THE DIFFERENTIAL REINFORCEMENT OF LOW RATES AND STIMULUS CONTROL

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This is to certify that the

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ABSTRACT

THE DIFFERENTIAL REINFORCEMENT OF LOW RATES AND STIMULUS CONTROL

By

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Research in the past several years has suggested that stimuli associated with some positive reinforcement schedules may possess some of the properties normally attributed to stimuli associated with extinction, such as an inhibitory generalization gradient around the training stimulus. One important question is whether this inhibition is the result of discrimination training or the result of the contingencies of the reinforcement schedule itself. The purpose of Experiment I was to investigate the effect of the presence or absence of discrimination training on the shape of the generalization gradient around a stimulus correlated with a differential-reinforcement-of-low-rate schedule (DRL), a schedule which requires the subject to pause a certain minimum time between responses in order to obtain reinforcement. Eighteen White Carneaux pigeons were trained to peck during a successive discrimination under a multiple DRL 8-sec - DRL 8-sec schedule for 20 days (Phase

I). Each unreinforced response was followed by darkening the response key for 0.8 sec in order to provide feedback for each criterion response. A plain green key was correlated with the first component and a white vertical line on a green background with the second component. After 20 days the subjects were divided into three groups of six each (Phase II). During Phase II the schedule was changed to multiple DRL 8-sec - DRL 64-sec for one group, multiple DRL 8-sec - Ext for the second, and DRL 64-sec only for the third. The DRL 8-sec component was correlated with the plain green key, and either the DRL 64-sec or Ext component with the white vertical line on the green background. After 15 days a standard generalization test in extinction was administered to all subjects along the line-orientation dimension, the dimension correlated with the white vertical line.

The results showed that the generalization gradient for the DRL 64-sec group was inhibitory in shape, while the gradients for the other two groups were not. These results indicate that standard discrimination training (1) is not always necessary for the production of inhibitory stimulus control, and (2) discrimination training does not always lead to inhibitory stimulus control around the stimulus which controls the lower response rate.

The purpose of Experiment II was to assess the effect of removal of the feedback for each unreinforced response on the generalization gradients and on the rate of responding in the presence of the DRL 8-sec correlated stimulus. The procedure was identical to Experiment I except that no feedback was provided for each unreinforced response.

The results of Experiment II showed that none of the group gradients along the line-orientation dimension were inhibitory. Comparing the response rate data of Experiment II with that of Experiment I, the subjects maintained on either the multiple DRL 8-sec - DRL 64-sec or the multiple DRL 8-sec - Ext schedule showed a higher rate of responding in Experiment II (no feedback) during the DRL 8-sec component than the comparable subjects in Experiment I, and also greater variability in response rates. In addition, the subjects in Experiment II showed an increase in the rate of responding (behavioral contrast) during Phase II while the subjects in Experiment I did not. Almost all the difference in the rate of responding between the feedback vs. no-feedback subjects was accounted for by the difference in the per cent of responses with interresponse times less than 0.8 sec.

Date Aug 7, 1970 Signed Marle alling

THE DIFFERENTIAL REINFORCEMENT OF

LOW RATES AND STIMULUS CONTROL

by Thomas J. Kramer

A THESIS

Submitted to Michigan State University in partial fulfillment of the requirements for the degree of

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DEDICATION

To Nancy

2+2=5

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INTRODUCTION

Research in the past several years has suggested that stimuli associated with some positive reinforcement schedules may possess some of the properties normally attributed to stimuli associated with extinction. More specifically, schedules of positive reinforcement which maintain low rates of responding produce behavioral contrast and peak shift in a manner similar to extinction, when alternated with another schedule which maintains a higher rate of responding (Guttman, 1959; Terrace, 1968; Weisman, 1969). It has been suggested that these behavioral phenomena, peak shift and behavioral contrast, are the result of an inhibition of responding in the presence of the stimulus which maintains the lower response rate (Thomas & Williams, 1963; Terrace, 1966a; Weisman, 1969). The question then arises as to whether this inhibition is the result of discrimination training or is the result of the contingencies of reinforcement per se which control the behavior. The primary purpose of Experiment I was to investigate the effect of the presence or absence of discrimination training on the shape of the generalization gradient around a stimulus correlated with a differential-

reinforcement-of-low-rate schedule. Experiment II was conducted to assess the effect of removal of a feedback stimulus for each peck on the generalization gradients and response rates.

