GENERALIZATION OF AUDITORY INTENSITY AS A FUNCTION OF AMOUNT OF DISCRIMINATION TRAINING¹

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Generalization gradients have been obtained both following reinforcement at a single stimulus value (Blough, 1959; Hanson, 1959) and following discrimination training (Hanson, 1957, 1959). When discrimination training precedes generalization test procedures, there appears to be a sharpening of the gradient (Hanson, 1959; Honig, Thomas, & Guttman, 1959) and a displacement of the response maximum along the stimulus continuum away from S^D in a direction opposite to S^A (Hanson, 1959; Pierrel & Sherman, 1960). This dependence of gradient form upon previous reinforcement conditions suggested the present experiment, which deals with the effects of varying amounts of discrimination training.

Without some specification of the relationship between the extent of discrimination training and the resultant form of the generalization gradient, the data in this area may reflect some unassessed interaction between training time and the independent variable in question. Previous studies have dealt with the problem of training time for each individual experiment by sampling generalization behavior at a point when some arbitrary criterion is met. The criteria used have been a training period of standard duration (Blough, 1959), attaining a previously specified response value (Thomas, Ost, & Thomas, 1960), or some combination of the two procedures (Hanson, 1959). Cumming and Schoenfeld (1960) have discussed certain problems which may occur when a stability criterion is established for behavior without an empirical foundation. They point to the inadequacy of basing such a criterion upon the behavior currently being measured in a given experiment. In order to resolve these difficulties, a "base-line" study might be performed for each experimental situation. This would establish the behavioral effects of varying the amount of training. The results of such a study allow us to formulate an "instability criterion" to be used in setting up pretraining periods in later investigations. Such data provide an estimate of ranges of variability to be expected at different points in training.

In this study, three periods of discrimination training were established. The periods selected were based on a previous study (Pierrel, 1958) in which rather marked changes in the discrimination behavior were noted at about these points in training.

METHOD

The subjects were 12 naive, male albino rats of the Sprague-Dawley strain, 90–110 days old at the start of experimentation. The apparatus used was the same as

that described in an earlier report (Pierrel & Sherman, 1960). Prior to experimentation, all animals were reduced to 80% of their free-feeding weights and thereafter maintained at these base-weight values. These values were adjusted weekly to parallel the normal growth curve as nearly as possible. The animals were randomly assigned to three groups of four, and were trained as follows:

Regular Reinforcement. On the first day of training, all animals received 100 regular reinforcements (The P. J. Noyes Company, 4 millimeters–45-milligram food pellets) for bar pressing. An auditory signal, which served as the S^D during subsequent discrimination training, was continuously present.

Discrimination Training I. Beginning on the second day, all animals were presented with the same two stimuli as S^D and S^A . The S^A stimulus was a tone of 4 k cps at 100 decibels above 0.0002 dyne per centimeter squared. This intensity (S^A) will hereafter be referred to as 0 decibels. Other intensities are specified in terms of the decibels *attenuation* from this reference value. The S^A intensity differed from the S^D training intensity by 40 decibels. The sessions were 4 hours in length, 3 hours of the 4 consisting of S^A . The S^D periods ranged from 1 to 3 minutes, whereas the S^A periods were from 2 to 9 minutes. The S^D and S^A periods alternated according to a predetermined "random" order taken from the Gellerman series designed to prevent double alternation sequences. The reinforcement program within S^D was a variable-interval schedule with a mean of 1 minute. The four animals were run simultaneously, and each group was run daily at the same hour. The three groups differed only in the length of time each was exposed to the Discrimination I conditions. These were carried out for 27 days for Group I, 13 days for Group II, and 6 days for Group III.

Discrimination Training II. Following the prescribed number of Discrimination I sessions, multi- S^A -valued discrimination training was begun. This phase of the experiment lasted 20 days for all animals. Under these conditions, during the 3 hours previously assigned to the single value of S^A , eight S^A intensities were presented (one being the original S^A), each one for a total of 22.5 minutes. The conditions of S^D presentation were unchanged from those of Discrimination Training I. That is, 1 hour of the session was still devoted to S^D , the duration and temporal position of S^D within the session was maintained as before, and the same VI reinforcement schedule was used.

RESULTS AND DISCUSSION

The S^A/S^D rate-ratio data for a single animal (Rat 4, Group I) during 27 days of simple discrimination train-

¹This study was conducted as a portion of a research program supported by Public Health Service Grant M-2554.

ing are presented in Fig. 1. These ratios were calculated omitting the first 30 minutes of each daily session in order to eliminate the high variability generally found at the beginning of a day's run. Prior to processing, the total number of responses in S^A was divided by three to correct for the larger proportion of session time devoted to S^A . Differential response rates in S^D and S^A characteristically develop with prolonged discrimination training. There is a rapid decrement in the size of the ratios during the first 5 or 6 days. The proportion of the total responding emitted in S^D continues to increase throughout the study. However, after the first week, the magnitude of the rate of decrease in the ratio and the rate of decline in day-to-day variability is relatively low.

