JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR VOLUME 9, NUMBER 3 MAY, 1966

DISCRIMINATION LEARNING AS A FUNCTION OF STIMULUS LOCATION ALONG AN AUDITORY INTENSITY CONTINUUM[1]

STEPHEN SADOWSKY[2]

BROWN UNIVERSITY

Eight groups of rats were trained on an auditory intensity discrimination in which the discriminative stimuli were separated by 10 decibels (db). Four pairs of stimuli were selected from different regions along a 60 — 100 db (SPL) intensity continuum. Counterpart groups were trained on each stimulus pair, with the relative intensity positions of the reinforced stimulus (S^D) and the non-reinforced stimulus (S^Δ) reversed for the two groups. Discrimination acquisition curves were compared to determine whether stimuli separated by equal logarithmic units were of comparable "difficulty", and to determine the relative effectiveness of an S^D serving as the more versus less intense member of a stimulus pair. It was concluded that: (1) When S^D is the more intense, auditory intensities of constant logarithmic separation are graded in "difficulty" along the intensity continuum; high intensity discriminative stimuli are most readily discriminated. When S^Δ is the more intense, this graded effect is not evident. (2) For a given continuum location, discrimination is inferior when S^Δ is the more intense. This effect is most pronounced at the high intensity end of the continuum and is chiefly attributable to differences in the rate of S^Δ responding.

Two-valued and multi-valued discrimination learning in the rat have been extensively investigated by Pierrel and her co-workers using an auditory intensity continuum (Pierrel, 1958; Pierrel and Sherman, 1960, 1962; Sherman, Hegge, and Pierrel, 1964). These studies have suggested a further examination of the effects of intensity *per se* upon the development of a two-valued discrimination. The present study investigates possible evidence of stimulus intensity dynamism and examines the rate of acquisition of differential responding when discriminative stimuli are selected from a broad range of auditory intensities.

Many investigators have used a logarithmic spacing of stimuli along a continuum on the assumption that equal log steps will yield the best approximation to equal j.n.d. steps. Since no j.n.d. function for auditory intensity in the rat is available, the present study investigates continuum location ("difficulty") effects by determining whether pairs of discriminative stimuli of equal logarithmic separation, located at different regions of the auditory intensity continuum, yield comparable rates of acquisition of differential responding.

Little support has been found for Hull's notion of stimulus intensity dynamism (1949). Blough (1959), using a non-differential generalization procedure, found no evidence for dynamism with pigeons responding to visual intensity. Hegge, Pierrel, Sherman, and Sadowsky, (1965) found no dynamism, suppression, or preference when rats were presented equal reinforcement over a 40 db range of auditory intensity. It was suggested that although dynamism was not demonstrated, it may be that a stimulus must be established as a discriminative stimulus for dynamism to be observed. Pierrel (1958), and Pierrel and Sherman (1960), found post-discrimination generalization gradients for animals reinforced at the higher intensity of a stimulus pair to be similar to those of animals reinforced at the lower intensity stimulus. However, they used considerably larger reinforced-non-reinforced ($S^D - S^\Delta$) differences than in the present study, and their

[1]This research was submitted in partial fulfillment of the requirements for the Master of Science degree in Psychology at Brown University. The research was carried out under the supervision of Dr. Rosemary Pierrel, and supported by Public Health Service grant HD-00928. Reprints may be obtained from the author, Dept. of Psychology, Brown University, Providence, Rhode Island 02912.

[2]The author would like to thank Dr. Rosemary Pierrel, Dr. J. Gilmour Sherman, and Mr. Frederick W. Hegge for their invaluable assistance in the preparation of this manuscript, and Mr. Scot Blue for his help in the care and running of the animals.

analyses were restricted to a multi-valued discrimination situation.

Hull (1952) stated that stimulus intensity dynamism was observable in a two-valued discrimination. He suggested that discrimination behavior would be facilitated when the S^D was the more intense of the discriminative stimuli. In his words:

> "When the simple discrimination of two stimulus intensities occurs, the difference between the intensities remaining constant, the process is more effective in terms of the net reaction potential ($s\dot{\bar{E}}_R$) yield when reinforcement is given to the more intense rather than to the less intense of the two discriminanda." (Theorem 17B, 1952)

Hull also predicted that discrimination behavior would be facilitated, the higher the absolute intensities of the discriminative stimuli:

> "When the simple discrimination of two stimulus intensities occurs, the difference between the intensities remaining constant, the effectiveness of the discriminatory process in net reaction potential ($s\dot{\bar{E}}_R$) yield increases as the intensities of the two discriminanda increase." (Theorem 17C, 1952)

In the present experiment, rates of discrimination development were compared for several groups of animals trained on discriminations in which the $S^D - S^\Delta$ intensity difference was constant. For each of four groups a 10 db difference was located at a different region of the auditory intensity continuum. By training four counterpart groups, with each of the stimulus pairs reversed, *i.e.*, the S^D value in the first experiment became the S^Δ value in the counterpart group, the effect of the relative position of S^D as the higher or lower intensity member of a stimulus pair (dynamism) was assessed. The "difficulty" of a discrimination due to the location of the stimuli on the continuum was evaluated in terms of the rate of acquisition and asymptotic level of discrimination behavior. A slower acquisition and lower final level attained was considered to represent the more difficult discrimination.

METHOD

The subjects were 32 male albino rats of the Sprague-Dawley strain, 90-110 days old at the start of experimentation. They were maintained at 80% of their mean free-feeding weights.

The animal was placed in an enclosure within a sound-shielded chamber. Each of four enclosures was equipped with a speaker, a retractable bar, a pellet dish and associated feeder, and a water bottle. Electrical connections to the control equipment in an adjacent room were made through the back of the chamber. Construction of the chambers provided a uniform sound field within the enclosure with point-to-point intensity differences not exceeding 2 db in the absence of sound input. The four animals in each group were run daily at the same hour.

The chambers, stimulus generating equipment, and automatic programming and recording equipment have been described in Pierrel and Sherman (1960). The stimuli were various intensities of a 4 Kcps tone. The reference intensity was 100 db re .0002 dynes/cm²; all stimuli are specified in terms of decibels attenuation from this value.

Four animals were randomly assigned to each of eight groups. The stimuli presented are shown schematically in Table 1. Groups I-IV (Exp I) were trained to discriminate intensities separated by 10 db, the four stimulus pairs spaced between 0 and 40 db attenuation. In addition, Groups I-IV all had S^D as the higher intensity of the two stimuli. Groups V-VIII (Exp II) were trained on the same stim-

Table 1
Plan of Stimulus Presentation
STIMULUS INTENSITY (db ATTENUATION)

Experiment	*0—10*	*10—20*	*20—30*	*30—40*
I	Group I S^D S^Δ	Group II S^D S^Δ	Group III S^D S^Δ	Group IV S^D S^Δ
II	Group V S^Δ S^D	Group VI S^Δ S^D	Group VII S^Δ S^D	Group VIII S^Δ S^D

ulus pairs as Groups I-IV, but with S^{Δ} as the higher intensity. Thus, the Exp II groups were the counterparts of those in Exp I, having the reversed $S^D - S^{\Delta}$ positions.

Bar-training. Each animal remained in the experimental enclosure until it had collected 100 reinforcements (4 mm-45 mg Noyes pellets) for bar pressing on a 10-sec fixed-interval schedule of reinforcement. The stimulus intensity that was to be S^D was present at all times during bar-training.

Discrimination training. Animals were trained for 21 days in daily sessions lasting 4 hr and 12 min. S^D and S^{Δ} presentations alternated throughout. The S^D intensity was presented in intervals ranging from 1-3 min and was followed by an S^{Δ} period of either 4 or 8 min. In addition, 0.2-sec periods of silence were interpolated between intensity changes and at the mid-point of each S^{Δ} interval. For a given cycle, the S^D presentations totalled 15 min, the S^{Δ} intervals 48 min, the cycle being presented four times during a session. Reinforcements during S^D were programmed on a 1-min variable-interval schedule. The inter-reinforcement intervals were derived by randomizing the terms of a geometric progression.