Some Characteristics of Discrimination Training

Hanson (1959) trained pigeons to peck a response key illuminated from behind with a 550 nanometer (nm) light on a variable-interval schedule with a mean interreinforcement interval of 1 min (VI 1-min). After five days of training a second stimulus, either 555, 560, 570, or 590 nm for four separate groups, alternated with 550 nm. Responding in the presence of this second stimulus was never reinforced (extenction). A fifth group did not receive discrimination training, but was reinforced on the VI 1-min schedule in the presence of 550 nm for an equal number of sessions. All generalization gradients obtained from the groups given discrimination training reached a peak at 540 The gradient for the control group peaked at 550 nm, nm. the training stimulus. This shift of the gradient peak from the training stimulus in a direction away from the stimulus correlated with extinction has been called "peak shift." Many experimenters have demonstrated the peak shift phenomenon after discrimination training on the wavelength continuum (Honig, Thomas, & Guttman, 1959; Honig, 1962; Pierrel & Sherman, 1960, 1962; Thomas, 1962; Thomas &

Williams, 1963; Terrace, 1964, 1966c; Friedman & Guttman, 1965; Stevenson, 1966) and with the line-orientation dimension (Bloomfield, 1967).

Some investigators have suggested that the peak shift is the result of the formation of an underlying Ushaped inhibitory gradient around the extinction-correlated stimulus (Thomas & Williams, 1963; Terrace, 1966a; Weisman, 1969). An inhibitory gradient is a stimulus generalization gradient, usually obtained during extinction, in which responding increases along the stimulus continuum as the distance from the stimulus that has previously been correlated with extinction increases (Catania, 1968). To directly evaluate the possibility that peak shift is the result of an underlying inhibitory gradient the reinforced stimulus and the unreinforced stimulus must be on orthogonal dimensions. Jenkins and Harrison (1962) trained pigeons to discriminate a 1000 cps tone correlated with extinction from white noise correlated with VI reinforcement. They later obtained an inhibitory gradient around the 1000 cps tone. Honig, Boneau, Burnstein, and Pennypacker (1963) found that the post-discrimination generalization gradient around a black vertical line on a white background was inhibitory if the stimulus was correlated with extinction, whereas the gradient was excitatory if the stimulus had been correlated with positive reinforcement. Terrace (1966b) found a similar result when the reinforced stimulus

was on the wavelength dimension and the extinctioncorrelated stimulus was on the line-orientation dimension, provided that the subjects had responded in extinction. In all these studies the inhibitory gradients were relatively shallow when compared to the excitatory gradients.

It does not appear, however, that discrimination training must occur with extinction in order to produce peak shift or inhibitory stimulus control. Guttman (1959) exposed pigeons to a multiple VI 1-min VI 5-min schedule. In a multiple schedule two or more component schedules operate in alternation, each in the presence of a different stimulus (Catania, 1968). In Guttman's experiment the key light during the VI 1-min component was illuminated with a 550 nm light and during the VI 5-min component with a 570 nm light. The two schedule components alternated every 5 min, two of each component per session for 12 days. Across the 12 days of acquisition, the response rates in the two components diverged. The rate in the VI 1-min component became progressively higher (up to 60 per min) while the response rate in the VI 5-min component stabilized at about 20 responses per min. The post-discrimination generalization gradient was unimodal, reaching a peak at 540 nm, indicating a shift away from the stimulus correlated with the VI 5-min component. Terrace (1968) replicated this finding using a similar procedure. Weisman (1969) exposed pigeons to a similar procedure except that the VI 1-min

component was correlated with a plain green key light while the VI 5-min component was correlated with a white vertical line on the green background. A post-discrimination generalization test along the line-orientation dimension yielded a U-shaped inhibitory generalization gradient centered around the VI 5-min stimulus.