It may be considered that in this study we have sampled generalization behavior at three points on a discrimination curve such as the one shown above. In Table 1, the performance of each animal in each group is shown at various stages in simple discrimination training. For all groups, it was possible to obtain an S^A/S^D ratio for Day 6. Ratios are presented for Day 13 for Groups I and II, as well as those for Day 27 for Group I. It may be noted that the ratios are of similar orders of magnitude for the various groups at comparable stages in training and might have been roughly predicted from Fig. 1.

For all of the data treatment which follows, the total number of responses in S^D has been multiplied by a constant to correct for the larger proportion of session time devoted to S^D as compared with each of the eight S^A 's in Discrimination Training II. Representative results from the initial 4 hours' exposure to the multi- S^A -valued discrimination situation are shown in Fig. 2. In this figure, as well as in a number of those to follow, data for a single animal from each group has been presented. In each case an attempt was made to select an animal which was fairly representative of the four animals in its group. The functions shown in Fig. 2 are an hour-by-hour plot of the total number of responses (S^D responses corrected) emitted at each stimulus intensity for a single animal from each group. Despite some inversions in the response totals between adjacent intensities, the curves exhibit a similar trend in that rate

Fig. 1. The S^A/S^D response ratios for a single Group I animal (Rat 4) during 27 days of simple discrimination training.

tends to decrease, moving along the continuum from S^D toward the original S^A intensity. The Group I animal yields the steepest function, while the Group III animal produces a nearly linear gradient. More responses at the original S^A intensity (0 decibels) appear in the records of animals with the least Discrimination I training. This is particularly apparent in Fig. 2, when a comparison is made between the S^A responding of the Group III animal and the S^A response totals for the Group I and Group II animals. There is no evidence of any systematic change in the shape of the gradients within this first 4-hour session for the Group II and III animals. The Group I animal develops a fairly smooth, concave curve form within this first session.

Figures 3, 4, and 5 present individual data for one animal in each group (same animal shown in Fig. 2) for the even-numbered days throughout generalization training. These functions represent the total number of responses per session (S^D responses corrected) as related to stimulus intensity. As noted also in Fig. 2, the

Table 1
Individual and Group Mean S^A/S^D Ratios Taken at Three Stages of Simple Discrimination Training I

Day 6			Day 13		Day 27
Group I	Group II	Group III	Group I	Group II	Group I
.129	.121	.095	.070	.063	.022
.308	.145	.103	.006	.057	.038
.108	.167	.136	.119	.073	.011
.085	.116	.199	.148	.040	.062
Mean .158	Mean .137	Mean .133	Mean .086	Mean .058	Mean .033

Fig. 2. Total number of responses as a function of intensity level. Each set of functions depicts a single animal from one group. Each single function represents 1 hour of the total session.

sharpness of the gradient increases with increased pre-generalization discrimination training. The Group I animals respond at a low rate in the presence of intensities at the S^A end of the stimulus continuum. The Group II animals maintain higher response rates at intensities approaching S^A , and the Group III animals exhibit the highest rates of the three groups at the right of the continuum. These functions show fewer departures from a smoothly decreasing gradient with increased Discrimination I training. There appears to be less day-to-day variability in the gradients of animals with longer discrimination training histories. The early change in the gradients of the Group I animal shown in Fig. 2 appears to forecast the rapid development and "shape" of the new discrimination. A mode of responding evolves, which is highly consistent, following the first week of generalization training.

As training continues in the multi- S^A -discrimination situation, the sharp drop in the gradients for the

Fig. 3. Total number of responses per session as a function of intensity level for a single Group I animal. Each curve represents a single session. A curve is presented for each even-numbered day throughout Discrimination Training II.

Group I animals is displaced farther to the left as low rates obtain at intensities successively closer to S^D . This trend toward a steeper gradient with increased generalization training is not evident in Fig. 4 and 5, although it was apparent in the data for some of the other Group II and Group III animals. The same trend is also seen in the mean data for all groups (Fig. 6). Figures 4 and 5 suggest that the less regular aspects of the gradients tend to disappear as Discrimination Training II is continued. The final curves approach a fairly smooth hyperbolic form. It may be noted that with extended generalization training, the day-to-day variability in curve form decreases for all animals in all groups. This is clearly shown in Fig. 4, where the gradients for the Group II animal on Days 2 and 4 come close to describing an envelope for the eight other curves representing the even-numbered days of Discrimination Training II. The curves for the last 3 days presented are nearly superimposed upon one another.

Figure 6 presents the mean response data for the four animals in each group at each intensity. This is plotted

GROUP II RAT 6

Fig. 4. Total number of responses per session as a function of intensity level for a single Group II animal. Each curve represents a single session. A curve is presented for each even-numbered day throughout Discrimination Training II.

in blocks of 5 days. The major trends evident in the individual curves of Fig. 3, 4, and 5 are also shown in these mean functions. At any stage in generalization training, the steepness and smoothness of the gradients appear to be directly related to the number of previous Discrimination I sessions. Continued exposure to the generalization situation produces similar effects upon all groups as the new discrimination develops.

