# ANTECEDENT REINFORCEMENT CONTINGENCIES IN THE STIMULUS CONTROL OF AN AUDITORY DISCRIMINATION[1]

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In order to assess possible confounding of discriminative stimulus effects with those produced by the reinforcing stimulus, three groups of four rats each were trained for 45 hr on a variable-interval 1-min reinforcement program. Two groups were run on a multiple variable-interval extinction schedule in which the reinforcement stimulus ($S^D$) and the nonreinforcement stimulus ($S^\Delta$) were two intensities of a 4-kHz (cps) tone separated by 40 or 10 db. The third group was run on a mixed schedule with a single intensity constantly present. The mixed-schedule animals showed no discrimination of the reinforcement program. Under the multiple schedule, the highest $S^\Delta$ rates were obtained after $S^D$ intervals, regardless of the reinforcement availability in the $S^D$ interval. These local rate variations in $S^\Delta$ were small in proportion to those produced by the $S^D$ versus $S^\Delta$ intensities.

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Jenkins (1965) has criticized much of the previous operant discrimination work on the basis that the effects produced by the discriminative stimulus are confounded with effects produced by the stimulus used as a reinforcer. The problem of parceling out various aspects of the stimulus control of responding is not a new one (Pavlov, 1927). In studies of generalization and discrimination the interest is in assessing the extent to which variations along a specific stimulus continuum produce co-variations in rate of responding (Dinsmoor, 1950; Guttman and Kalish, 1956; Pierrel and Sherman, 1960). It is well established that the occurrence or non-occurrence of reinforcement produces local variations in rate (Ferster and Skinner, 1957). Jenkins suggests, however, that the presentation of a reinforcing stimulus produces an immediate and major effect upon rate. If such local variations are assumed to be comparable in magnitude to those effects resulting from varying the discriminative stimulus continuum, it is difficult to assess continuum effects without separating them in the data analysis from effects due to the reinforcement schedule. Jenkins describes a discrete trial procedure in which the effects of antecedent reinforcement and nonreinforce-

ment are analyzed separately from the effects of the current external stimulus. In his procedure, the trial (and responding) is terminated when reinforcement is delivered. Comparison trials of equal duration are terminated without reinforcement. His data, obtained from pigeons trained on a visual discrimination, show that response probability is related not only to the visual stimulus but also to reinforcement or nonreinforcement on the immediately preceding trial.

Boneau, Holland, and Baker (1965) collected wavelength generalization gradients for pigeons, separating responses made just before and just after reinforcement. While they found some post-reward effect, the gradient being displaced upwards when responses immediately following reinforcement were isolated, the general shape of the gradient was largely unaffected by the reinforcement-nonreinforcement contingency. There were essentially no differences among response probabilities measured one or two trials before reinforcement, and two trials after reinforcement.

An alternative to adopting a trial procedure to assess the confounding of stimulus continuum and reinforcement effects, is to attempt to analyze and evaluate the extent to which reinforcement delivery controls response rate in an operant discrimination situation. Such an inquiry adds to the information concerning multiple stimulus control and permits continuing contact with the con-

siderable body of discrimination-generalization data measured in terms of response rate.

The present experiment utilized an operant discrimination paradigm in which an "easy" and a "difficult" two-valued auditory discrimination was trained. A control group was run on a mixed schedule. Intensity effects, as related to the presence and absence of immediately antecedent reinforcement, were analyzed.

## METHOD

### Subjects

Twelve male rats of a Sprague-Dawley derived strain, obtained from Carworth, Inc., were about 100 days old at the start of experimentation. They were reduced to 80% of their free-feeding weights, and were maintained at approximately this level by the food reinforcers received during experimental sessions.

### Apparatus

Four similar sound-shielded operant spaces were used. Each was equipped with a retractable bar, water bottle, pellet dispenser, food dish, and speaker. The animal chamber was constructed so as to produce an acoustically transparent enclosure with a homogenous sound field. Programming and recording equipment were located in an adjacent room. The auditory stimuli were various intensities of a 4-kHz (cps) interrupted tone. The tone was on for 1.5 sec, followed by 2.5 sec of silence. Intensity changes were made only during a silent period. The temporal scheduling of intensity changes, reinforcements, and counter printouts was controlled by a Space Mechanisms Five Channel Photoelectric Programmer (Model SM607). A more detailed description of the enclosures, sound generating, recording, and control equipment is given in Pierrel and Sherman (1960).

