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Stimulus Generalization along the Light Intensity Dimension as a Function of Discrimination Training

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STIMULUS GENERALIZATION ALONG THE LIGHT INTENSITY DIMENSION AS A FUNCTION OF DISCRIMINATION TRAINING

by

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The phenomenon of a shift in the peak of a generalization gradient after discrimination training was originally described by Hanson (1959). Working with the wavelength continuum, Hanson demonstrated that discrimination training between two stimuli on the same continuum produced a change in the gradient as compared to the gradient that is produced by training on one value only. The specific form of the change was a shift in the gradient away from the positive stimulus (S+, the stimulus associated with reinforcement) in a direction opposite to the negative stimulus (S-, the stimulus associated with extinction). Hanson also found that the smaller the difference between the S+ and S-, the greater the shift in the peak. Bloomfield (1967) has observed the same phenomenon when training and testing along the line angle dimension. Malott and Malott (1967) obtained a peak shift while investigating the tone intensity continuum.

In an attempt to account for this phenomenon, Hanson alluded to the explanation of a similar phenomenon, transposition, supplied by Spence (1937). Transposition referred to the behaviors displayed by animals trained to discriminate between two stimuli varying along a dimension such as intensity or size. For example, when trained to choose the shorter of two line lengths and tested with the original short line and one even shorter, subjects showed a preference for the shortest line.

Spence attempted to explain these transposition data in terms of the inhibitory gradient formed around the S- resulting from the extinction of responding in the presence of that stimulus. This gradient in conjunction with the positive gradient around the S+ might then produce a shift in the peak or area of the composite gradient as compared to each individual gradient. This summation of gradients theory, however, was not complete enough of itself to account for all of the data which Hanson presented. Hanson found that responding during generalization tests after discrimination training was as high as responding during tests prior to any discrimination training. Hanson pointed out that summation of the theoretical gradients of Spence would produce a decrement in total number of responses. Later investigators such as Terrace (1966) and Reynolds (1961) showed that the phenomenon of behavioral contrast, an increase in response rate during S+ with a corresponding decrease in the rate during S-, could supplement the notion of summation of gradients to produce the type of gradients described by Hanson.

One purpose of the present study was to investigate the effects of discrimination training along the light intensity dimension, a continuum not previously studied with regard to these phenomena.

Earlier studies in the area of the generalization of light intensity have investigated the theory of stimulus intensity dynamism as postulated by Hull (1949). Stimulus intensity dynamism proposes that, other things being equal, a subject will respond at a higher rate to stimuli of greater intensity. According to Mednick and Freedman (1963), this theory would predict gradients extending from stimuli less intense than the training value to the training value to be slowly increasing over very low intensities with a rapidly accelerating rate just prior to and including the training value. For the range extending from the training value to stimuli of greater intensity, the theory would predict rapid acceleration of rates until an asymptote was reached. The most common form for studies of stimulus intensity dynamism to take was the conditioning (either operant or respondent) of a response in the presence of one stimulus value (either high or low intensity) on the end of a range of test values, and the testing for production of that response by other values. The general results for studies using a direct light source support Hull's theories (Brown, Fink and Patton, 1953; Frick, 1948).

More recent investigators, however, have presented other arguments to explain the phenomenon attributed to stimulus intensity dynamism. Perkins (1953) and Logan (1954) have suggested that the phenomenon attributed to stimulus intensity dynamism is in reality a function of an inhibitory response built up in the absence of the training stimulus and is similar to the inhibitory gradient developed during discrimination training as hypothesized by Spence (1937). This absence of the training stimulus can be interpreted as lying on the intensity continuum and being a stimulus of zero intensity. Hence, the inhibitory generalization gradient developed around the no-stimulus value (zero intensity) interacts with the positive generalization gradient developed around the training value to produce a steepening of the lower intensity side of the gradient and a relative flattening of the higher intensity side.