Certain of the relations between the gradients for the different groups are most clearly apparent in Fig. 7.² In this figure, a group of functions, one representing the S^A/S^D ratios for each of the eight S^A 's, is presented at three stages in generalization training for each group of animals. Each point represents the mean S^A/S^D ratio for the four animals in a given group at a single S^A intensity during one session. At all stages in generalization training, there seems to be little difference between the responding of Group I and Group II animals in the presence of intensities at the S^A end of the stimulus con-

²We are indebted to W. W. Cumming for suggesting the data treatment shown in Fig. 7.

GROUP III RAT 5

Fig. 5. Total number of responses per session as a function of intensity level for a single Group III animal. Each curve represents a single session. A curve is presented for each even-numbered day throughout Discrimination Training II.

tinuum. It appears that by Day 20 of Discrimination II, the S^A/S^D ratios for these two groups are similar throughout the intensity range. It is not surprising that Groups I and II show more likeness than Groups II and III in view of the similar result shown during Discrimination I (Fig. 2). Since the major changes in simple discrimination responding occur within the first week, even larger differences in gradient form as a function of amount of Discrimination I training might have been obtained had generalization performance been sampled after only one or two sessions of Discrimination I training. The curves of Fig. 7 drop down with increased generalization training, indicating proportionally fewer responses in all S^A 's as the new multi- S^A -valued discrimination develops in each group. Initially, the gradients shown in the earlier figures become steeper, though little change appears in the size of the ratios shown in Fig. 7 after 10 days of the generalization procedures.

At most of the S^A intensities, it may be noted that the 6-day pretraining group (Group III) yields a higher

Fig. 6. Mean number of responses per session as a function of intensity level. Each point on each function represents the mean of a group of four animals taken across 5 consecutive days during Discrimination Training II.

ratio than does the 27-day pretraining group (Group I). This effect is most consistently shown in the Day 20 data. Graded responding within each group is apparent in the decreasing magnitude of ratios with increasing disparity from S^D .

SUMMARY AND CONCLUSIONS

Three groups of four rats each were trained on a simple auditory-intensity discrimination for 6, 13, or 27 days. Following these sessions, the bar-press response was sampled in the presence of seven new S^A 's, which were presented in a random order along with the old S^D and S^A . The new S^A 's fell in 5-decibel steps between the original S^D and S^A intensities. The following conclusions may be drawn from this experiment:

1. The relative rates of S^D and S^A responding exhibit the greatest change during the first 6 days of simple discrimination training.
2. Regardless of the amount of simple discrimination training, a concave gradient was obtained over the range between S^D and S^A . Response totals systematically decreased with increasing distance from S^D .
3. Animals with the most pregeneralization training produce the sharpest, smoothest gradients and exhibit the least day-to-day variability throughout.
4. Continued generalization training results in increasingly steep and orderly functions. The slope

Fig. 7. The S^A/S^D response ratios as related to the number of preliminary discrimination sessions. Ratio data is presented for Days 1, 10, and 20 of Discrimination Training II. A separate function is presented on each set of coordinates for each S^A intensity used. Each point on each curve represents the session mean for the four animals in a given group.

of these curves, however, is still related to the amount of prior discrimination training.

5. Within the first week or 10 days of exposure to the discrimination situation, rough asymptotes appear to be reached for the effects of both Discrimination I and Discrimination II training.

REFERENCES

- Blough, D. Generalization and preference on a stimulus intensity continuum. *J. exp. anal. Behav.*, 1959, **2**, 307-317.
- Cumming, W. W., and Schoenfeld, W. N. Behavior stability under extended exposure to a time-correlated reinforcement contingency. *J. exp. anal. Behav.*, 1960, **3**, 71-82.
- Hanson, H. Discrimination training effect on stimulus generalization gradient for spectral stimuli. *Science*, 1957, **125**, 888-889.
- Hanson, H. Effects of discrimination training on stimulus generalization. *J. exp. Psychol.*, 1959, **58**, 321-334.
- Honig, W. E., Thomas, D. R., and Guttman, N. Differential effects of specific extinction and discrimination training on the generalization gradient. *J. exp. Psychol.*, 1959, **58**, 145-152.
- Pierrel, R. A generalization gradient for auditory intensity in the rat. *J. exp. anal. Behav.*, 1958, **1**, 303-315.
- Pierrel, R., and Sherman, J. G. Generalization of auditory intensity following discrimination training. *J. exp. anal. Behav.*, 1960, **3**, 313-322.
- Thomas, D. R., Ost, J., and Thomas, D. Stimulus generalization as a function of the time between training and testing procedures. *J. exp. anal. Behav.*, 1960, **3**, 9-14.

Received October 21, 1960: