

CONCURRENT ASSESSMENT OF SCHEDULE  
AND INTENSITY CONTROL ACROSS  
SUCCESSIVE DISCRIMINATIONS<sup>1</sup>

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Two chinchillas were trained on a series of two-valued auditory intensity discriminations. Lever presses were reinforced when no tone was present and not reinforced in the presence of a four-kiloHertz tone. The intensity of the nonreinforced tone was successively decreased, increasing the difficulty of the discrimination, until differential responding resembled that on a mixed schedule (no-tone-no-tone). Response data were partitioned in such a way as to provide a continuing assessment of the relative amounts of control exerted by the reinforcement schedule and the sound intensity, respectively. Control by reinforcement density was a direct function of discrimination difficulty, whereas the control exerted by intensity was inversely related to difficulty. For these chinchillas, the absolute threshold value obtained at four kiloHertz was about two decibels referenced to 20 microNewtons per meter squared.

In operant discrimination studies employing a multiple schedule, it is usually not possible to parcel out the relative amounts of control exerted by the imposed exteroceptive stimuli and that of the reinforcement schedule, *per se*. For example, in an auditory discrimination experiment, S<sup>D</sup> might be a high-intensity tone with reinforcement scheduled in its presence, while S<sup>A</sup> is a low-intensity tone associated with extinction. Given that clear differential responding is established in such a situation, it is impossible to separate the relative amounts of control over this responding by the differences in sound intensity and those associated with reinforcement, respectively. In this connection, Jenkins (1965) argued that any effects produced by the discriminative stimuli in a multiple schedule are seriously confounded with those produced by the reinforcement schedule. On the one hand, though, it has been demonstrated that the occurrence of reinforcement has relatively little effect upon local response rates (Pierrel and Blue, 1967), at least where the reinforced tone is located at the high end

of the intensity continuum. On the other hand, Sadowsky (1969) showed that the alternation of a variable-interval schedule and extinction within a mixed schedule can produce high and stable levels of differential responding. In view of the facts that schedule effects are not marked in a readily acquired discrimination, but that clear differential responding is obtained in an "impossible" discrimination (the absence of multiple schedule-imposed stimulus changes), it is possible that the degree of schedule control may be related to the level of "difficulty" of the discriminanda presented. That is, reinforcement density cues may assume increasing importance as the salience of the multiple-schedule stimuli decreases.

Logically, the relative amount of control exerted over differential responding by differences in reinforcement availability and differences in discriminative stimuli can be assessed by means of a three-ply schedule of stimulus and reinforcement conditions. Such a schedule has two types of S<sup>D</sup> intervals: half have no reinforcement availability, and thus differ from the remaining S<sup>D</sup> periods only in reinforcement availability. Typical S<sup>A</sup> periods are also employed, and these differ from the nonreinforced S<sup>D</sup> periods in discriminative stimuli, but not reinforcement availability. The present study used the three-ply schedule outlined above to determine the contribution to differential responding of discriminative stimulus differences in the absence of differences in reinforcement

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availability, and of differences in reinforcement availability in the absence of discriminative stimulus differences across a series of two-valued auditory intensity discriminations of varying difficulty.

## METHOD

### *Subjects*

Two male Chinchilla *Laniger*, bred in the Brown Laboratory, and approximately 510 days of age at the start of experimentation, were used. The animals were reduced to 75% of their free-feeding weights and maintained at this level throughout the study. They were fed a combination of Big Red Rabbit pellets in their home cages, and the food reinforcers earned during experimental sessions (P. J. Noyes, 4 mm 45 mg alfalfa pellets). Water was continuously available in both the experimental and living cages.

### *Apparatus*

The two experimental enclosures were similarly constructed. These were shock-mounted 12.8-ft<sup>3</sup> (504.3-cm<sup>3</sup>) refrigerator shells, lined on all interior surfaces with 1.8 in. (4.5 cm) of Owens-Corning NoiseStop Fiberglas board covered with Fiberglas cloth. The floor level was raised with styrofoam board blocks and a 1.8-in. (4.5-cm) partition inserted to divide the area into experimental and equipment sections. The equipment section housed a pellet dispenser (Davis, Model PD 104) and a custom built motor-driven retractable lever. A slot in the partition accommodated the tube from the feeder and the lever. The experimental section measured 13 in. deep by 17 in. wide by 29 in. high (33.0 by 43.2 by 73.7 cm). The experimental enclosure was constructed of stainless steel rods 0.5 in. (1.27 cm) apart, mounted horizontally in a narrow Lucite frame. The enclosure dimensions were 8.0 in. wide, 5.8 in. high, and 5.0 in. deep (20.3 by 14.6 by 12.7 cm). The lever was calibrated to operate a microswitch upon application of force of 0.027 N. A stainless-steel pan containing a 2-in. depth (5.1 cm) of Absorb-Dri animal bedding was situated below the cage for feces and urine collection. Centered 7.5 in. (19.1 cm) above the cage was a shock-mounted Janszen Electrostatic speaker (Model 65). A sound-silenced ventilating unit (Custom made by Industrial Acoustics Co.) provided a complete change of air in the boxes

every 3 min through two apertures in the rear of the chamber. These arrangements provided a uniform sound field within the acoustically transparent animal enclosure. All sound levels were specified in terms of a reference level of 20  $\mu\text{N}/\text{M}^2$ . When a 4-kHz tone was present at 90 dB, point-to-point differences within the enclosure did not exceed 2 dB. With the chamber door closed and with no imposed sound input, the background level of midrange frequency noise was about 30 dB. Ambient sound levels were measured with a General Radio Sound Level Meter (Model 1151), set to its A scale. Imposed sound-level calibrations were carried out using a Bruel and Kjaer 0.25 in. condenser microphone (Type 4136) and a Bruel and Kjaer Microphone Amplifier (Type 2604), set to its root mean square, linear 10 to 200,000 scale.

Sound generating, scheduling, and response-recording equipment were situated in an adjacent room. The sound stimuli were pulsed (1.6 sec on, 0.4 sec off) 4-kHz tones of fixed intensity. The tones were produced by a Wavetek Function Generator (Model 111), the output of which was fed to a Scientific Prototype Audio Switch (Model 4042-J). The audio switch permitted the signal to be reduced to zero amplitude within 50 msec, thus eliminating switching transients. The audio switch output was fed to a custom-built amplifier (Scientific Prototype) before passing to the attenuation panel. Any one of a series of Daven fixed attenuators (Type T-691) could be selected by a stepping switch triggered by a Gerbrands punched tape programmer. The output of the attenuation panel was led to a Bruel and Kjaer Band Pass Filter (Type 1612) set to  $\frac{1}{3}$  octave around 4 kHz, and from there distributed to two final-stage amplifiers (custom built, Scientific Prototype) connected to the speakers. All changes in sound-intensity levels occurred during the "off" period of the stimulus to avoid transmission of switching transients. Bar insertion at the start of the session and retraction at end of session, sound stimuli, and food reinforcement were scheduled by means of relay and timing circuits. Data were recorded on Gerbrands Cumulative Recorders and Sodeco Counters.

### *Procedure*

*Bar training (Days 1 and 2).* Each animal was placed in the experimental enclosure in

the absence of any imposed sound level and the response lever extended into the enclosure. Reinforcement followed the first response made after each 10-sec interval (FI 10-sec). This schedule was in effect until the chinchilla had collected 50 reinforcers for lever-pressing, whereupon the schedule was changed so that reinforcement would follow responses occurring after variable time periods averaging 1 min (VI 1-min). The animal collected an additional 75 pellets on the VI 1-min schedule. On Day 2, the VI 1-min schedule was again in effect until the animal had collected 100 pellets. By this time, consistent bar pressing had been established.