Malott and Malott (1967) have presented data supporting the position that stimulus intensity dynamism can be attributed to the effects of the Hanson peak shift discussed earlier. Using the tone intensity continuum and giving training on a single intensity value, they found flat generalization gradients when testing over a range of intensities. However, when discrimination training was given between tone on (60 decibels) and tone off (0 decibels), they found that the subjects produced what initially appeared to be an example of stimulus intensity dynamism. Testing over a wider range on the continuum, however, revealed the presence of decreasing rates of response at very high intensities. They interpreted these data as showing the existence of a generalization gradient with the peak shifted away from the zero intensity. From these data one could predict that, had the studies mentioned earlier in support of Hull's theory involved testing over a wider range of stimulus values, they would have revealed a shift in the peak of the generalization gradient.

Pierrel and Sherman (1960) have provided data which show that rats given discrimination training between a low intensity tone as the S+ and a high intensity tone as the S- will produce a generalization gradient with a peak shifted in the direction of dimmer intensities. This study lends strong support to the position that stimulus intensity dynamism could be really a peak shift phenomenon.

A second purpose of the present study was to test with light intensity the theory that the effects attributed to stimulus intensity dynamism could be in reality a shift in the generalization gradient as a function of training.

METHOD

Subjects

The subjects were three experimentally naive White King barren hen pigeons, housed in individual cages. They were fed at the end of each experimental session or once daily when sessions were not conducted so that at the start of each experimental session, they would be at 70% of their free-feeding weight. Purina Pigeon Grains were used to maintain weight and served as the reinforcer. Grit and water were continuously available in the home cage.

Apparatus

A Lehigh Valley Electronics pigeon test chamber #1519c was used with the houselight off and the window covered. Only one response key was operative; it consisted of a transparent plastic paddle behind a hole 1¼ in. in diameter. A diffusing Plexiglas plate, located directly behind the key, was transilluminated from the rear by a 120 volt, 6 watt G.E. lamp. The lamp was mounted 4 in. from the rear of the key in a flat-black rectangular enclosure which directed the light through a Kodak Wratten filter, series V, on to the Plexiglas plate. The intensity of this direct light source was measured by placing a Gossen Luna-pro exposure meter against the front of the key so that the light coming from the light source filled the meter's aperture. The intensity of the food magazine light was dimmed by placing a resistor in series with the light. The intensity of the light coming from the magazine was 1.2 footcandles (fc), when measured with the exposure meter held directly in front of the opening to the magazine.

White masking noise was provided by a Grason-Stadler noise generator and was presented through a speaker in the chamber. A fan provided ventilation and additional masking noise.

Programming during training was done automatically with solid state digital switching circuitry. Intensity changes during training were controlled by a resistor series and a relay system which alternated between two resistor values to produce intensity changes. During generalization tests, the key light intensity was manually controlled with an Adjust-a-volt variable transformer. Time in each stimulus, responses and reinforcements were recorded with electromechanical counters.

A styrofoam picnic freezer, painted flat-black inside, was used as a dark-adaptation chamber. Ventilation was provided by a baffled fan system. Subjects were transferred from the dark-adaptation chamber to the experimental chamber in a container having a flat-black interior. The room lights were off. Precautions were taken to avoid exposure to any light during this time.

Procedure

Prior to each experimental session, the subjects were placed in the dark-adaptation chamber for one hour. They were then transferred to the experimental chamber. Through the use of standard operant conditioning procedures, they were trained to eat from the food magazine and to peck the response key transilluminated with a light of 0.88 fc. When the key peck response was established, the subjects received 200 reinforcements (50 each day for 4 sessions) on a continuous reinforcement (CRF) schedule. Reinforcement consisted of a

3 sec presentation of the food magazine accompanied by the magazine light. The average interval between the successive periods of the availability of reinforcement was then increased each day according to the criteria listed below.

If the subject received:

50 reinforcements in 10 min on CRF

50 reinforcements in 20 min on random interval (RI) 8 sec

50 reinforcements in 30 min on RI 16 sec

50 reinforcements in 40 min on RI 32 sec

the schedule was increased to the next value the following day until an RI 64 sec schedule was reached. With the RI 64 sec schedule, the probability of reinforcement for the first response in each successive 4 sec period was 1/16 (Farmer, 1963). Sessions were conducted seven days per week and lasted until 50 min had elapsed or 50 reinforcements had occurred, whichever came first.

