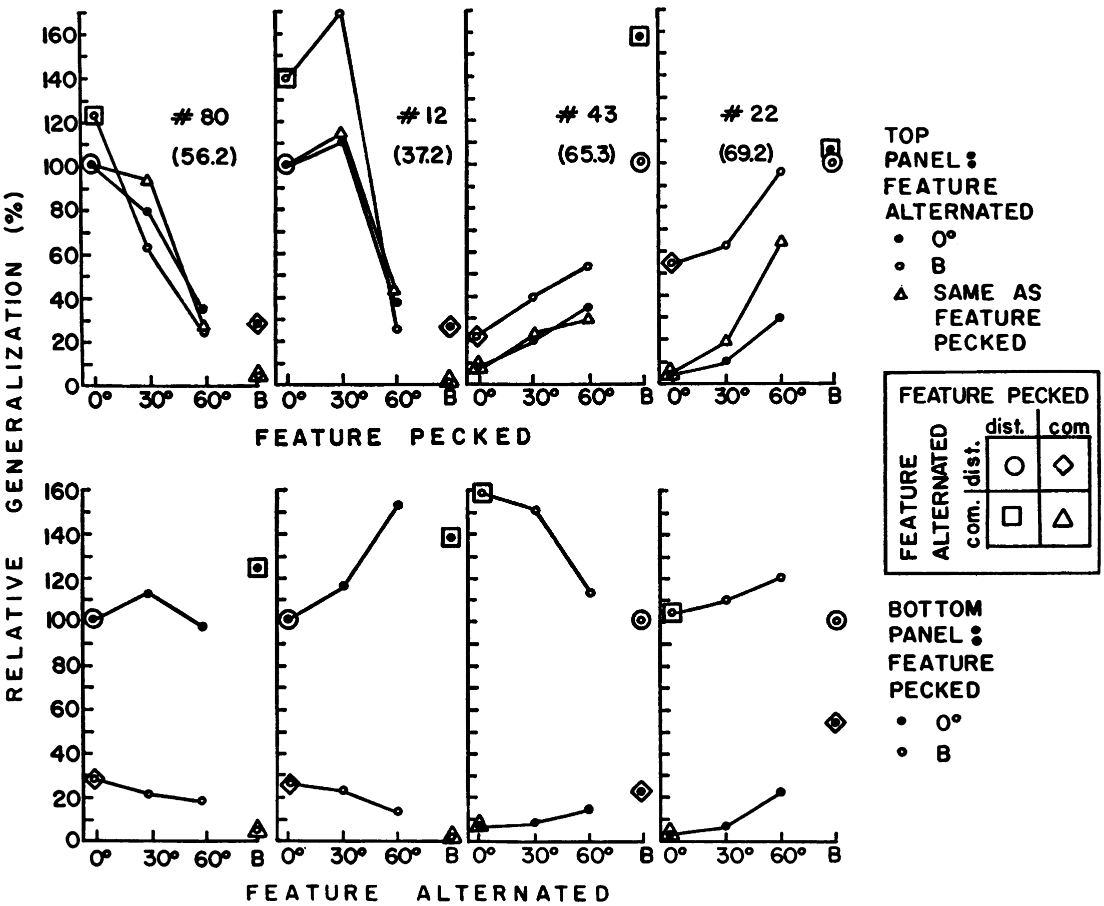

Fig. 6. Relative generalization gradients for birds trained on feature-positive discriminations. The top panel indicates pecks at the various features as a function of the feature pecked at, with the feature alternated with it as a parameter. The bottom panel indicates pecks at the 0° and B features, as a function of the feature alternated with them. (See text for additional details.)

panel), incremental line-tilt gradients were obtained, with pecking at the line features increasing as the line was tilted further away from vertical. Incremental gradients were obtained regardless of which feature alternated with the feature pecked at. Also, pecking at the common feature, 0° (filled circles, bottom panel), increased as the line feature that alternated with it was tilted further away from vertical. However, between the two birds there were no consistent changes in pecking at the distinctive feature, B (open circles, bottom panel) as a function of the orientation of the line-feature that alternated with it.

For all four birds trained on feature-positive discriminations, the rate of pecking at the distinctive feature during the test was higher when it alternated with the common feature (points surrounded by squares) in S+ than when it alternated with itself (big circles), and the rate of pecking at the common feature was higher when it alternated with the distinctive feature (diamonds) in S+ than when it alternated with itself (big triangles) in S−.

After training on the 0°-feature-negative discrimination (Fig. 7, Birds 67 and 58, top panel), incremental line-tilt gradients were obtained, regardless of which feature alternated with the feature pecked at. Also, pecking at both the distinctive feature, 0° (filled circles, bottom panel), and the common feature, B (open circles, bottom panel), increased as the line feature that alternated with them was tilted further away from vertical.

After training on the B-feature-negative discrimination (Fig. 7, Birds 19 and 48, top panel), decremental line-tilt gradients were obtained, regardless of which feature alternated with the feature pecked at. Also, pecking at the distinctive feature, B (open circles, bottom panel), decreased as the line feature that alternated with it was tilted further away from vertical. Pecking at the common feature, 0° (filled circles, bottom panel), tended to decrease as the line feature that alternated with it tilted further away from vertical, but this effect was somewhat ambiguous due to the fact that both birds pecked more at 0° when it alternated with 30° than when it alternated with itself.

For all four birds trained on feature-negative discriminations, the rate of pecking at the distinctive feature during the test was higher when it alternated with the common feature (squares) in S− than when it alternated with itself (big circles), and the rate of pecking at the common feature was higher when it alternated with itself (big triangles) in S+ than when it alternated with the distinctive feature (diamonds) in S−.