*Initial discrimination training (30 days).* The animals were studied daily at the same time for an 8-hr session and returned to their living cages between sessions. They were exposed to a multiple schedule composed of three types of intervals in order to parcel out the relative amounts of control of responding by the sound-level cue ( $S^D - S^A$  difference) and those cues associated with the schedule of reinforcement. The interval types were: (1)  $S^A$  intervals—an auditory tone of 4 kHz at 50 dB and no reinforcement availability; (2)  $S^D_R$  intervals—no tone and reinforcement scheduled on VI 30-sec; (3)  $S^D_N$ —no tone and no reinforcement. The three types of interval were presented in a predetermined counterbalanced order throughout the session with 75%, 12.5%, and 12.5% of the total time devoted to  $S^A$ ,  $S^D_R$ ,

and  $S^D_N$  intervals, respectively. The range of  $S^A$  interval lengths was 3 to 9 min, with a mean of 386 sec. For each type of  $S^D$  interval, lengths ranged between 1 and 3 min with a mean of 150 sec. The distribution of interval lengths was identical for the two  $S^D$  classes. The order of succession of interval lengths for  $S^D$  and  $S^A$  was taken from a Gellerman Series designed to avoid double alternation sequences. The VI 30-sec reinforcement schedule was generated according to the procedure described by Flesher and Hoffman (1962). Under this schedule, the probability of reinforcement is approximately constant when time since the last reinforcement is considered.

*Discrimination training with successively decreasing  $S^A$  intensities.* The conditions in this phase were the same as those that obtained in the initial discrimination training, except for the intensity of the  $S^A$  tone. The  $S^A$  intensities employed were: 30, 15, 10, 5, 3, 1, 0, and -0.5 dB.

*Mixed-schedule responding (15 days).* With the exception that  $S^A$  as well as  $S^D$  was no tone, all conditions in this phase and its replication were the same as for discrimination training.

*Recovery of previously trained discriminations.* The animals were studied again under the same discrimination conditions used previously at each of the following intensities: 50, 10, 5, and -0.5 dB. The sequence of the various phases and their duration in sessions are given in Table 1.

Table 1

Sequence and durations of training successive discriminations and a mixed schedule.

Phase	$S^A$ Intensity (dB)	Duration (Sessions)
1	50	30
2	30	12
3	10	12
4	15	10
5	10	10
6	5	10
7	no-tone (Mixed Schedule)	15
8	5	10
9	3	10
10	1	7
11	0	10
12	-0.5	10
13	no-tone (Mixed Schedule)	15
14	-0.5	10
15	50	15

## RESULTS

*Data Analysis*

As indicated above, three types of intervals comprised the multiple schedule:

- $S^D_R$ —no tone, VI 30-sec reinforcement;
- $S^D_N$ —no tone, no reinforcement;
- $S^A$  -4-kHz tone, no reinforcement.

Response rates occurring in these three intervals were compared using the following three Discrimination Indices (DIs):