Following 15 days of training with the RI 64 sec schedule (a period which produced stable response rates in all subjects as determined by visual inspection of a graph of response rates as a function of sessions), the subjects were tested in extinction for generalization along the light intensity dimension. The test was preceded by 10 min of warm-up exactly like training. The stimuli used for the generalization test were selected so that each stimulus above the lowest one was approximately twice as intense as the one preceding it. The intensities used were: 0.00 fc, 0.03 fc, 0.06 fc, 0.11 fc, 0.23 fc, 0.45 fc, 0.88 fc (S+ intensity), 1.75 fc, 3.5 fc and 7.0 fc. During the test, these 10 stimuli were presented in 10 blocks of 10 stimuli each, each value appearing once in each block. The stimulus appeared on the key for 20 sec followed by a time-out (period of complete darkness) for 10 sec. The intensity was changed during time-out. The number of responses occurring in each stimulus presentation was recorded.

Training with the single stimulus on an RI 64 sec schedule continued for seven days following the generalization test. Discrimination training was then begun. The positive stimulus (S+), the stimulus associated with reinforcement on an RI 64 sec schedule, was the same intensity (0.88 fc) as had been present during initial training. The negative stimulus (S-), the stimulus associated with extinction, was set at 0.03 fc. This value was the second lowest test value, the lowest being 0.00 fc. The S+ remained on the key until the end of the first reinforcement. The S- was then presented and remained on until 30 sec of no responding occurred. The S+ then reappeared and the stimuli were alternated in this manner throughout the session. Each day a discrimination ratio consisting of the rate in S+ divided by the rate in S+ plus the rate in S- was computed. When this value reached 0.90 or greater, a second generalization test was conducted. This test was identical to the first generalization test.

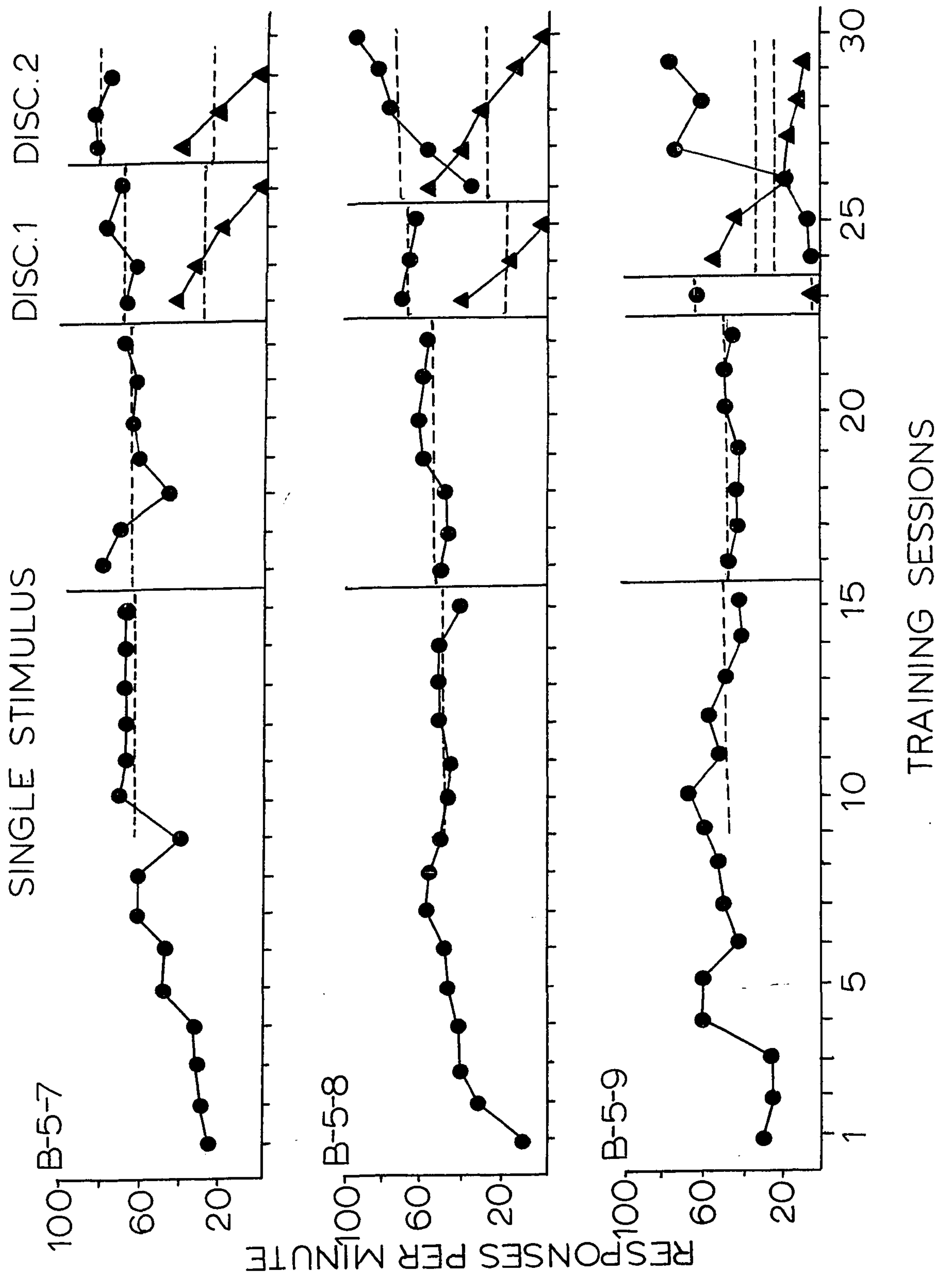
Following the second generalization test, a new S- was substituted in the discrimination procedure described above. The S- was changed from 0.03 fc to 0.11 fc. The S+ remained at its value of 0.88 fc. When the discrimination ratio reached 0.90 or better, a third generalization test, identical to the first two, was conducted.