### Procedure

The animals were randomly assigned to three groups of four each and placed in an experimental chamber in the presence of the 100-db intensity. This stimulus was to be $S^D$ (multiple-schedule groups), or was to be constantly present (mixed-schedule group). All intensities are specified from a 0.0002 dynes/cm² reference level. Each rat was bar-trained

by being given 50 reinforcements on a fixed-interval 10-sec schedule, immediately succeeded by 75 reinforcements presented on a variable-interval (VI) 1-min schedule. The animals were returned to the enclosures approximately 20 hr after bar-training and remained there for the next 60 hr.[2] Experimental sessions lasted 9 hr. At the end of a session the sound went off and the bars were retracted. These conditions were in effect for 3 hr, after which the next session began. Thus, the animals were run 18 out of every 24 hr.

The multiple-schedule animals had 16 min exposure to the $S^D$ intensity (100 db) and 44 min of the $S^\Delta$ intensity (60 or 90 db) during each experimental hour. $S^D$ periods ranged from 1 to 3 min and $S^\Delta$ periods from 2 to 9 min in duration. Reinforcement in the $S^D$ was programmed on a geometric VI schedule with a mean of 1 min. The stimulus intensity sequence and times of reinforcement availability are shown in Table I. This program was repeated every 30 min of the session. A third group was run on a mixed schedule with the 100-db intensity present throughout. Reinforcements were programmed to occur at the same points in time within the mixed schedule as they did during the $S^D$ periods of the multiple schedule. Each group is referred to by the two stimuli that were present during the $S^D$ and $S^\Delta$ periods; *i.e.*, Group 100-60,

Table I

Stimulus intensity sequence and reinforcement availability schedule.

| Minute in Session of $S^D$ intensity | Reinforcement Setup (Sec from interval onset) |
|---|---|
| 1 | 9,52 |
| 2 | no reinforcement |
| 3 | 10 |
| 10 | 30,40 |
| 13 | no reinforcement |
| 23 | 15 |
| 24 | 48 |
| 28 | 25 |

The $S^\Delta$ intensity was present during minutes 4-9, 11, 12, 14-22 *etc.* That is, all minutes in the session not shown above were the $S^\Delta$ condition.

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Group 100-90, and Group 100-100. Response totals for any given minute were partitioned into one of six categories (2 for $S^D$s and 4 for $S^\Delta$s) corresponding to the intensity present during that minute and the intensity and reinforcement contingencies in effect in the immediately preceding minute. That is, $S^D$ responding was separated into those 1-min intervals which were preceded by either an $S^D$ or an $S^\Delta$ interval. $S^\Delta$ responses were also separated into those following $S^D$s and those following $S^\Delta$s. $S^\Delta$ intervals succeeding $S^D$ intervals were further subdivided into those following an $S^D$ in which one, two, or no reinforcements were made available.

Animals in the multiple-schedule groups received from 96 to 100% of the pellets programmed and the mixed-schedule group obtained about 83% of them. Since such a high percentage of the reinforcements were collected, no attempt was made to determine possible rate variations as a function of whether or not each opportunity for reinforcement was in fact fulfilled.

## RESULTS AND DISCUSSION

The histograms in Fig. 1 were constructed to show local rate variations in $S^D$ and $S^\Delta$ periods as a function of the reinforcement and stimulus conditions in the antecedent interval during an early, middle, and late portion of the experiment. The first two sets of three bars refer to responding in $S^D$ intervals preceded by either an $S^D$ or an $S^\Delta$ interval. The other four sets of bars show responding in $S^\Delta$ separated into categories according to the type of preceding interval: an $S^D$ with one, two, or no reinforcements, or another $S^\Delta$. For this analysis, each 1 min of session time served as an antecedent interval and as a data point as well. Since the six types of interval categories appeared an unequal number of times during the session, totals were multiplied by appropriate constants to equate them. These histograms represent the mean data for each group of four animals.

