

Stimulus Generalization as a Function of Discrimination Learning with and without Errors

Abstract. After discrimination learning with and without errors, three groups of pigeons were tested for generalization to the angularity (negative stimulus) dimension. For half the subjects from each group, each angle was superimposed on a light of 555-nanometer wavelength, the positive stimulus during training; for the other half, the angles were on a black background. When tested to the angularity alone, the group which had made errors (pecked at the negative stimulus) during discrimination training showed a typical incremental (inverted) gradient of responding to the negative stimulus dimension. The control group and the one learning the discrimination without errors showed no differential control by the negative stimulus dimension. When each angle was superimposed on the positive stimulus during testing, a decremental gradient with maximum response strength to the negative stimulus was evidenced by the two groups learning with and the one group learning without errors.

Interdimensional discrimination training refers to a procedure in which one of the stimuli used in training, either the positive (correlated with reinforcement) or the negative (correlated with extinction), is off of and orthogonal to the dimension used in subsequent generalization testing. Testing for generalization along the dimension of the negative stimulus usually reveals a gradient of inhibition around that stimulus. That is, an incremental or V-shaped gradient occurs, in which the lowest response rate accrues to the stimulus correlated with extinction during training (1). However, in Terrace's study, the gradient of inhibition was made contingent on the pigeons' having made errors (pecked the key) in the presence of the negative training stimulus. If the birds acquired the discrimination between a vertical line (positive) stimulus and a monochromatic (negative) stimulus without ever (or nearly ever) responding in the presence of the latter, no differential control of responding by the negative stimulus was observed. Terrace related these findings to those of his

earlier work on errorless learning, involving a positive and a negative stimulus from the same dimension to conclude that the negative stimulus in errorless discrimination learning becomes a neutral stimulus to the organism (2). What seems to be significant in making the stimulus correlated with extinction an inhibitory stimulus is the presence (or absence) of a history of extinguished key pecking at that stimulus. I repeated and extended Terrace's study with a new training method. The animal is prevented from responding in the presence of the negative stimulus by the key and chamber being momentarily blacked out every time the pigeon attempts to peck the key in the presence of that stimulus.

Sixty untrained pigeons, divided into groups of 20 and maintained at 70 to 75 percent of their weight when given free access to food, were used. The study was carried out in standard Grason Stadler pigeon chambers with associated automatic programming and recording equipment. Industrial Electronics Engineers in-line display cells provided the stimuli, which consisted of a 555-nm light and lines at angles of 30°, 60°, 90°, 120°, or 150°.

Group 1 was given single-stimulus training with the 555-nm light on the key throughout and served as the control. Group 2 was trained to discriminate without error between a wavelength of 555 nm (positive stimulus) and a white vertical line on a black background (negative stimulus). The negative stimulus was introduced early in training, but at full intensity and duration any attempt by the pigeon to peck the key in the presence of the negative stimulus resulted in the key and the house light being momentarily (2

seconds) blacked out. Any movement toward the key when the negative stimulus was present was judged as an attempt to peck, and the key and house light were blacked out. As training progressed, birds made fewer and fewer attempts to peck in the presence of the negative stimulus, thus allowing it to stay on longer and longer until no (or few) attempts were made to peck while it was present. To insure that any differences in generalization between the control and that without error were not due to blackouts or reinforcement patterning, control subjects were paired with the errorless birds so that whenever the chamber was blacked out because an errorless bird tried to peck at the negative stimulus, the chamber of the corresponding control was also blacked out; whenever an errorless subject earned a reinforcement, the next peck by the corresponding control pigeon also earned a reinforcement. This procedure equates the number and pattern of both blackouts and reinforcements in the two groups. Group 1 remains a control which receives only one stimulus, because for it the stimulus on the key is always the 555-nm light. Pairing control and experimental animals permits a direct test of Terrace's notion that the negative stimulus after learning without error becomes a neutral stimulus by providing a group for which the angularity dimension is neutral. Since the controls had never seen the vertical line before testing, it should hold no significance for the birds; if the negative stimulus is truly neutral after learning without errors, the generalization gradients for these two groups should be the same.

Group 3 learned the same discrimination as Group 2, but no attempt was

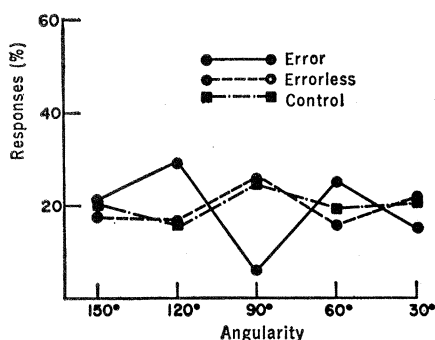


Fig. 1. Mean percentage of total responses to each angle for the three groups tested to angularity alone.