In summarizing the results of his experiment Guttman stated that "a stimulus associated with <u>relatively</u> weak reinforcement can become <u>functionally</u> negative [p. 338]." He also pointed out that stimuli associated with extinction and relatively weak reinforcement schedules may both possess suppressive or inhibitory properties. "The obvious inference is that during training the behavior in the presence of this stimulus is under an active restraint, and that the observed level of performance is the resultant of this discriminative restraint and the positive factor of reinforcement [p. 339]." The results obtained by Terrace and Weisman would seem to make this conclusion more defensable.

Differential Reinforcement of Low Rates and Stimulus Control

Under a schedule which differentially reinforces low rates of responding (DRL), interresponse times (IRTs) that end after a predetermined time interval are reinforced. The IRTs shorter than this time reset the timing contingency. For example, if a subject is responding under a DRL 10-sec

schedule, all IRTs of 10 sec or more are followed by reinforcement and all IRTs less than 10 sec "reset" the contingency of waiting at least 10 sec to respond for reinforcement.

In many studies concerned with DRL, IRTs are recorded in class intervals, usually of 1, 2, or 3 sec widths. For example, all IRTs from 0 to 1 sec are recorded in the first category, all IRTs from 1 to 2 sec in the second category, etc. When the data are recorded in this way, a plot of the relative frequency of responses in the various class intervals usually produces a bimodal curve once stable performance is obtained. The first mode occurs at the first category, after which responding drops to near zero for the next category. As the IRT category in which the shortest reinforced IRT falls is approached, the relative frequency of responses in each category begins to rise, reaching a maximum at or just before the first reinforced category. After this the relative frequency decreases to zero (Kramer, 1970).

The large number of IRTs in the first category has been a subject of considerable interest to many investigators. These short IRTs have been called "bursts" of responding by Sidman (1956), defined as any sequency of two or more responses in which no consecutive responses are separated by more than 2 sec. It is somewhat surprising that these bursts occur with such a high frequency since

they are relatively far removed in time from reinforced Blough (1963, 1966), using sensitive recording IRTs. equipment, noted that pigeons reinforced for certain IRTs tended to emit responses with IRTs which clustered at around 0.4, 0.8, and 1.2 sec. To further investigate these short IRTs, Blough (1966) recorded their occurrence in 0.1 sec categories up to 2 sec. Although the details of this experiment are somewhat complicated, suffice it to say that while the independent variables of varying reinforcement probabilities and varying IRT category widths significantly affected IRTs greater than 0.8 sec, IRTs less than this were insensitive to these contingencies. In addition, while the behavior of all pigeons was quite similar under the various conditions, individual differences in the probability of IRTs less than 0.7 sec were large. The data also indicated that response probabilities in the short IRT region showed the greatest session-to-session variability.

Kramer (1970), in a review of the DRL contingency, noted that not all investigators have found a large number of bursts being emitted by their subjects on DRL schedules. Kelleher, Fry, and Cook (1959) found very few bursts with rats, although in this case they were providing an audible "click" for each bar depression as feedback. Noting that this was an unusual finding, they attempted to investigate further. After the rats had been exposed to a DRL 20-sec -LH 5-sec schedule for over 120 hrs, the click was removed

for three animals. The effect of removing the auditory click was consistent; all animals increased the percentage of bursts, although the magnitude of the increase was small. Kramer (1968) recorded a large percentage of bursts for pigeons on both DRL 20-sec and DRL 30-sec. However, virtually no bursts occurred after a reinforced response. Each reinforced response was followed by immediate feedback; the key light went out and the food magazine was presented. Sidman (1956) also found a reduced number of bursts following reinforced responses. Here again food presentation provided immediate feedback.

