GENERALIZATION OF AUDITORY INTENSITY FOLLOWING DISCRIMINATION TRAINING¹

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In a previous study (Pierrel, 1958) a gradient of generalization was obtained for rats following prolonged training in an auditory intensity discrimination. In that situation, S^D and S^A were at opposite ends of a 40-decibel intensity continuum. When generalization stimulus intensities intermediate between S^D and S^A were presented, a concave function was obtained relating response rate to stimulus intensity. The maximum of this function occurred at the S^D intensity and the minimum at the S^A intensity.

Hanson (1959), using a nonintensive continuum, obtained generalization gradients showing a maximum displaced from S^D in a direction away from S^A . This would suggest the desirability of placing S^D and S^A away from the extremes of the continuum explored in order to get at certain other relationships. In the current study, we proposed to examine generalization rate relations within the same range of intensities employed in our previous study. However, in this case, S^D and S^A were situated only 20 decibels apart and generalization stimuli were presented at both extremes of the intensity continuum from S^D and S^A , as well as intermediate between them.

By means of a recent pilot study, it was established that, within this intensity range, rats can develop stable discrimination behavior to stimuli separated by a 5-decibel difference. It was therefore decided to obtain a generalization gradient employing stimuli spaced at 5-decibel steps across a 40-decibel range.

METHOD

The subjects for this experiment were eight male albino rats of the Sprague-Dawley strain. These animals were obtained from the Charles River Breeding Houses, Brookline, Massachusetts, and were 90 to 110 days old at the start of experimentation.

Four identically constructed operant spaces were used. One of these is shown in Fig. 1. The box on the right is shown with the door open. The outer shell of the animal enclosure consisted of a 12.8-cubic foot refrigerator shell equipped with shock mounts. The inner surfaces, including the door, were lined with 2-inch Fiberglas board covered with glass cloth. The floor of the box was built up with Fiberglas blocks and a slotted partition inserted between the animal chamber and the space enclosing the pellet dispenser and the motor related to the retractable bar. This reduced the spread of noise from equipment operation to the animal. The resulting dimensions of the animal chamber were 15 inches in depth, 13.5 inches in width, and 23.5 inches in height. A University model 4401 tweeter was shock-mounted through the Fiberglas onto the inner shell of the refrigerator, with its base 7.5 inches above the experimental cage. The experimental cage was 5 inches deep, 8 inches wide, and 5.75 inches high. It was constructed from 0.1875-inch-diameter stainless steel rodding, with a separation of 0.5 inch between the rods. The cage frame was made of Lucite, and the entire front of the cage was a hinged door with a water bottle held onto it by a spring. The motor on the right side of the partition was programmed to either extend the bar into the cage or withdraw it back through the dividing wall. The bar was extremely

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Figure 1. Photograph of sound-shielded experimental enclosures.

light, requiring a force of 2 grams to depress it sufficiently to activate its microswitch. A 4-inch-deep stainless steel pan containing 3 inches of wood shavings was situated below the cage for feces and urine collection. These arrangements yield a homogeneous sound field, the point-to-point difference (at 4K cps) within the cage not exceeding 2 decibels. The animal enclosure with the door closed provides attenuation of 50 decibels for mid-range frequencies.

All electrical connections from the box interior were made via Nu-Way connectors to a bakelite panel mounted behind a Fiberglas block on the rear inner wall of the refrigerator

shell. A 30-connector Blue-Ribbon (Amphenol) plug related the peripheral unit by a cable to the control room.

The sound stimuli were produced by feeding the constant level output of a Heathkit signal generator through a fader amplifier.² The characteristics of this amplifier are such that a change in signal level may be effected without the production of transients audible to the human ear. From the fader amplifier the signal went to one of a bank of Daven fixed attenuators which reduced the signal to the appropriate level. The active attenuator was selected by a stepping relay triggered by a punched-tape programmer. The output from the attenuator was fed into four individual amplifiers, each of which was related to one of the tweeters in the animal enclosures.

Bar insertion and retraction, sequence and level of sound stimuli, and food reinforcement were programmed automatically by means of relay and timing circuits. Data were registered on Gerbrands cumulative recorders, Sodeco counters, and a Clary print-out counter. The programming and data registration equipment were located in a separate control room situated between the two experimental rooms.

The animals were reduced to 80% of their free-feeding weights over a period of about 3 weeks prior to the start of experimentation. The animals were maintained at an 80% weight value throughout the experiment. The base weight from which the 80% value was calculated was changed weekly in an effort to parallel increases in free-feeding weight exhibited by animals in this age range.