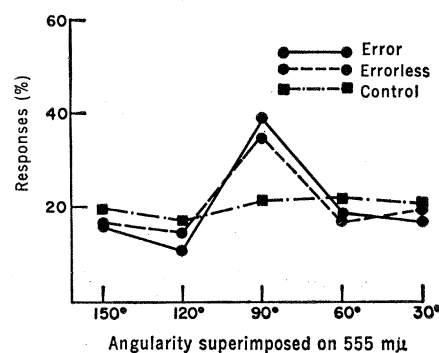


Fig. 2. Mean percentage of total responses to each angle for the three groups tested to angularity with the positive stimulus present.

made to prevent the birds from responding in the presence of the negative stimulus. In fact, to insure that all birds in this group made errors, each animal was given 2 days of continuous reinforcement in the presence of both the 555-nm light (which became the positive stimulus) and the white vertical line (which became the negative stimulus). After key-peck training, the reinforcement schedule was changed to a variable-interval schedule with a mean interreinforcement time of 30 seconds. This schedule remained in effect throughout training. A criterion of 20 responses in the presence of the positive stimulus to one response (for the error group) or an attempt to respond (for the errorless group) in the presence of the negative stimulus for two consecutive days determined the discrimination was learned; that is, the total responses to positive stimulus had to be at least 20 times greater than the total responses or blackouts, depending on the group, to the negative stimulus (3).

Each bird was tested in extinction for generalization to the angularity negative stimulus dimension. The test stimuli were lines at angles of 30°, 60°, 90°, 120°, and 150° rotated counterclockwise from horizontal. The order of presentation of the stimuli, within each series of five stimuli, was determined randomly; nine such series were presented. Half the birds in each group were tested to the angles alone; the other ten were tested with each angle superimposed on the 555-nm light.

The lack of an inverted gradient in the responses of Terrace's errorless group may have been due to the extremely low responding maintained by his testing procedure. A test in which each test angle is superimposed on the 555-nm light can be expected to induce greater responding in the presence of those stimuli, possibly revealing differences in response strength which Terrace's procedure may have concealed.

The mean percentage of total responses for the errorless and control groups are virtually identical (Fig. 1). Since the control group had never been exposed to any angle of line, the fact that the gradient for the errorless group is similar to that for the control suggests that insofar as angularity is a "neutral" stimulus for the control group it is also a neutral stimulus for the errorless group. In agreement with Terrace's findings the gradients of the errorless and control groups show no

significant differences attributable to stimuli (4). Only the group trained with errors showed the lowest response tendency to the 90° negative stimulus; this response depression at the negative stimulus is highly reliable (5).

Figure 2 presents the mean percentage of total responses for the three groups tested to each angle superimposed on the 555-nm light positive stimulus. The presence of the positive stimulus causes the gradient around the previous negative stimulus to be positive (decremental). This preference for the 90° line by both the error and errorless groups is statistically reliable (6). The control group again showed no preference for any angle, which indicates that angularity was a neutral stimulus dimension for this group.

Only the response rate of the error group changes as a function of the presence of the positive stimulus (7); the rate increases in its presence (the error group was the only one which showed a gradient of inhibition when tested to angularity alone). The fact that there are no significant changes in rate for either the errorless or the control group in the two test situations indicates again that there is no negativity (in the sense of response suppression) connected with negative stimulus for the errorless group.

Furthermore the negative stimulus is not a neutral stimulus after errorless discrimination learning; there is a positive gradient which peaks at the negative stimulus when the values from the dimension of the negative stimulus were superimposed on the positive stimulus

during test. Why this should be so remains to be determined. One possibility is that during errorless training the bird became familiar with the negative stimulus training stimulus, which somehow became a positive stimulus in the context of the generalization test with positive stimulus present.

The method of bringing about errorless learning used in this study is more flexible than those used by Terrace, and it produces the same results. Discrimination training can be introduced either early or late. Subjects are not assigned to the errorless group after the fact, and elaborate programming equipment is not necessary to bring about errorless learning.

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References and Notes

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2. H. S. Terrace, *J. Exp. Anal. Behav.* **6**, 1 (1963); *Science* **140**, 318 (1963); *ibid.* **144**, 78 (1964).
3. J. Lyons, *J. Exp. Psychol.*, in press.
4. Analysis of variance shows no effect of stimuli: Errorless group: $F_{4,36} = 1.37$, $P > .05$; control group: $F_{4,36} = 2.33$, $P > .05$.
5. Error group: $F_{4,36} = 4.51$, $P < .01$.
6. Errorless group: $F_{4,36} = 9.61$, $P < .01$; error group: $F_{4,36} = 8.49$, $P < .01$.
7. The t test between error group with and without positive stimulus shows $t_{(40)} = 5.35$, $P < .01$.
8. I thank D. R. Thomas for his help and encouragement. These results were presented at the annual meetings of the Midwestern Psychological Association in Chicago, 1968. This study also constitutes part of a dissertation submitted to the Graduate School at Kent State University in partial fulfillment of the requirements of the Ph.D. degree.

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Occupancy Principle: Identity with That of Mean Transit Time of Tracers in Biological Systems

Orr and Gillespie (1) propose application of the occupancy principle to design and analysis of experiments with tracers in steady-state biological systems. I agree with their proposal, which is especially applicable to noncompartmental systems, such as the circulation, but I am not sure that it is really different from one which I made in different language and symbols (2).

For those who might wish to relate the language of Orr and Gillespie to that used in certain biological fields, I wish to point out that what they call occupancy, their symbol θ , is what I

and others call the mean transit time or mean residence time \bar{t} . In earlier tracer experiments in biology, the term "turnover time" was used widely. This term, strictly speaking, applies to systems through which the probability-density function of transit times is exponential, ke^{-kt} , in which case the turnover time is $1/k$, which is identical with \bar{t} .

The definition has been extended to other systems in which it is also equated with \bar{t} . I prefer \bar{t} as less ambiguous. The dimensionless function $f(t)$, used by Orr and Gillespie, is, I