GENERALIZATION GRADIENTS FOLLOWING TWO-RESPONSE DISCRIMINATION TRAINING¹

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Stimulus generalization was investigated using institutionalized human retardates as subjects. A baseline was established in which two values along the stimulus dimension of auditory frequency differentially controlled responding on two bars. The insertion of the test probes disrupted the control established to the two S^Ds during training. The discrimination was recovered between each test probe and the resulting gradients were stable across 10 test sessions. These gradients, supported by other two-response generalization studies, indicate that this type of two-response discrimination training divides the stimulus dimension into two functional classes separated by a region of transition from one class to the other. Each stimulus value in a class, which extends from an S^D outward to the functional limit of the dimension, controls a similar proportion of the two responses as each other value in the class. All values on the stimulus dimension control identical response rates with an absence of the usual generalization decrement. The latency of the initial response, however, shows a bimodal gradient with the modes at the S^D values.

Traditionally, generalization has been looked upon as a phenomenon with fixed intrinsic properties. Consequently, most research in this area has been directed toward discovering these intrinsic properties (e.g., Mednick and Freedman, 1960). Recently, however, this search for the "true" generalization gradient has been replaced by an analysis of the parameters which produce and maintain generalization gradients of widely differing properties (e.g., Blough, 1961; Jenkins and Harrison, 1960; Peterson, 1962; Reynolds, 1961).

To investigate the generalization gradient across a wide range of values on the auditory frequency dimension following two-response discrimination training, the present study utilized (1) a complex training and testing procedure, which allowed repeated tests to be made with little decrement due to extinction. This allowed an extensive sampling of points along the stimulus dimension. (2) A multiple-

response chain positioned the subjects at a fixed point in the experimental room, allowing meaningful latency measures to be taken.

METHOD

Subjects

Male adolescent residents of the Rainier School, Buckley, Wash., an institution for the retarded, were used. All resided in the same hall and were among the more capable residents at the school.

Apparatus

The room was 10 ft square and 10 ft high. Two Lindsley manipulanda (hereafter referred to as "bars") were mounted 6 ft apart against one wall. Beside each was a tray and chute by which reinforcers were dispensed from the control room. On the wall above each bar was a translucent panel which could be illuminated by lights mounted behind it. Between these light panels was a one-way mirror through which S could be observed from the control room. In the center of the wall above the mirror an 8-in. speaker (Jensen model ST 461) was mounted in a small cabinet. The opposite wall was covered with a pleated curtain to absorb sound. Against the center of this wall, 6 ft from either bar, a chair faced the center of the room. The room

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was illuminated by a 200-w bulb in the center of the ceiling. Background noise was 35 db above .0002 dyne/cm².

Sound stimuli were produced by three signal generators (Knight model 83XY137) and fed through relays into the speaker. Two of the generators were set at fixed frequencies throughout the study (600 and 1900 cps) and the third was varied for the generalization tests. The output frequencies were checked periodically against line frequency with an oscilloscope. The output voltages were continuously monitored and adjusted using a vacuum-tube voltmeter (RCA model WV-77E). Voltage readings were initially correlated with and periodically checked against sound-pressure readings in the experimental room made with a sound-pressure meter (General Radio type 1551-A).

Stimuli and reinforcers were programmed automatically by means of relays, timers, stepping switches, and tape programmers. Reinforcers were dispensed by Gerbrands universal dispensers and responses were recorded on cumulative recorders and counters. Initial latencies were recorded automatically on a Standard timer. The signal generators and programming and recording apparatus were located in the control room next to the experimental room.

Procedure

The Ss were seen at varied times of the day, two to four times a week for up to eight months. Sessions were approximately 20 min at the start of training and were gradually increased to approximately 60 min by the end of the study.

In the early sessions, Ss were trained to pull the right bar in the presence of the 600 cps tone and the left bar in the presence of the 1900 cps tone. After a randomly variable time (either 15 or 30 sec) the tone ended and the room light dimmed. In the presence of this stimulus, Ss were trained to sit in the chair at the rear of the room. After a randomly variable time of sitting in the chair, the room light brightened and one of the tones was presented. The sequence of tone presentation was programmed according to a semi-random series. Bar-pulling was maintained with candy or tokens (which could be traded for pennies) and chair-sitting was maintained by the onset of the S^D for bar-pulling.

The schedule of reinforcement and the length of the S^D periods for bar-pulling were gradually adjusted so that Ss eventually were responding steadily to the appropriate bar during all S^D periods under the following conditions: 35% of the S^D periods were 30 sec in length with reinforcement programmed on a VR 30 throughout the period, 35% were 30 sec with reinforcement programmed on a VR 30 during the final 15 sec, 30% were 15 sec with no reinforcement programmed. This procedure was adopted to minimize extinction during testing and to minimize the discriminative function of the reinforcement. The length of the S^D periods was timed from the first response to the appropriate bar. Any "incorrect" responses (responses on the right bar during a 1900 cps tone or responses on the left bar during a 600 cps tone) reset the interval timer which started timing again when a "correct" response was made.