DISCUSSION

In most cases, the results of the present study, using successive-compound stimuli, are consistent with the results obtained by Jenkins and Sainsbury (1969, 1970) in experiments employing simultaneous-compounds.

In the feature-positive discriminations, the birds learned the overall successive discrimination between S+ and S−, and in S+, the 0°−B compound, they pecked more at the distinctive feature than at the common feature (Fig. 2 and 3).

In the feature-negative discriminations, in S−, the 0°−B compound, the birds pecked less at the distinctive feature than at the common feature. However, contrary to Jenkins' and Sainsbury's results, the birds in the present study learned the overall feature-negative successive discrimination between S+ and S−. Although the feature-negative discrimination was learned somewhat (not significantly) more slowly than the feature-positive discrimination, by the final training session discrimina-

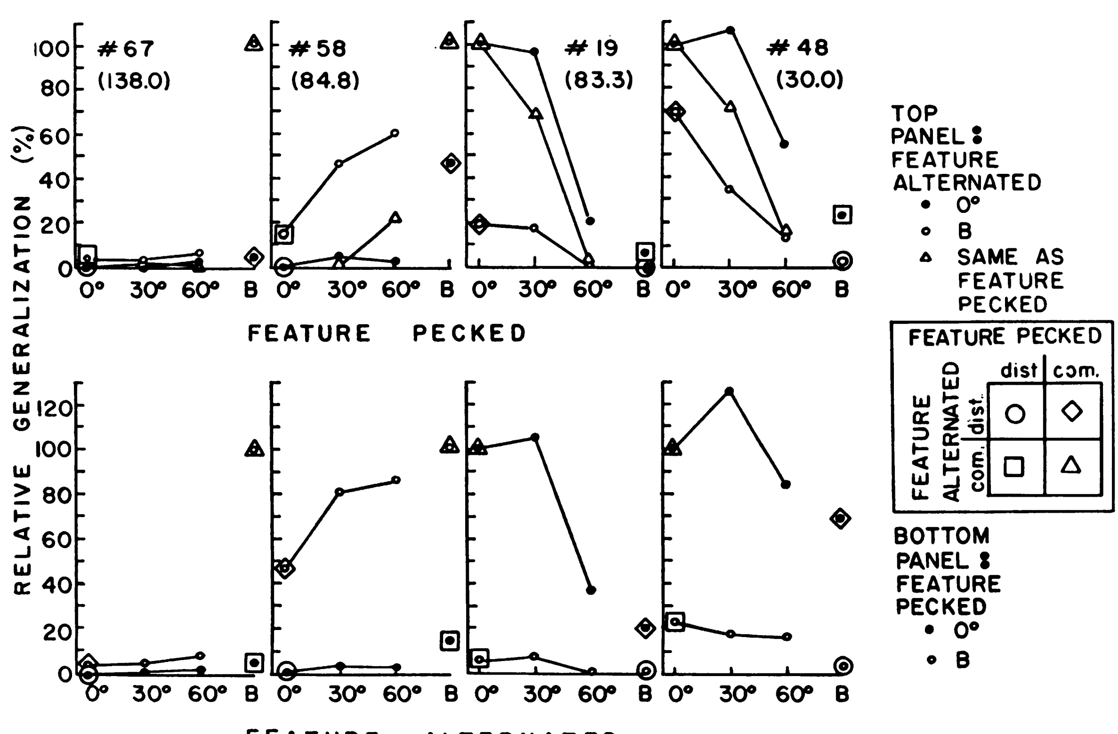

Fig. 7. Relative generalization gradients for birds trained on feature-negative discriminations. The top panel indicates pecks at the various features as a function of the feature pecked at, with the feature alternated with it as a parameter. The bottom panel indicates pecks at the 0° and B features, as a function of the feature alternated with them. (See text for additional details.)

tion ratios for both types of discrimination were at the same low level.

The line-tilt generalization tests revealed that the nature of the stimulus control exerted by the 0° line feature depended both on whether 0° had been the distinctive feature or the common feature during discrimination training, and on whether the distinctive feature had appeared in S+ (feature positive discriminations) or in S− (feature negative discriminations). After training on the feature-positive discriminations, decremental line tilt gradients were obtained when 0° had been the distinctive feature, whereas incremental gradients were obtained when 0° had been the common feature. After training on the feature-negative discriminations, incremental line tilt gradients were obtained when 0° had been the distinctive feature, whereas decremental gradients were obtained when 0° had been the common feature.

Jenkins (1965) suggested that decremental and incremental generalization gradients can be taken as evidence for excitatory and inhibitory stimulus control, respectively, when these gradients are obtained following training on a discrimination in which one of the stimuli (S+ or S−) is orthogonal to the dimension of the other stimulus on which generalization is tested. Thus, if no-line (the B feature) is orthogonal to the line tilt dimension, then the present data indicate that the distinctive feature in a feature-positive discrimination becomes an excitatory stimulus, whereas the distinctive feature in a feature-negative discrimination becomes an inhibitory stimulus. The feature common to both S+ and S− is not a neutral stimulus, in spite of the fact that it is not a reliable cue indicating reinforcement *versus* extinction; rather, the common feature acquires an inhibitory or excitatory function opposite that of the distinctive feature. Although Jenkins' ideas about excitatory and inhibitory generalization gradients have been widely cited in recent research on stimulus control, Hearst, Besley, and Farthing (1970) have shown that caution must be used in interpreting incremental generalization gradients as indicative of inhibitory stimulus control. Regardless of whether the notions of excitatory and inhibitory control are accepted, the present experiment shows that a distinctive feature has different effects in the acquisition of a discrimination, depending upon whether that feature appears in S+ or in S−.

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