RESULTS

The changes in response rates for both S+ and S- during initial conditioning and discriminations 1 and 2 are shown in Fig. 1. (Dashed lines show mean response rates for S+ and S- during each experimental phase.) All subjects show stable response rates, both prior to and immediately following the first generalization test (represented by the first vertical dividing line). Following the introduction of discrimination 1 (second vertical line), the response rates in the presence of the S+ increased above their previous mean rates while the rates in S- rapidly decreased. The introduction of discrimination 2 (third vertical line) produced a slight overall rise in the S+ response rate for subject B-5-7 while the S- rate was initially high and declined rapidly. For both subjects B-5-8 and B-5-9, this discrimination drastically lowered the S+ rate and raised the S- rate. These rates then changed so that both subjects reached S+ response rates higher than any previously shown and S- rates near zero. Because of the initially low rates produced by B-5-9 in discrimination 2, the mean S+ rate for that phase is low. The actual response rate at the end of training, however, is higher than any seen previously.

The regularity of changes in the S+ and S- rates is further illustrated in Fig. 2. This figure shows the changes in the discrimination ratio as a function of sessions. For all birds the ratio is a monotonically increasing function for each discrimination. The figure shows that the discrimination learning was an orderly, regular process.

Fig. 1. Changes in response rates as a function of treatments. This figure shows daily response rates (responses per minute) for each phase of the study. Circles represent responses made in the presence of the positive stimulus while triangles represent responses made in the presence of the negative stimulus. Dashed lines represent mean response rates for each period and for S+ and S-.



SINGLE STIMULUS
DISC.1
DISC.2
B-5-7
B-5-8
B-5-9
RESPONSES PER MINUTE
100
60
20
TRAINING SESSIONS
1
5
10
15
20
25
30

Fig. 2. Discrimination ratio changes as a function of sessions and treatments.