RESULTS AND DISCUSSION

Discrimination indices (D.I.) were calculated by dividing the number of responses in S^D by the S^D responses plus the corrected number of S^{Δ} responses emitted during a session. The corrected number of S^{Δ} responses was obtained by multiplying S^{Δ} responses by 0.31 to equate for the disproportionate exposure to S^{Δ}. This index represents the percent of corrected responses emitted in the presence of S^D:

$$D.I. = \frac{R^{S^D}}{R^{S^D} + 0.31\, R^{S^{\Delta}}}$$

Figure 1 shows acquisition functions for the four groups in Exp I. The data from one animal in Group III are not included, since its high variability and low D.I.'s differed markedly from the other 31 animals. The overall mean acquisition function resembles a negatively accelerated positive growth function. The function for Group I exhibits the most rapid acceleration toward the highest asymptote of the four groups. There is little difference between Groups II and III; these curves often overlap one another and lie between those for Groups I and IV.

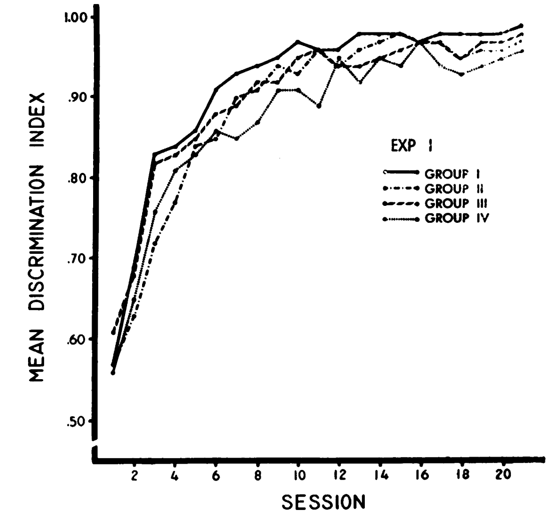

Fig. 1. Mean discrimination acquisition functions for those groups having S^D as the more intense of the discriminative stimuli (Groups I-IV). Each point represents the mean discrimination index of four animals (for Group III, N=3) plotted as a function of the 21 training sessions.

Figure 2 represents the mean acquisition curves for the four groups in Exp II. Aside from the somewhat slower acceleration of Group VI, there are no systematic differences among the four groups either during the initial rise of the functions, or near asymptote.

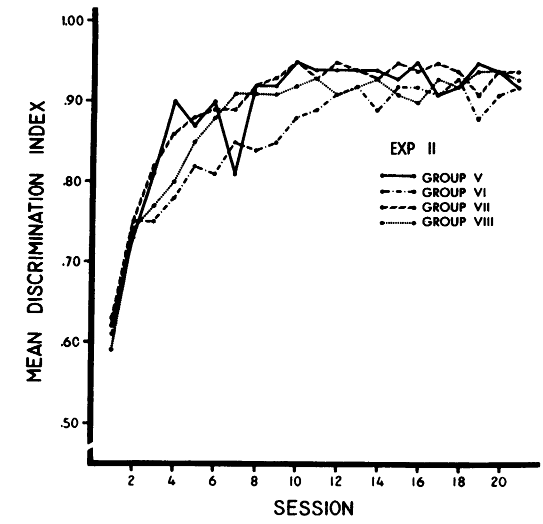

Fig. 2. Mean discrimination acquisition functions for those groups having S^{Δ} as the more intense of the discriminative stimuli (Groups V-VIII). Each point represents the mean discrimination index of four animals plotted as a function of the 21 training sessions.

To show the nature of the individual performances and the variability these contributed to the group data, single animal D.I. curves are presented for Groups I and V in Fig. 3.

Comparing the group mean curves for Exp I and Exp II, it is apparent that if S^D is the more intense of the discriminative stimuli (Exp I), the groups are roughly ordered as a function of their location on the intensity continuum. When the discriminative stimuli are located at the more intense end of the continuum, differential responding is superior to that observed when they are at lower intensity. However, when S^Δ is the more intense (Exp II), there is no differential difficulty effect over the range of intensities studied.

If the measure of differential responding, or discrimination index used in this study, is assumed to be directly related to "net reaction potential yield", and a higher D.I. to indicate Hull's "more effective process", then these findings would appear to lend partial support to Theorem 17C. When S^D is the more intense of the two stimuli, discrimination acquisition can be considered more "effective" the higher the intensities of the discriminative stimuli. Although Theorem 17C makes no distinction between the high S^D and high S^Δ conditions, Hull's prediction is not confirmed by the present data when S^Δ is the more intense stimulus.

Figure 4 represents the group means for each of the four stimulus pairs in Exp I and Exp II. The curves for the Exp II groups (more intense S^Δ) approach a lower asymptote than those for the Exp I groups, with the most marked differences appearing at the high intensity end of the continuum.

This finding supports Hull's prediction of Theorem 17B that discrimination acquisition will be more "effective" when the more intense stimulus is the reinforced stimulus, and also suggests that the magnitude of the effect is dependent on the location of the stimuli on the continuum.

The differences among the various conditions are most pronounced as asymptote is approached, suggesting that these effects are related to the level of discriminative control attained by the stimuli. This is in accord with the suggestion made by Hegge, *et al.* (1965) that a stimulus must be established as an S^D to observe intensity effects.

A Lindquist Type III analysis of variance (Lindquist, 1953) confirms the differences discussed with reference to Fig. 1-4. This analysis partitions the total sum of squares into variance components attributable to continuum location, S^D position, training sessions effect, within and between subjects variance, residual errors, and the main effect interactions. Table 2 presents the summary data for the analysis of variance. Significant differences were demonstrated among the various continuum locations, when the higher versus the lower intensity of S^D in the stimulus pair was considered,

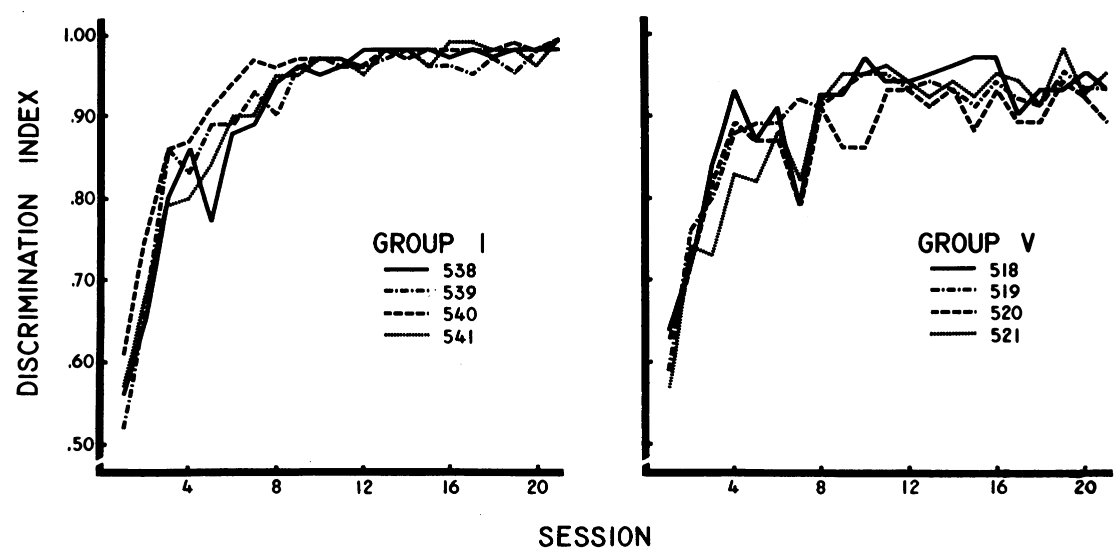

Fig. 3. Individual discrimination acquisition curves for counterpart Groups I and V (0-10 db). Discrimination indices are plotted as a function of training sessions.

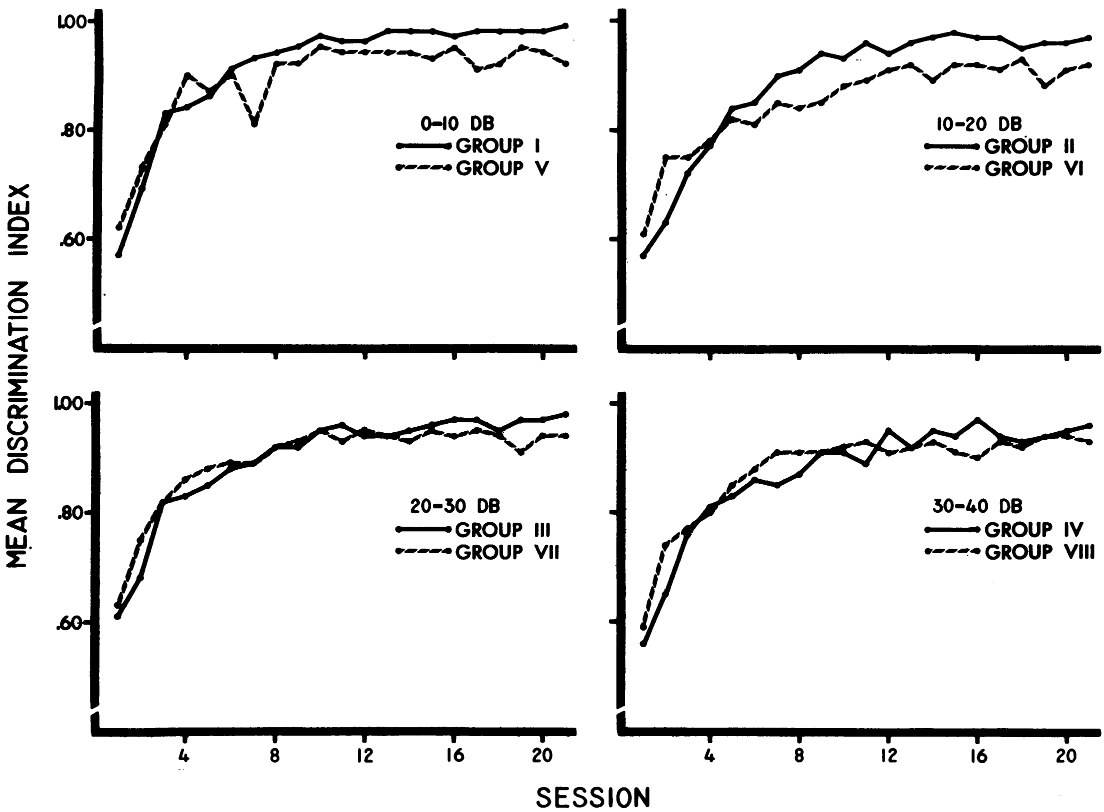

Fig. 4. Mean discrimination acquisition curves comparing the counterpart groups in Exp I and Exp II at each of the four continuum locations. Each curve represents the mean of four animals (for Group III, N=3) plotted as a function of the 21 training sessions.

and when the discrimination indices were examined as a function of training sessions. In the course of another investigation, Groups I, IV, V, and VIII were systematically replicated. The results of these replications are in line with the differences reported here. Thus, although the differences in Fig. 1-4 are small, they are statistically significant and experimentally reproducible.

Hull's theory predicts that stimulus intensity dynamism will facilitate responding in the presence of the more intense stimulus. When

Table 2

Analysis of Variance Summary Data

Source of Variance	*S.S.*	*df*	*M.S.*	*F-Ratio*	*Significance Level*
Between Subjects	1.4820	30	0.0494		
Continuum Location	0.3623	3	0.1207	3.7138	0.05
S^D Position	0.2400	1	0.2400	7.3846	0.025
Cont. Loc. X S^D Pos.	0.1322	3	0.0440	1.3538	0.50
Error (between)	0.7475	23	0.0325		
Within Subjects	25.7215	620	0.0414		
Sessions	23.0454	20	1.1522	338.8823	0.001
Sessions X Cont. Loc.	0.2861	60	0.0047	1.3823	0.10
Sessions X S^D Pos.	0.5024	20	0.0251	7.3823	0.001
Sess. X Cont. Loc. X S^D Pos.	0.2854	60	0.0047	1.3823	0.10
Error (within)	1.6023	460	0.0034		
Total	27.2035	650	0.0418		

S^D is the more intense member of a stimulus pair, the difference between S^D and S^Δ responding should be augmented, while a more intense S^Δ should attenuate this difference. These predictions suggested the examination of S^D and S^Δ responding shown in Fig. 5. The scale used on the S^Δ ordinate is one-fourth that of the S^D ordinate.