Concurrent with the adjustments in S^D length and the reinforcement schedule, the intensity of the S^D tones was increasingly varied between S^D periods until Ss were responding equally and accurately to S^D tones of the two frequencies (600 and 1900 cps) which varied in intensity between 50 db and 64 db. This procedure was deemed necessary in view of the literature on "subjective" intensity changes with frequency changes. It seemed preferable to handle this problem by establishing stimulus classes across the intensity dimension during training, rather than attempt to adjust the absolute intensity to keep subjective intensity constant during training and testing.

Finally, when S's rate and initial latencies had stabilized and incorrect responding had been essentially zero over several sessions under the final training conditions, generalization testing was begun.

During testing, the reinforcement schedule and S^D series was unchanged from the training conditions; where 15-sec non-reinforced S^D periods had been programmed during training, 15-sec "probes" of 12 tones of differing frequencies were now programmed. These tones ranged from 300 to 6000 cps in roughly logarithmic steps as follows: 300, 400, 500, 600, 900, 1200, 1500, 1900, 2600, 3500, 4600, 6000 (which includes the two S^D tones of 600 and 1900 cps). All test tones were separated by one to three 30-sec S^D periods with reinforcement

programmed either throughout or during the final 15 sec of each S^D period. Each test tone appeared equally often in the first and last half of the session and equally often after each of the two S^D s during testing.

After four sessions of testing, the session length was doubled and the range of test frequencies was extended to range from 160 to 12,000 cps in approximately logarithmic steps as follows: 160, 220, 300, 400, 500, 600, 900, 1200, 1500, 1900, 2600, 3500, 4600, 6000, 9000, 12,000. Additional frequencies were inserted between those test frequencies which appeared to control markedly different behavior. Two S s failed to respond to the 12,000 cps tone and for these, the upper end of the test range was reduced to 8000 cps in one case and 10,500 cps in the other. The test tones and the S^D tones were presented at 57 db during the generalization test sessions.

RESULTS

Effects of the Generalization Test Tones on the Initial Discrimination. The training and testing procedures were such that the only difference between the baseline sessions and the test sessions were the test tones themselves. The lengths of the tone periods and the distribution of reinforcements were determined by the same programmers during the test sessions as during the training sessions. Consequently, it was possible to assess the effects on the initial discrimination of the insertion of additional values of the stimulus dimension.

Figure 1 represents the discrimination in terms of cumulative incorrect responses. Each point represents one complete session. The test probes were inserted at the ratio of three probes per seven S^D s, beginning at the vertical line.

In general, the test probes disrupted the discrimination, but this disruption was transitory. Errors tended to occur to the first S^D following a test tone. As was the case during discrimination training, an S^D tone remained on until 30 sec after the first correct response, provided that no incorrect response had occurred consequently. Therefore, when an S made incorrect responses, the S^D remained on until he had switched to the appropriate bar and had responded correctly for 30 sec, receiving several reinforcers. This procedure was clearly adequate to recover the discrimination

Fig. 1. Cumulative incorrect responses in the presence of the two S^D s. Each point represents one session. Interposed generalization testing began at the vertical line.

baseline between test probes, for errors were never made during two S^D periods unseparated by a test probe.

Insertion of the test probes had no apparent systematic effect on response rate or initial latency to the S^D tones.

Generalized Stimulus Control. The top graph of Fig. 2 shows the mean reciprocal latency of each S for each sampled point on the stimulus dimension. The gradients of all four S s are similar, with the shortest latencies around the two S^D frequencies and maximum latencies at the extremes of the distribution and between the S^D s. A given frequency controlled latencies of a given range of magnitude regardless of which bar was pulled initially.

The middle graph of Fig. 2 shows the mean combined response rate on both bars of each S for each sampled frequency. There is no systematic change in rate across the dimension. The gradients of all four S s are essentially flat.

The bottom graph of Fig. 2 shows the proportion of total responses on the right bar. The proportion of responses on the left bar would be the exact complement of this gradient. The 600 cps frequency was the S^D and the 1900 cps was the S^A for responding on the right bar. All S s responded entirely on the right bar during the 15-sec probes of the 600 cps tone and entirely on the left bar during the 15-sec probes of the 1900 cps tone. Two S s also responded entirely on the right bar on all frequencies below 600 cps and entirely on the left bar on all frequencies above 1900 cps. The other two S s showed more variability, but responded predominantly on the right bar on the lower frequencies and on the left bar on

Fig. 2. The top graph shows the mean reciprocal latency of each *S* for each sampled frequency on the stimulus dimension. The middle graph shows the mean combined response rate of each *S* for each sampled frequency. The bottom graph shows the proportion of the total responses of each subject which were made on the right bar.

the higher frequencies. There is a systematic shift in response distribution between the two *SD* points except at 1500 cps, where three *Ss* show a reversal of their trend.