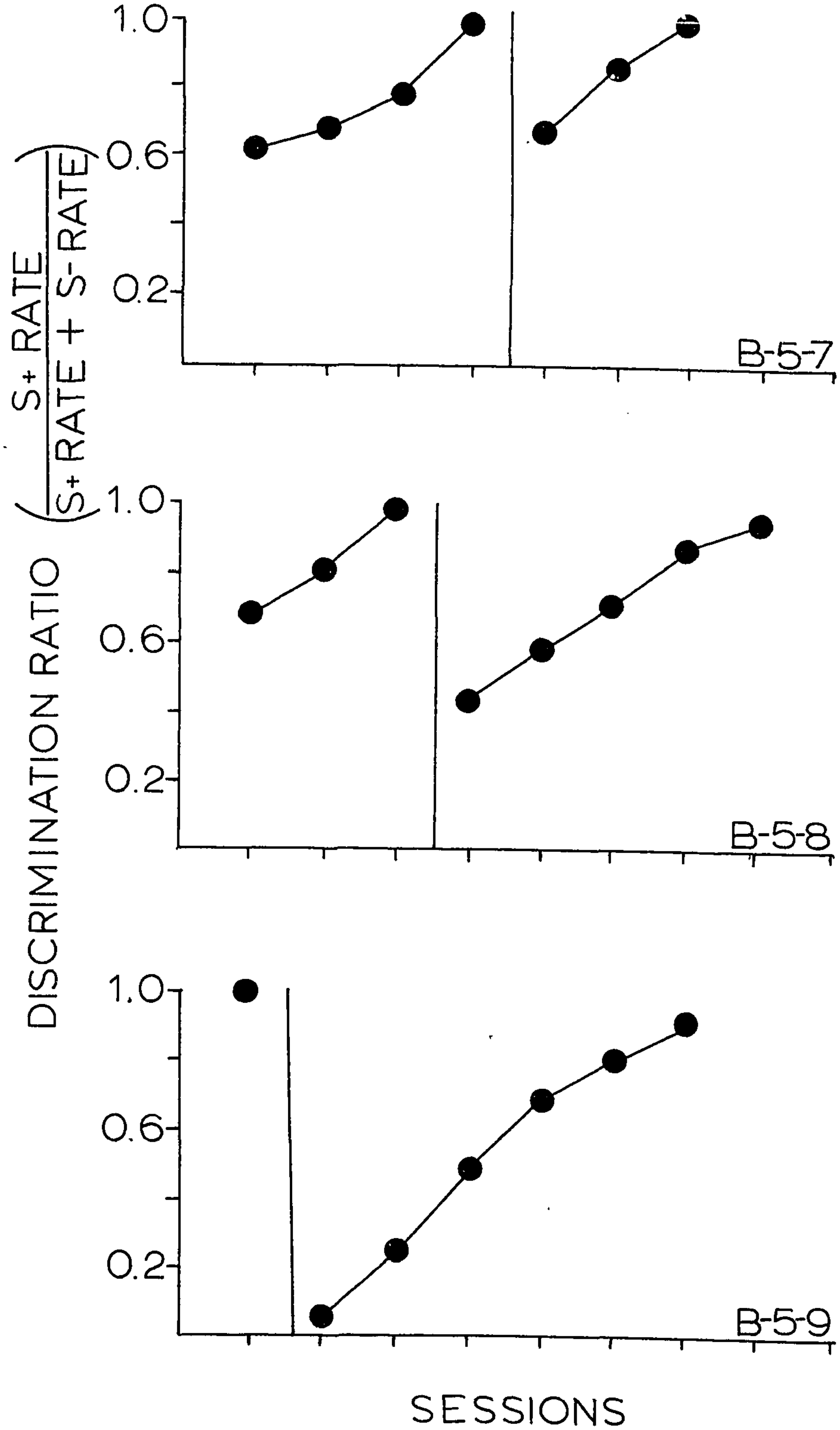

DISCRIMINATION RATIO (S+ RATE / S+ RATE + S- RATE)
1.0
0.6
0.2
B-5-7
1.0
0.6
0.2
B-5-8
1.0
0.6
0.2
B-5-9
SESSIONS

Figure 3 is a comparison of the three generalization gradients produced by each subject. Median gradients are also included to summarize the results. The total number of responses occurring at the peak of each gradient is given in Table 1. All of the gradients are based on a large number of responses and are therefore reliable. For B-5-7 and B-5-8, the gradients produced after training on one stimulus value are relatively flat on the left or dimmer side of the S+. If a reliable peak for these gradients exists, it is located between 0.00 fc and the training stimulus. Since the response rates are so similar, the slight amount of variability prevents determining the exact location of the peak. Subject B-5-9 shows some generalization decrement in both directions with the peak at the training value. All subjects responded near zero at the 0.00 fc intensity. The median curve for the first generalization gradient follows the form of the first two subjects, being flat over intensities below the S+ and dropping in rates for intensities above the S+.

The second generalization test (following discrimination 1) shows a sharpening of the slopes on both sides of the S+ value. Only one subject (B-5-8) shows what may be a shift in the peak after training on the first discrimination problem. For all subjects there is a more clearly defined peak. The median gradient shows a sharpening of the gradient over the dimmer intensities, a somewhat flat area around the S+ value and a sharp increase in the slope of the gradient over the highest values relative to the first gradient.

For the third gradient, B-5-7 and B-5-8 show a shift of the peak to the more intense values, which had previously been rather low.

Fig. 3. A comparison of generalization gradients obtained following (1) single stimulus training (solid line), (2) discrimination 1 (triangles with dotted line), and (3) discrimination 2 (squares with dashed line). The intensities are: -6 = 0.00 fc; -5 = 0.03 fc ($S-_1$ intensity); -4 = 0.06 fc; -3 = 0.11 fc ($S-_2$ intensity); -2 = 0.23 fc; -1 = 0.45 fc; 0 = 0.88 fc (S+ intensity); +1 = 1.75 fc; +2 = 3.5 fc; and +3 = 7.0 fc.