The first phase of the experiment was termed Discrimination Training I. When the 80% body-weight criterion had been met, the rats were randomly assigned to two groups of four and trained as follows:

Day 1—The animals were placed in the experimental enclosures in the presence of the sound intensity which was to serve as S^D in the subsequent discrimination training. Each was allowed to remain in the enclosure until 100 regular reinforcements had been collected for bar pressing.

Day 2–Day 47—Discrimination training sessions were carried out in which S^D and S^A were two sound intensities of a tone of 4K cps which differed from one another by 20 decibels. In the following, zero decibels is taken as 100 decibels above 0.0002 dyne per centimeter squared, measured from a rat's ear-view position. Other values are presented in terms of decibels of attenuation from the reference value. Group I was presented with an intensity of 10 decibels as S^D and 30 decibels as S^A , whereas Group II (their mirror image) had 30 decibels as S^D and 10 decibels as S^A .

The animals were run daily at the same hour.³ All four animals in each group were run simultaneously. Group I was run at 4:00 A.M. and Group II at 8:30 A.M. Sessions were 4 hours in length, 1 hour of these consisting of S^D . The S^D periods ranged from 1 to 3 minutes in length, whereas the S^A intervals ranged from 2 to 9 minutes. The order of alternation of lengths of S^D and S^A periods was a predetermined "random" order taken from the Gellerman series designed to avoid simple alternation sequences. The mean inter-

²Mr. W. A. Munson, Bell Telephone Laboratory, Murray Hill, New Jersey, made available the circuit design for the fader amplifier and generously assisted us in many ways in matters relating to design of the experimental chamber and the sound system.

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reinforcement interval within S^D was 1 minute. The program of reinforcement intervals was obtained from a randomized geometric progression. In certain instances an entire S^D period would pass without opportunity for reinforcement, or some intervals would have several reinforcements programmed.

The animals were run under these conditions until stable rate differences appeared between S^D and S^A conditions. One rat in Group I exhibited marked variability relative to the other animals. Data from this animal will not be discussed. In all other cases the ratio of S^A/S^D rates attained was between 0.10 and 0.01. Rate ratios were calculated omitting the first 30 minutes of each session in order to eliminate the more variable behavior evident at the start of each day's run.

In the latter part of the experiment, testing for generalization was carried out: this phase of the investigation was termed Discrimination Training II. It was run for 7 days. Under the new conditions, the 3 hours of the experimental session previously devoted to S^A were now subdivided such that eight S^A 's were presented (one of these being the original S^A), each one for a total of 24.5 minutes. The S^D employed in the first phase of training continued to appear for the same amount of time and in the same temporal positions within the session. The same VI schedule of reinforcement in S^D was continued as in Discrimination Training I. The stimuli presented to the two groups are shown diagrammatically in Fig. 2.

PLAN OF STIMULUS PRESENTATION

SOUND LEVELS IN DECIBELS ATTENUATION

Figure 2. Diagram of stimuli employed in discrimination training and generalization.

It will be noted that the S^D intensity for Group I serves as the S^A for Group II and vice versa. The new S^A 's appear at the extremes and intermediate between S^D and the original S^A .

RESULTS

For all of the data treatment, the total number of responses in S^D has been divided by 2.45 to correct for the larger proportion of session time devoted to S^D as compared with each S^A . Figure 3 presents a day-by-day plot of the mean data for the three animals in Group I, showing the course of generalization training. These functions represent the total number of responses per session (S^D responses corrected) as related to stimulus intensity. Figure 4 is a display of the means of the four animals from Group II. It may be noted that the abscissa has been laid out in terms of *increasing* attenuation from left to right for

Figure 3. Total responses per session as a function of intensity level. Each point on each curve represents the mean of the three Group I animals for a given session.

Group I, and of *decreasing* attenuation from left to right for Group II, so that S^D and S^A were maintained in the same positions on both abscissae.