The session totals for Group 100-60, the multiple-schedule group trained on the 40-db $S^D$-$S^\Delta$ difference, show no differences in $S^D$ response rate as a function of being preceded by an $S^D$ or an $S^\Delta$ interval. The number of responses in all $S^\Delta$ categories was markedly lower than in the $S^D$ categories. The $S^\Delta$ rates

following reinforced and nonreinforced $S^D$ intervals are comparable, and the lowest rates were obtained in $S^\Delta$ intervals which followed other $S^\Delta$s. Finally, as training proceeded, the $S^D$ rates became higher while rates in all $S^\Delta$ categories decreased.

The data for Group 100-90 (10-db multiple-schedule group) are also presented in Fig. 1. The data are quite similar to those of Group 100-60 except that the $S^D$ rates were lower throughout and the $S^\Delta$ rates were higher during the early part of training. As in the case of Group 100-60, responding in the two $S^D$ categories was essentially the same. Also, the levels of responding in $S^\Delta$ intervals preceded by an $S^D$ in which no reinforcements were programmed ($S^R0$) are not unlike those measured in $S^\Delta$ intervals preceded by a reinforcement $S^D$ ($S^R1$ or $S^R2$). Again, the smallest number of responses occurred in $S^\Delta$ periods which followed other $S^\Delta$s. Taken together, these findings indicate that there is an antecedent interval effect ($S^\Delta$ responding is lower when preceded by $S^\Delta$), but this sequential effect results from the recent presence of the intensity which has set the occasion for reinforcement, rather than from the recent occurrence of a reinforcement. Under these experimental conditions, the rate in $S^\Delta$ following an $S^D$ was about the same whether the preceding $S^D$ included the primary reinforcement of a pellet and the presence of the $S^D$ intensity, or merely the presence of the $S^D$ stimulus intensity alone.

An analysis of variance on the data depicted in Fig. 1 for Groups 100-60 and 100-90 statistically confirmed the observations just noted. A significant difference can be demonstrated ($F = 10.53$, df $= 1/6$, $p < .025$) in $S^\Delta$ rate preceded by an $S^D$ interval as opposed to an antecedent $S^\Delta$ interval. There is no difference between the $S^\Delta$ intervals which follow the various types of $S^D$s ($F = 0.59$). No comparable antecedent interval effect appears for $S^D$ responding. That is, the rate controlled by an $S^D$ following an $S^\Delta$ interval is the same as an $S^D$ following another $S^D$. The discriminative control of a current $S^D$ intensity is apparently enough to override any sequential effects from the preceding interval.

The response data for the mixed-schedule animals (Group 100-100) have been partitioned in the same way as for the two multiple schedule groups (Fig. 1). However, for Group
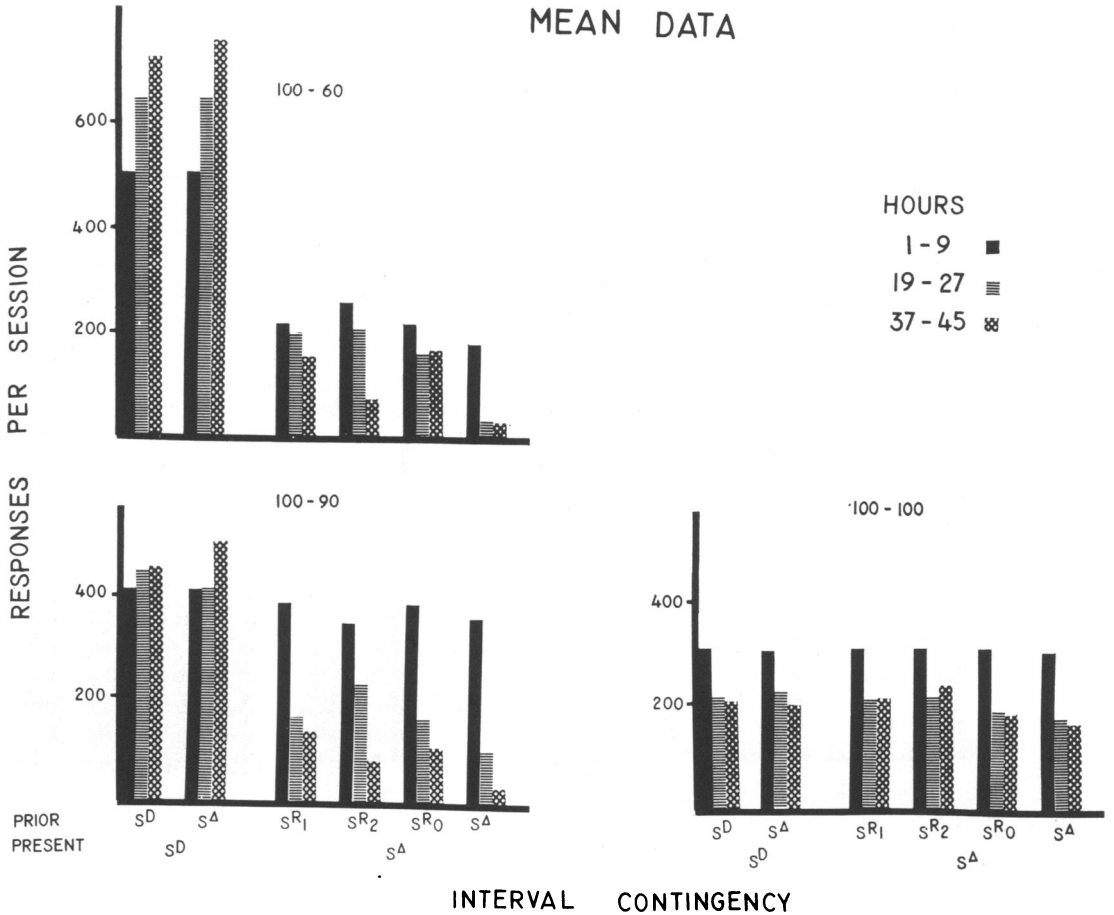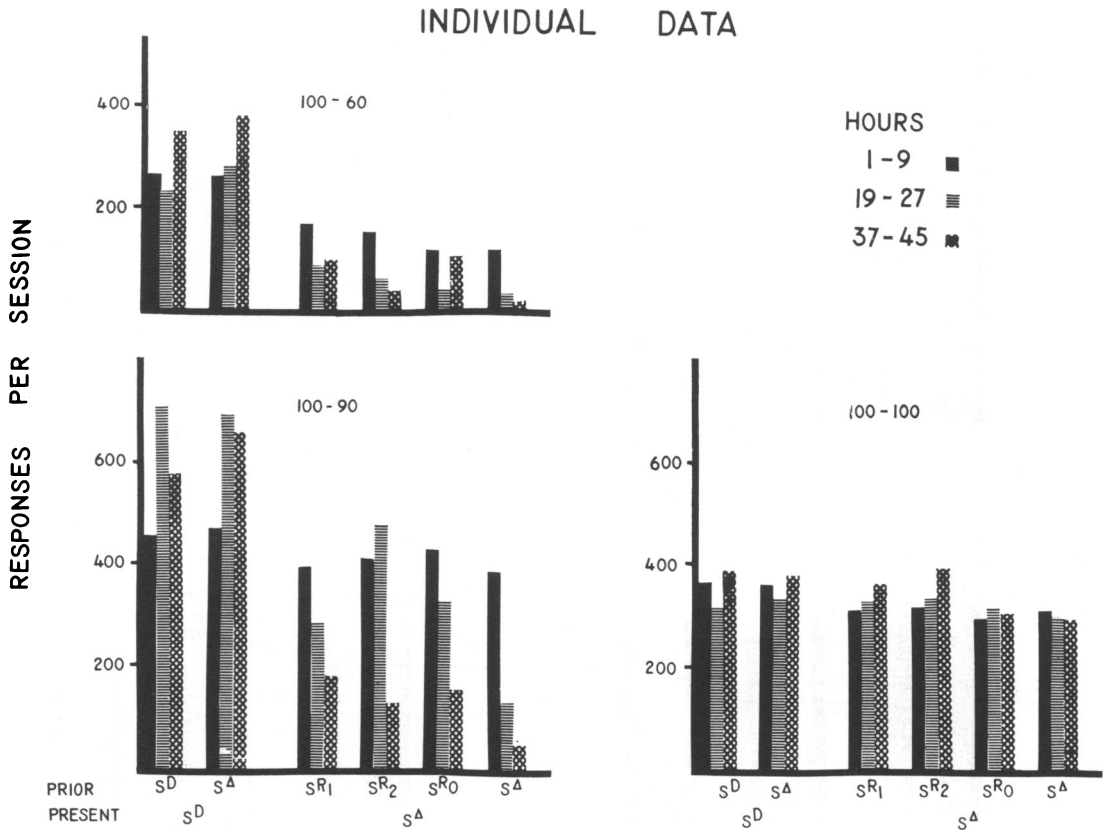
Fig. 1. Responses per session as a function of present and prior interval contingencies—Mean Data. Each bar on each histogram represents the mean response total for the four animals in a group for a given 9-hr training session. Responding in each 1-min interval was subdivided in terms of the intensity and reinforcement conditions prevailing in the immediately preceding 1-min interval. Each 1-min interval served as an antecedent interval and a data point as well.

100-100 the intervals categorized as "$S^D$" and "$S^\Delta$" did not differ in terms of the imposed stimulus intensity. Only the fact that reinforcements were programmed during some "$S^D$" periods distinguished these intervals from periods of "$S^\Delta$". Such a differential stimulus condition might serve a cue function. However, the histograms for Group 100-100 show little in the way of differences among the interval categories, except for an overall reduction in response rate after the first session. That is, without differential stimuli from the imposed intensity continuum, the subjects did not learn to discriminate $S^D$ from $S^\Delta$. The presence or absence of prior reinforcement produced no differential responding.

The data for a representative animal from each of the three groups are presented in Fig. 2. Aside from individual differences in rate, no effects are noted here which were not evident in the mean data.

In order to assess more clearly the development of discriminated responding over the course of training, a Discrimination Index was calculated for each session. The index yields the per cent of responding in $S^D$ (Discrimination Index = responses in $S^D$/responses in $S^D$ + responses in $S^\Delta$). The $S^\Delta$ totals were first multiplied by 0.3636 to correct for the disproportionate amount of the session devoted to $S^\Delta$. Figure 3 shows the Discrimination Index curves for each individual animal in each of the three groups. Both multiple-

Fig. 2. Responses per session as a function of present and prior interval contingencies-Individual Data. Each bar on each histogram represents the response total for an individual animal from one of the three groups for a given 9-hr training session. Responding in each 1-min interval was subdivided in terms of the intensity and reinforcement conditions prevailing in the immediately preceding 1-min interval.

schedule groups show increasing Discrimination Indices with continued exposure to the discriminanda. The performance of the 40-db group (100-60) was consistently superior to that of the 10-db group (100-90) as acquisition for these animals proceeded more rapidly. This difference between the "easy" and "difficult" discriminations was not unexpected; rate of acquisition is a direct function of the $S^D$-$S^\Delta$ intensity difference (Pierrel and Sherman, 1962). The mixed-schedule group showed little evidence of discrimination. Their Discrimination Indices show no systematic change and approximate chance (0.50) levels of performance throughout the 45 hr of training. A trend analysis (Lewis, 1960, pp. 379 ff.) confirmed this result as no significant training effect was revealed

(F = 1.39, df = 4/12, p > .20). The performance of Group 100-100 was obviously inferior to the performance of either multiple-schedule group.