Stability of Individual Generalization Gradients. In Fig. 3 the data of R. D. have been divided into three blocks of test sessions to show the changes in the gradients during repeated testing. The stability of this *S's* behavior is representative of the stability of the other three *Ss*.

This *S* did not respond at all to the first presentation of the 12,000 cps test tone. The high end of the test range was consequently reduced to 10,500 cps. Test tones of 750, 1350, and 1700 cps were inserted midway in the test series.

Initial latencies showed no progressive changes during testing. They form bimodal gradients with the modes at the *SD* frequencies. Combined response rate decreased approximately 10% during testing. There are no systematic differences between frequencies, resulting in flat gradients.

Fig. 3. The performance of subject R.D. divided into three blocks of test sessions to show the effects of repeated testing.

The proportion of responses to the right bar decreased progressively during testing at all frequencies between the two *SDs* and also at the 500 cps frequency. The distribution of responses at most of the other points was stable, with higher frequencies controlling responding on the left bar and lower frequencies controlling responding on the right bar.

DISCUSSION

A recurrent observation in operant studies involving institutionalized retardates is that while response stability is easily attained, it frequently remains stable in the face of large changes in experimental variables (Ellis, Barnett and Pryer, 1960; Heid, 1963; Orlando and Bijou, 1960). Therefore, while it does not alter the reliability of these data, the subject variable necessitates a close examination of their generality, particularly with respect to the flat combined rate gradients and the equal proportions of the responses across many points.

Cross and Lane (1962) report a series of studies using normal human subjects, Lane and Curran (1963) report a study using blind retardates, and Honig and Day (1962) report a study using pigeons. In these studies the

subjects were trained to make one of two responses to each of two stimuli. After a short training period other stimuli were inserted to assess generalization.

The results of these studies closely resemble the comparable points of the present data (the area between and around the S^P s). These similarities with the data of other studies contribute to the generality of the present results. The equal combined response rate at all points along the dimension and the constant proportion of responses at the points beyond the S^P s differ markedly from more traditional studies and consequently might otherwise be suspected of being specific to these training procedures or the histories of these subjects.

The results of this study, in combination with the other two-response generalization studies discussed, may be incorporated into the following general statement:

At least some parameters of two-response discrimination training divide the stimulus dimension into two stimulus classes separated by a region of transition from one class to the other. These stimulus classes extend from each S^D frequency outward to what is probably the functional limit of the stimulus dimension. Each stimulus value in a class controls a similar proportion of the two responses as each other value in the class. In addition, all values on the stimulus dimension control identical over-all combined response rates (an absence of the usual generalization decrement). The latency of the initial response, however, does show a systematic change along the stimulus dimension, forming a bimodal gradient with peaks at the S^D values. As the present study and the other studies mentioned have involved complicated training and testing procedures, the identification of the specific parameters producing these results will require a systematic investigation of these procedures.

A major aspect of this study is the demonstration that the generalization testing affected the initial discrimination and that the discrimination baseline was adequately recovered and maintained by continuing differential reinforcement between each test probe. As most generalization studies do not incorporate these recovery procedures, the maintenance of the original discrimination may be a factor in the stability of the flat combined rate gradients and the undifferentiated responding at several points beyond each S^D observed in

the present study. (Sherman and Pierrel [1961], in a single-response study involving S^D - S^A training, obtained gradients characterized by equal response probabilities across several points around the S^D which changed with repeated testing into a peaked gradient.) Honig and Day similarly used a procedure of inserting test probes into a series of reinforced S^D presentations.

Latency appears to be a unitary dependent variable in this study. At those frequencies where initial responses were made to both bars at different times in the test series, the latencies to both bars were within the same range of values. Moreover, these latency gradients are markedly similar to the rate gradients obtained in studies where two points on a dimension were established as S^P s controlling the same response (Thomas and Williams, 1963; Kalish and Guttman, 1957).

It is tempting to assign to the latency gradient the status of the "true" gradient in this study and to discount the rate and proportion gradients as contaminated by the training and testing procedures. However, it would seem that all the gradients are "true" gradients; a comparison of these gradients only points to the lack of equivalence of different measures of behavior purported to be indicators of some hypothetical "general" response strength (cf. Gilbert, 1958). Where present, the variations in the rate and proportion gradients show almost no relationship to the changes in the latency gradient. The three dependent variables appear to be functionally independent. Whether they are controlled by at least some common variables remains an experimental question.

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