It may be seen (Fig. 3 and 4) that the Day 1 generalization data for the two groups show similar trends. Group I animals produce response totals bearing an inverse relation to intensity. In other words, maximum rate occurs at the extreme of the continuum farthest displaced from S^A . This is comparable with an earlier finding by Hanson and may be partially attributable to generalization of extinction effects resulting from previous discrimination training. In terms of this analysis, rates higher than the S^D rates are obtained at a point displaced from S^D (and also even farther displaced from S^A) since the generalization

MEAN DATA GROUP II

Figure 4. Total responses per session as a function of intensity level. Each point on each curve represents the mean of the four Group II animals for a given session.

effects of extinction of the original S^A training may operate along the continuum as far as and beyond S^D

When the data for the Group II animals are partitioned in terms of consecutive *hours* of exposure to the generalization stimuli, all of the four animals show a fairly systematically decreasing function (from left to right) during at least 1 hour of the first session. All animals show a maximum response rate at the extreme left of the continuum at the intensity farthest displaced from S^A . Following Day 1, the two groups exhibit similar trends as the new discrimination between the old S^D and the eight S^A 's is developed. It is apparent from a comparison of the two groups (Day 2 forward) that the control exerted by the various intensities is systematically related to their position with regard to S^D and the original

S^A , rather than to their *absolute* intensity value. This confirms an observation previously made by us in a comparable auditory discrimination situation (Pierrel, 1958), and is similar to a more recent finding by Blough (1959) using pigeons and a visual intensity continuum. However, in his experiment the control was effected by a stimulus constantly present during training prior to the generalization sessions.

In the figures above, the rates obtained to the two intensities plotted to the left of S^D on the abscissa are of particular interest. As generalization training progresses, these rates tend to drop below the S^D rate. The intensity immediately adjacent to S^D frequently

Figure 5. Total responses per session as a function of intensity level. Each point on each curve represents the data for a single Group I animal for a given session.

RAT 6 GROUP II

Figure 6. Total responses per session as a function of intensity level. Each point on each curve represents the data for a single Group II animal for a given session.

yields a lower rate than does the intensity displaced by 10 decibels to the right of the S^D level. On the other hand, the two intensities to the right of S^A show no systematic deviation from the original S^A . The portion of the gradient between the S^D and the old S^A shows a continual decrease and is comparable with that obtained over a broader intensity range in the first study of this series.

A comparison was made of the rate ratios between S^D and S^A during the last week of Discrimination Training I and Discrimination Training II. This indicated that the introduction of the new S^A 's decreased the large rate difference previously apparent between these two intensity values. This discrimination improved with continued exposure to the several S^A 's, but, within the limits of this experiment, did not re-attain the level exhibited in Discrimination Training I.

A day-by-day record from a single animal in Group I is given in Fig. 5. The characteristics evidenced here are quite similar to those shown in the mean data. Considerable day-to-day variability is shown in the relative positions of S^D and the two intensity values

at the extreme left. When the maxima of the seven daily functions are examined, it is found that they appear at *any* of these three positions. Figure 6 represents one rat from Group II. In this figure as well as in Fig. 4 (mean data for Group II), there is again day-to-day variability in the relative rates which correspond to the three left-hand values. The variability in the position of the maxima suggest several curve forms. These are shown in stylized fashion in Fig. 7. The histograms on the right of the figure show frequency of occurrence of a given curve style as a function of the seven generalization days. This figure summarizes the individual daily curves for all rats in Groups I and II. There is a suggestion here of a rough sequence in the development of the multi- S^A -valued discrimination. The early phase

DISTRIBUTION OF CURVE FORMS

Figure 7. Classification of curve forms exhibited in the course of generalization testing. The histograms represent frequency of occurrence of the particular curve form in the course of seven days.

is characterized by a maximum at the extreme left, which with further training moves to the right, ultimately producing a function with S^D as its maximum. An essentially hyperbolic curve form is attained within the range between S^D and the right-hand end of the continuum.

SUMMARY AND CONCLUSIONS

Rats were trained on an auditory intensity discrimination until stable rate differences appeared between S^D and S^A . The intensity values employed as S^D and S^A for the two groups bore a mirror-image relation to one another. Following the initial discrimination training the animals were tested for generalization of the bar-press response to seven novel intensity values which were presented intermingled with the original S^D and S^A values. The following conclusions may be drawn from this study:

1. A concave gradient was obtained over the range between S^D and S^A throughout the seven days of generalization testing.
2. All animals, in both groups, exhibit a constantly decreasing function from left to right within the first day of generalization testing.
3. A maximum develops at the S^D intensity within the first few days of generalization sessions and becomes a stable feature of the gradient.
4. The introduction of new S^A 's produces a decrement in the original S^D - S^A discrimination. This discrimination generally improves with continued generalization testing, but not to the level previously attained.
5. Within the limits of this experiment, the form of the gradients obtained appear to be a function of the location of S^D and S^A along the stimulus continuum rather than of the *absolute* intensity magnitudes employed.

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