The present results agree with those of Jenkins (1965) and Boneau, et al., (1965) in demonstrating some sequential effects. Response probabilities in $S^\Delta$ are higher following $S^D$ intervals containing reinforcement than in $S^\Delta$ intervals following other $S^\Delta$s. However, these local effects upon response rate cannot be attributed solely to the presence or absence of reinforcement in the immediately preceding interval, since $S^D$s without programmed reinforcement produce equally high response probabilities in the following $S^\Delta$s. The present study demonstrated that the positive discriminative stimulus controls a high rate in its
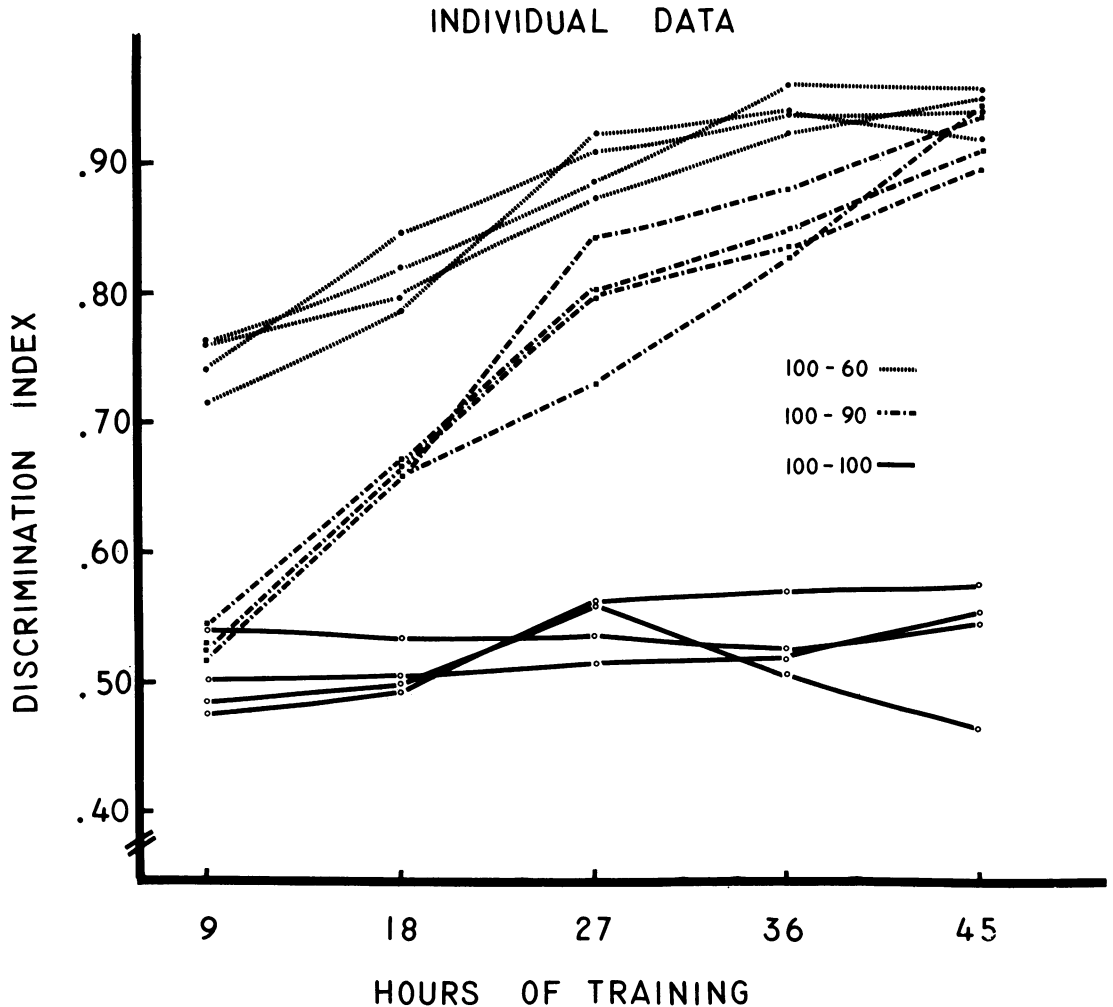
## INDIVIDUAL DATA



Fig. 3. Percentage of responding in S^D (Discrimination Index) as a function of hours of training. Each point on each function represents the D. I. for a 9-hr session for an individual animal.

presence and that some of this control carries over into a succeeding S^Δ interval. This effect appeared within the first 9 hr of training and was evident throughout all the discrimination training which followed.

Local variations in response rate can be attributed to properties of the stimulus sequence, but it is quite clear that the control exerted by the differential stimulus intensities dwarfs these local effects.

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