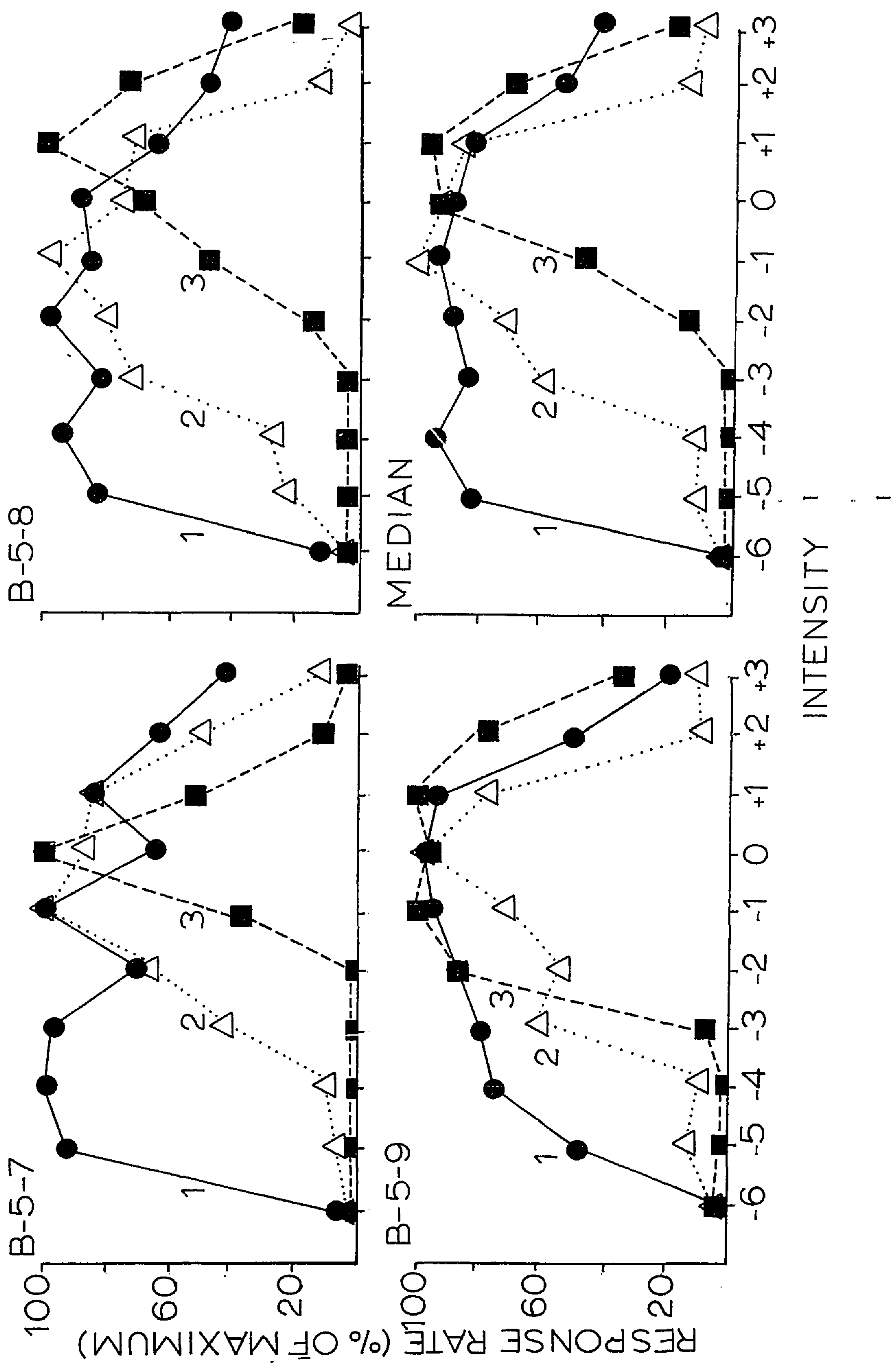

B-5-7
B-5-8
B-5-9
MEDIAN
1
2
3
RESPONSE RATE (% OF MAXIMUM)
100
60
20
INTENSITY
-6 -5 -4 -3 -2 -1 0 +1 +2 +3

Table 1

Maximum responses for each generalization gradient. Each cell contains the total number of responses made by a subject at the maximum point for a specific generalization gradient.

Subject	Generalization gradient 1	2	3
B-5-7	264	382	77
B-5-8	144	276	240
B-5-9	117	59	63

The third subject shows a flattening of the gradient around the S+ and a bimodal peak position which centers around the S+. The form of the gradient for subject B-5-7 is again much sharper than the gradients from the first two tests. For the other two subjects, there is a rise in the relative rates at higher intensities and an increase in the slope at the lower intensities.

The left hand column under each phase in Table 2 shows the progressive change in the area under the generalization gradient as a function of successive discriminations. (These values were obtained by summing the percentages for each stimulus value on a gradient.) There is a statistically significant decrease in the area under the curve as a function of the discrimination training ($F = 7.98$, $df = 2/4$, $p < 0.05$). This indicates a definite sharpening of the gradient as a function of discrimination training.

The second column in Table 2 shows the placement of the median stimulus value (the point at which 50% of the gradient falls above and 50% falls below). For B-5-7 and B-5-8, the median point shifts to the right toward the higher intensities with each discrimination. The median point shifts for B-5-9 for the first discrimination but not for the second discrimination. Overall there is a statistically significant shift of the median value to the higher intensities ($F = 10$, $df = 2/4$, $p < 0.05$).

Table 2

Areas and medians for each generalization gradient.
Values represent total percent under
each generalization gradient and
the position of the median of
total responses for each gradient.

Subject	Generalization gradient					
	1		2		3	
	Area	Median	Area	Median	Area	Median
B-5-7	709.6	-3.59	466.1	-1.13	188.3	0.08
B-5-8	719.6	-2.67	483.4	-2.23	324.8	-1.24
B-5-9	646.5	-2.11	397.1	-1.60	505.5	0.07
Median	717	-2.60	440	-1.76	349	0.63

DISCUSSION

The first generalization gradient obtained after training on only one stimulus value is particularly flat over the intensities dimmer than the S+ while relatively sharp over higher intensities. Blough (1959) obtained broad yet peaked generalization gradients over the light intensity dimension when he trained subjects on one stimulus value. His stimuli covered a much wider range than the present study (0.14 millalamberts to 820 millalamberts) thus making comparison of the two studies difficult. He did find, however, that pigeons showed a preference for the lower-middle values of his testing range. It is possible that the values covered by the present study lie within his range and the gradients of the present study represent parts of his gradients. The size of stimulus could have produced the difference in gradient shapes between the present study and Blough's. Blough used a pinpoint of light on the key while the present study had the entire key illuminated. Heinemann and Rudolph (1963) have shown that larger stimulus areas will produce flatter light intensity gradients than smaller areas. Their smallest stimulus (which produced the sharpest gradient) was somewhat larger than the one in the present study. There are, however, several other differences, such as their use of reflected light and the stimulus not being on the key but around it, which could explain their gradients as compared to those of the present study.

The relatively low response rates over the higher intensities, as compared to low intensities and the failure to produce peaks at the training value could be due to the magazine light intensity. First, because the magazine light was brighter than the key, the subjects had an opportunity to compare stimuli and associate dimmer stimuli with the key. Second, during training this more intense light could have produced a greater illumination of the chamber during reinforcement. This general increase in illumination during reinforcement could have become a discriminative stimulus for moving to the food magazine. This response is incompatible with key pecking and produces lower key peck rates. During testing then, brighter stimuli produced levels of illumination comparable to those during reinforcement and hence would result in lower response rates. Future studies will be needed to investigate the effects of this stimulus on generalization gradients.

All of these studies in the area of light intensity employed non-differential training at one stimulus value and produced no evidence to support the theory of stimulus intensity dynamism. Studies of tone intensity have produced similar results (Malott and Malott, 1967). It would appear from these studies that the effects of stimulus intensity dynamism are not inherent in the organism and might, therefore, require training to produce them.

The introduction of discrimination training produced drastic changes in the behavior of the subjects during both training and testing. The first of these changes is a decrease in the rate of responding during the S- component with a corresponding rise in the rate during the S+ component. These changes in response rates during S+ and S-, known as "behavioral contrast" (Reynolds, 1961), have been observed by other investigators working in the area of discrimination training (Hoy, 1954; Herrick, Meyers and Korotkin, 1959; Terrace, 1966). Reynolds has demonstrated that the increase in the S+ rate is a function of the decrease in reinforcement density in the presence of the S- and not necessarily a function of the decreased S- rate alone.

In the present study, it was noted that each successive generalization gradient was sharper than the previous gradients. This is supported by the work of other investigators who have shown that any discrimination training, whether interdimensional, intradimensional, or extradimensional, will sharpen the generalization gradient over the test continuum (Thomas, Mariner, and Sherry, 1968).

Another interesting result is the changing distribution of responding with each new S+ - S- discrimination. As the data presented show, there is a progressive shift in the position of the gradients to the higher intensities. These results are in line with the earlier studies of generalization gradients after discrimination training discussed previously (Hanson, 1959; Terrace, 1966). The gradients produced following the first discrimination in which the S- was distant from the S+ are not shifted as far as the gradients produced after the second discrimination problem in which the S- was close to the S+. As stated above, Hanson (1959) has described a similar phenomenon.

It is possible that changes in the gradients are only a product of continued training and/or testing rather than a result of the different discrimination problems (Mountjoy and Malott, 1968). It would be desirable, therefore, to conduct an additional control experiment in which the order of the discrimination problems was changed or training continued on one value with several tests conducted at varying intervals.

CONCLUSION

The present study does not support the notion of stimulus intensity dynamism. The proposal of Hilgard and Marquis (1961) that the effects of stimulus intensity dynamism should interact with the generalization decrement effects to produce flatter gradients on the higher intensities side of the S+ than over lower intensities finds no substantiation. Testing after the initial training showed no evidence of the phenomenon. Discrimination training produced a sharpening of the initial gradient on both sides of the training value instead of the increase on the higher side of the S+ value. The shifting of the gradient to the higher intensities appears to follow the formulations and predictions of those theorists discussed earlier who propose the peak shift phenomenon as a sufficient explanation for effects commonly attributed to stimulus intensity dynamism.

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