Figure 5 indicates no systematic differences in S^D responding as a function of continuum location for either Exp I or Exp II. In addition, there are no appreciable differences in S^D responding between the counterpart groups for two of the four stimulus pairs (B and D). In those instances where there is a difference in S^D responding (A and C), the differences are in a direction opposite to that predicted by Hull's theory.

The characteristics of the discrimination index used in this study are such that the D.I. is relatively less affected by changes in S^D responding when the rate in S^Δ is low in contrast to that in S^D. Thus, the differences in the discrimination acquisition functions are largely attributable to the differences in S^Δ responding in the two experiments.

The decreases in the S^Δ curves closely parallel the increases in the mean D.I. curves for Exp I and II. The S^Δ rates for those groups having S^D as the more intense of the discriminative stimuli (Exp I) vary as an inverse function of continuum location. Group IV emits more S^Δ responses than Group I. As S^D responding does not vary as a direct function of stimulus intensity, the differences in the discrimination acquisition functions for Exp I cannot be attributed to stimulus intensity dynamism as postulated in Hull's Theorem 17C. The increase in the difficulty of a discrimination, as shown by the increase in S^Δ re-

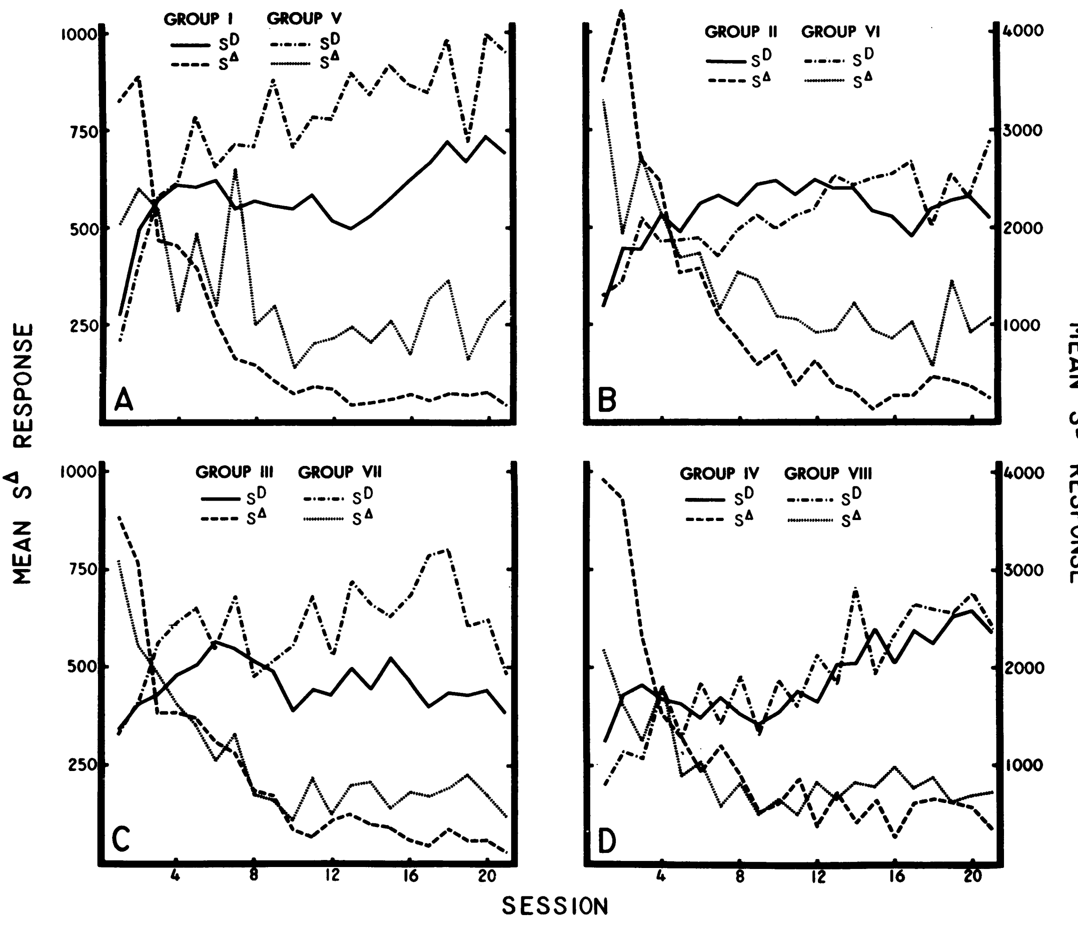

Fig. 5 Mean S^D and S^Δ responses per session for the counterpart groups in Exp I and Exp II at each of the four continuum locations.

sponding at the less intense portion of the continuum, might be attributable to differences in discriminability of the high *vs.* low intensity stimuli, although direct evidence for this cannot be obtained from the present study.

When S^{Δ} is the more intense of the discriminative stimuli (Exp II), S^{Δ} responding is maintained at a considerably higher level than in Exp I. In addition, there are no systematic differences between the groups such as those evidenced in Exp I. The relatively constant level of S^{Δ} responding in Exp II, coupled with the increases in S^{Δ} responding at the lower intensity stimuli in Exp I, account for the graded differences in the discrimination acquisition functions for the counterpart groups in Fig. 4.

Although the present study indicates no facilitation of S^{D} response rate when S^{D} is the more intense of the discriminative stimuli, it does provide evidence for the facilitation of S^{Δ} response rate when S^{Δ} is the more intense of the discriminative stimuli. Hull's prediction concerning the effects of the relative position of S^{D} and S^{Δ} (Theorem 17B) is therefore confirmed only when S^{Δ} is the more intense. It is important to note that the dynamism here observed does not facilitate discrimination acquisition, but rather maintains discriminative behavior at a lower overall level.

No systematic differences appear between those groups having S^{Δ} as the more intense stimulus (see Fig. 2), though it is possible that the location of the stimuli on the continuum produces a graded effect similar to that found in Exp I (Fig. 1). If such an effect exists, it would necessitate an interaction of roughly equal but opposite magnitude between an increase in S^{Δ} responding produced by higher intensities (dynamism) and the decrease-in-difficulty-effect attributable to continuum location. Such an interaction would account for the lack of systematic differences among the groups in Exp II.

REFERENCES

Blough, D. S. Generalization and preference on a stimulus-intensity continuum. *J. exp. Anal., Behav.*, 1959, **2**, 307-313.

Hegge, F. W., Pierrel, R., Sherman, J. G., and Sadowsky, S. Non-differential conditioning and extinction of operant responding across a sound intensity continuum. *Psychon. Sci.*, 1965, **2**, 11-12.

Hull, C. L. Stimulus intensity dynamism (V) and stimulus generalization. *Psychol. Rev.*, 1949, **56**, 67-76.

Hull, C. L. *A Behavior System*. New Haven: Yale University Press, 1952.

Lindquist, E. F. *Design and Analysis of Experiments in Psychology and Education*. Boston: Houghton Mifflin, 1953.

Pierrel, R. A generalization gradient for auditory intensity in the rat. *J. exp. Anal. Behav.*, 1958, **1**, 303-313.

Pierrel, R. and Sherman, J. G. Generalization of auditory intensity following discrimination training. *J. exp. Anal. Behav.*, 1960, **3**, 313-322.

Pierrel, R. and Sherman, J. G. Generalization and discrimination as a function of the S^{D} — S^{Δ} difference. *J. exp. Anal. Behav.*, 1962, **5**, 67-71.

Sherman, J. G., Hegge, F. W., and Pierrel, R. Discrimination formation as related to the amount of S^{Δ} training. *Psychon. Sci.*, 1964, **1**, 43-44.

Received October 14, 1964