$$DI_R = \frac{S^D_R}{S^D_R + S^A};$$

$$DI_N = \frac{S^D_N}{S^D_N + S^A};$$

$$DI_M = \frac{S^D_R}{S^D_R + S^D_N}.$$

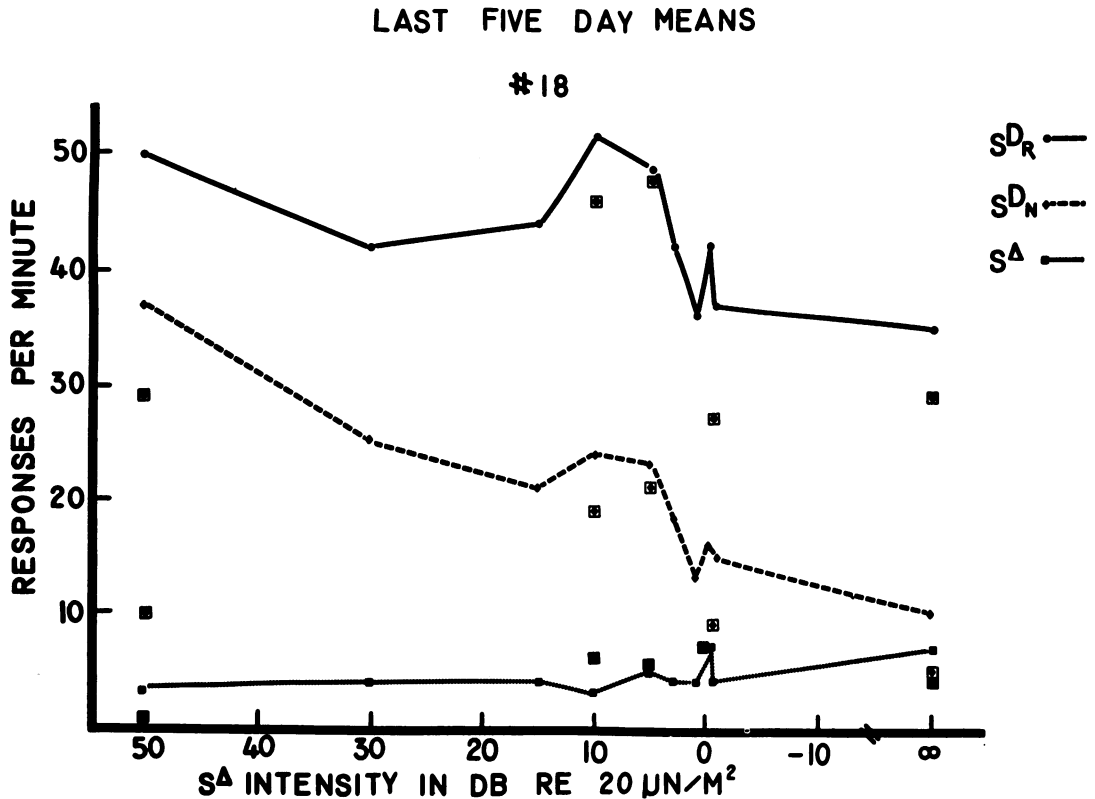


Fig. 1. Mean responses per minute as a function of  $S^A$  intensity across the last five 8-hr sessions of discrimination training for Chinchilla 18. Replication values have been enclosed.

$DI_R$  compares response rates in reinforced  $S^D$  intervals with response rates in  $S^A$  intervals. Since these intervals differ in both discriminative and reinforcing stimuli, this index measures the control exerted over differential responding by *both* discriminative and reinforcing stimuli.  $DI_N$  compares response rates in  $S^D$  periods without reinforcement ( $S^{D_N}$ ) and  $S^A$  intervals. Since  $S^{D_N}$  and  $S^A$  periods differ in discriminative stimuli but not in reinforcing stimuli, this index measures the control exerted over differential responding by discriminative stimuli in the absence of differences in reinforcing stimuli.  $DI_M$  compares response rates in  $S^{D_R}$  and  $S^{D_N}$  intervals.  $S^{D_R}$  and  $S^{D_N}$  intervals differ in reinforcing stimuli but not discriminative stimuli, so that this index measures the control exerted over differential responding by reinforcing stimuli in the absence of discriminative stimulus differences. If there are no differences in response rates between the two intervals compared in each  $DI$ , the index would have a value of 0.500. However, if responses occur exclusively during the interval

represented in the numerator of each equation, the index would have a value of 1.000.

Figures 1 and 2 show the mean responses per minute across the last five days of training at each  $S^A$  intensity for Subjects 18 and 35. With the exception of several inversions in the range between 10 and 0 dB, rate in both  $S^{D_R}$  and  $S^{D_N}$  periods declines with decreases in  $S^A$  intensity. However, response rate during  $S^A$  is inversely proportional to  $S^A$  intensity. For both chinchillas, the rates in the replication of 50 dB are markedly lower than those in the initial exposure, and in all cases for Subject 18, the replication rate values are lower than previously.

Figures 3 and 4 show the mean  $DI$ s for each chinchilla for the last five days of training at each  $S^A$  intensity. Both  $DI_R$  and  $DI_N$  tend to decrease as the  $S^A$  intensity decreases, while  $DI_M$  increases. Moreover,  $DI_N$  tends to decrease more rapidly than does  $DI_R$ . The pattern of changes evident in these three indices indicates that as the  $S^A$  intensity decreases, control of differential responding by discriminative stimuli ( $DI_N$ ) is decreasing, while control by the rein-

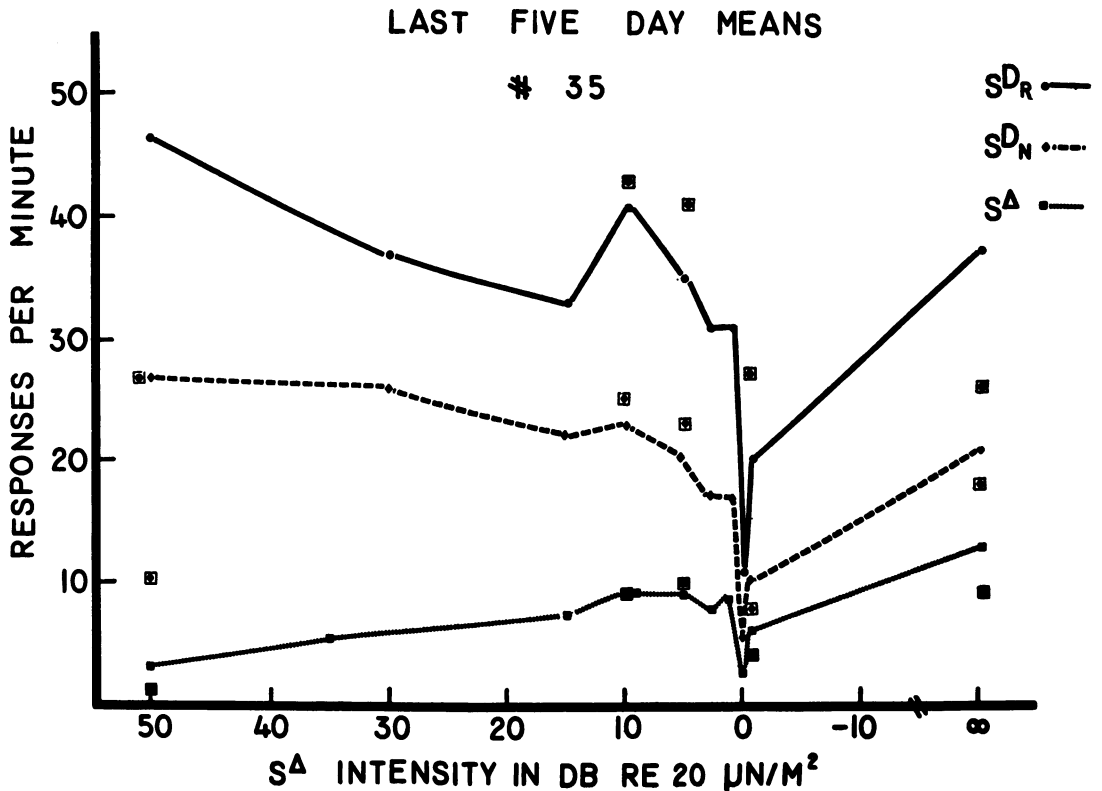


Fig. 2. Mean responses per minute as a function of  $S^A$  intensity across the last five 8-hr sessions of discrimination training for Chinchilla 35. Replication values have been enclosed.

forcing stimuli ( $DI_M$ ) is increasing.  $DI_R$  decreases less rapidly than does  $DI_N$  because  $DI_R$  measures the joint action of these two kinds of stimuli.

The points representing the replications at five  $S^A$  intensities show fairly good recoverability of the original  $DI$  values. The major exceptions to this are the  $DI_N$  and  $DI_M$  replication points at 50 dB. For both animals,  $DI_M$  is considerably higher on the second exposure than on the first, and  $DI_N$  is somewhat lower in the replication. However, Wilcoxon signed ranks tests (Bradley, 1968), indicated no significant differences between original and replication data points across  $S^A$  intensity for any of the three  $DI$ s of either chinchilla.

As indicated in Table 1, a nearly descending order of  $S^A$  intensity magnitude was employed in this study. It is evident from Figures 1 and 2 that replication rate values were frequently lower than those obtained originally. The decline in rates might be attributable, at least in part, to the amount of exposure to discrimination training, quite independently of the  $S^A$

values employed. In fact, the rank order correlation between phase sequence and  $SD_R$  rate was 0.81 for Subject 35 and 0.83 for Subject 18. Since the  $DI$ s represented in Figures 3 and 4 were derived from the response rates of Figures 1 and 2, it is possible that the changes observed in Figures 3 and 4 are time related as well. However, the lack of significant differences between the original and replication values of the  $DI$ s in Figures 3 and 4 demonstrate that although the replication rate values of Figures 1 and 2 did not approach those of the original determination, we may still conclude that comparable relationships between  $SD_R$ ,  $SD_N$ , and  $S^A$  were maintained.

## DISCUSSION

As shown previously (Pierrel, Sherman, Blue, and Hegge, 1970), the level of differential responding obtained on a multiple schedule is an inverse function of the intensity difference between  $SD$  and  $S^A$ . When the relative contributions to the control of differential re-

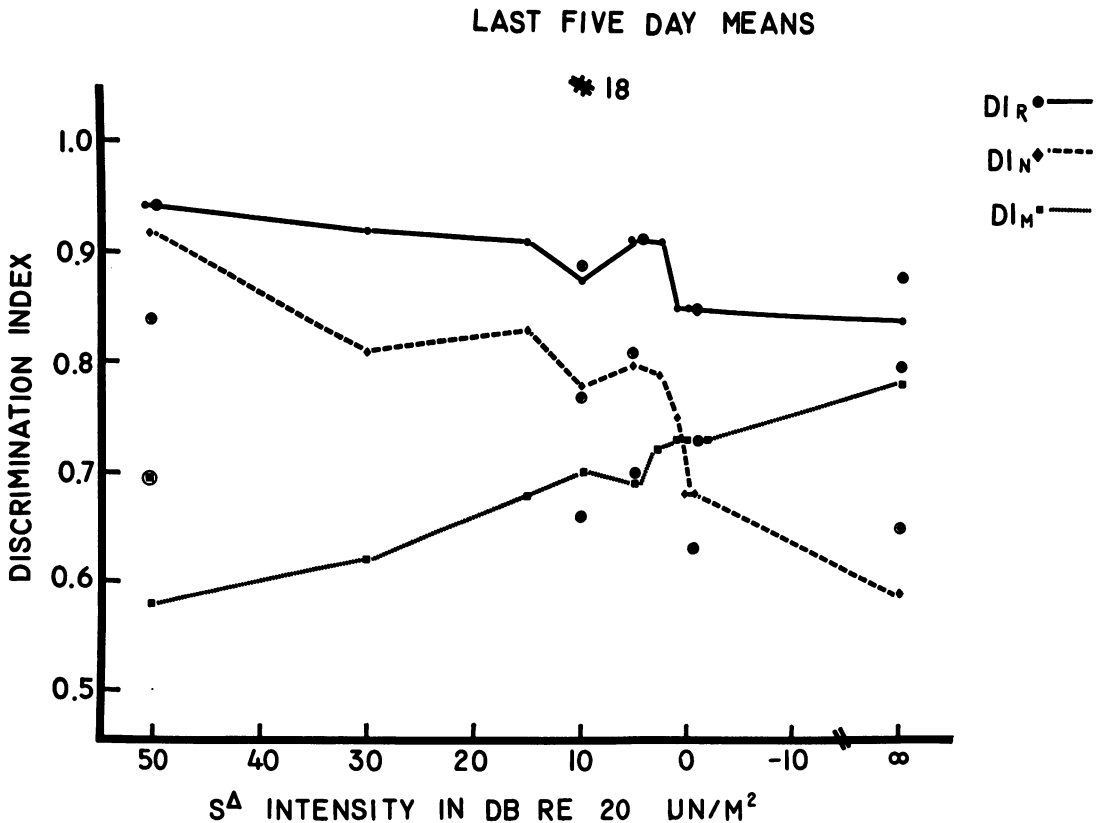


Fig. 3. Mean Discrimination Indices for the last five 8-hr sessions at each intensity for Chinchilla 18. The circled values are those obtained upon replication.

sponding by discriminative stimuli and reinforcing stimuli are considered, it is clear that as the differences between discriminative stimuli become smaller, responding is increasingly controlled by the differences in reinforcing stimuli. This is manifested in two ways: (1) with decreases in the  $S^D$ - $S^A$  intensity difference,  $DI_M$  increases, indicating that reinforcement availability is increasingly employed as a cue in discriminating between the two types of  $S^D$  intervals, as there are no other stimulus differences between them; (2) with decreases in the  $S^D$ - $S^A$  intensity difference,  $DI_N$  decreases more rapidly than does  $DI_R$ . Since  $DI_R$  measures control by both reinforcing and discriminative stimuli, the discrepancy between the slopes of these two functions also demonstrates the increasing utilization of reinforcement availability cues.

The mixed-schedule values of  $DI_R$  and  $DI_N$  indicate that stimulus sources other than sound-intensity differences were controlling behavior during these phases of the experiment.

In the absence of sound-intensity differences, the value of  $DI_N$  should approach 0.500 and  $DI_R$  should approach the value of  $DI_M$ . The obvious, and expected, source of this stimulus control was the use of a multiple schedule that employed three times as much  $S^A$  time as  $S^D$  time. Since  $S^D_N$  and  $S^D_R$  periods have the same lengths,  $DI_M$  is uninfluenced by this factor. Thus, although it cannot be said that  $DI_N$  represents *only* control exerted by the intensity cues, it is clear that reinforcement availability cannot be contributing to differential responding obtained between the two types of intervals in which reinforcement is never available ( $S^D_N$  and  $S^A$ ). More importantly, it has been demonstrated that as the intensity differences lose control over responding ( $DI_N$  decreases),  $DI_M$ , which is uninfluenced by time cues, consistently increases, demonstrating the increasing control exerted by presence or absence of the reinforcing stimuli.

It could be argued that the consistent changes in the DIs were due to some time-de-

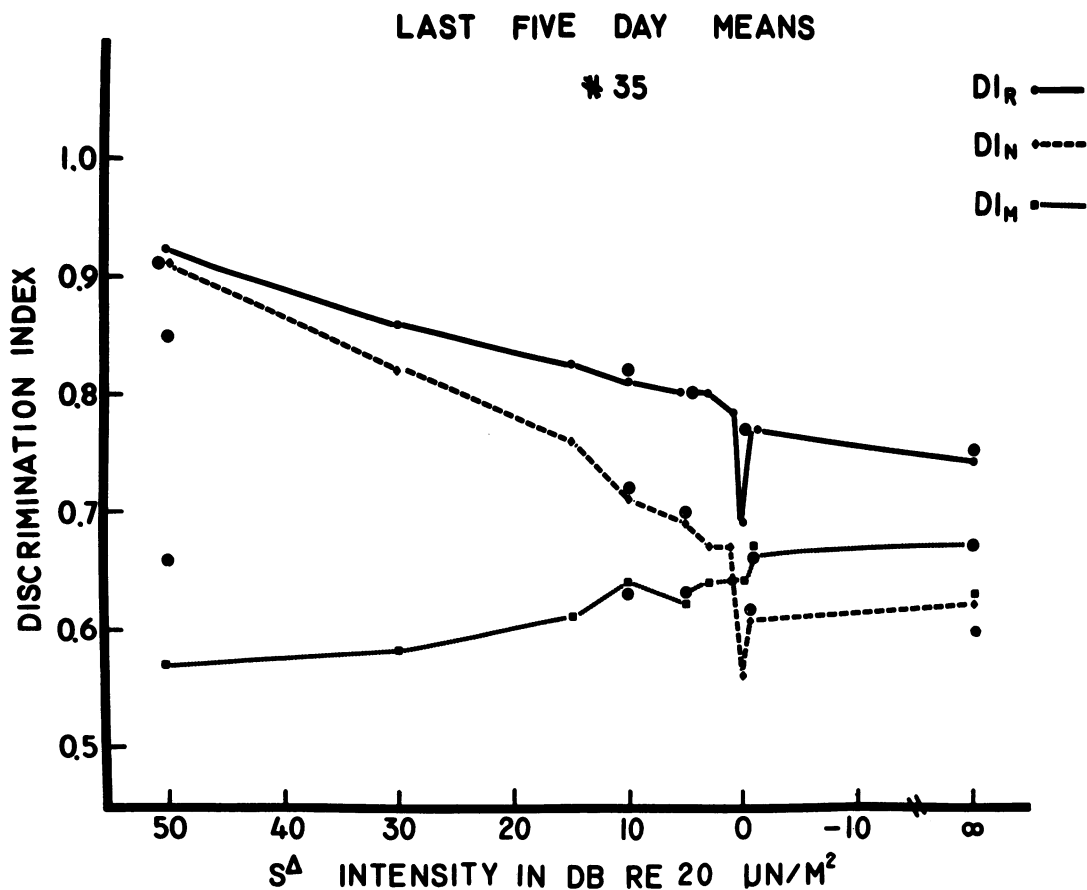


Fig. 4. Mean Discrimination Indices for the last five 8-hr sessions at each intensity for Chinchilla 35. The circled values are those obtained upon replication.

pendent variable, since the  $S^A$  intensities were largely trained in a descending order. However, the good recoverability of the DIs strongly argues against this interpretation. If the DIs changed from one phase to another because of the systematic operation of a time-dependent variable, then there should have been significant differences between replication and original data points. Moreover, two of the five replication points (50 dB and the mixed schedule) were studied more than 65 days after the original determination, while the remainder were studied after a 10- to 15-day interval. Since a 10- to 15-day interval was usually sufficient to allow the original change in the DIs, it is reasonable to expect the same time-dependent variable to exert its influence on the replication DIs within the time periods employed.

Performance at 0.5 dB and below for Subject 35, and at 1 dB and below for Subject 18, on all DIs approximated their respective mixed-

schedule performance. This would suggest that differential responding was no longer controlled by the sound-intensity differences at these  $S^A$  intensities. Thus, it could be considered that at these values, the absolute "threshold" has been passed. Therefore, by analogy to the Method of Limits, which the present procedure most closely approximates, the intensity midway between the lowest intensity tested that produced differential responding superior to that on the mixed schedule, and the highest intensity that produced mixed schedule-equivalent responding, could be taken as an absolute threshold value. This procedure would yield threshold values of 2 dB and -0.25 dB for the chinchillas in this study.

Miller (1970) presented monaural threshold values for chinchillas using a shock-avoidance method. Considering that his value was obtained monaurally, and that there were other major differences in procedure from the pres-

ent study, his value of 1.9 dB and ours of 2 and -0.25 dB are remarkably consonant.

This investigation has demonstrated that the method of successive discriminations is a viable technique for obtaining auditory thresholds in chinchilla when the subthreshold behavioral criterion is multiple-schedule performance equivalent to that on a mixed schedule. Moreover, we have shown that control by reinforcement density is a direct function of discrimination difficulty, whereas the degree of control by intensity is an inverse function of discrimination difficulty.

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