These results suggest that bursts of responding may be due to a lack of stimulus feedback for a criterion response. In any automated experiment, a certain minimum criterion must be exceeded in order for the response of the subject to be recorded as a response electrically. For example, the pigeon must exert at least some minimum amount of force on the response key, and the rat must move the bar at least some minimum distance, in order for a response to be recorded. On the other hand, these subjects may be making subcriterion responses that are not recorded electrically, but that are responses nonetheless to the subject. If subcriterion responses occasionally precede a criterion response that is reinforced, then these subcriterion responses would also be strengthened through contiguity with reinforcement. In summarizing the data on

bursts of responding Kramer (1970) suggested that manipulation of the kind and amount of stimulus feedback for each response might be a fruitful way of reducing the frequency of response bursts.

Another way of investigating stimulus control is through generalization testing. Hearst, Koresko, and Poppen (1964) conducted a systematic study of the shape of the generalization gradients after responding under several reinforcement schedules. In Experiment I a group of pigeons was trained to respond under either a DRL 6-sec or DRL 10-sec schedule. A second group was trained under a VI 1-min schedule. After 14 days a generalization test was conducted. The obtained gradients were quite different for the two schedules. For the VI group data, the gradient was sharply peaked at the training stimulus. In contrast, the group data for the DRL birds was quite flat in comparison, with the peak occurring at the training stimulus. Of the 24 birds given DRL training, however, only five had their peak at the training stimulus, whereas 18 of 20 VI gradients peaked at the training stimulus. The authors suggested that the relatively flat DRL gradients may have been the result of several factors, one of which was the following: "DRL is usually considered to be one of these 'semi-average' schedules, and therefore its negative properties might interact with its positive properties to affect the peak and slope of the generalization gradients. The fact that only

5 of the 24 DRL Ss had a gradient peak at the CS lends weight to the notion that DRL possesses inhibitory effects [p. 375]." One implication and extension of these results is that DRL schedules with longer time intervals may produce inhibitory generalization gradients.

Weisman (1969), in Experiment II of the study previously referred to, investigated the shape of the generalization gradient after discrimination training under a multiple VI 1-min DRL schedule. Initially, pigeons were exposed to a multiple VI 1-min VI 1-min schedule in the presence of a green light and a white vertical line which alternated randomly. After 20 sessions reinforcement in the presence of the white vertical line was contingent on a DRL schedule. The value of the DRL component was adjusted daily so that the number of reinforcements per session was equal for both components. The DRL value was eventually raised to 16 or 20 sec. A generalization test along the line-orientation dimension, the dimension which had been correlated with the DRL component, yielded an inhibitory gradient for four out of four birds. The question still unanswered is whether the inhibitory gradient obtained by Weisman was a function of the DRL schedule itself, as the results of Hearst et al. (1964) might suggest, or a function of discrimination training, as was implied by Guttman (1959).

Behavioral Contrast

Another behavioral phenomenon which appears to be highly correlated with peak shift and inhibitory gradients due to discrimination training is behavioral contrast (Terrace, 1966a,b,c, 1968; Weisman, 1969). Behavioral contrast has been defined as a change in the rate of responding from the baseline level in the presence of one stimulus in a direction away from the rate of responding generated in the presence of another stimulus (Reynolds, 1961). The behavioral contrast literature has been extensively reviewed by both Terrace (1966a) and Dunham (1968). Terrace (1968) has concluded that "a sufficient condition for both phenomena (behavioral contrast and peak shift) is a reduction in the rate of responding to one of two alternating discriminative stimuli [p. 737]." Weisman (1969) has obtained complementary data and has suggested that peak shift is an indicator of inhibitory stimulus If this is true, then the occurrence of behavioral control. contrast and inhibitory generalization gradients should also be highly correlated in the same way as behavioral contrast and peak shift appear to be.

With respect to DRL and behavioral contrast, Reynolds and Catania (1961) and Reynolds and Limpo (1968) have demonstrated that behavioral contrast results when a DRL schedule is the constant component in a multiple schedule and the rate of responding in the other component

is reduced by either extinction (Reynolds & Catania, 1961) or by signaling the availability of reinforcement in the second component (Reynolds & Limpo, 1968). But the amount of behavioral contrast found by Reynolds and Catania was small. It appeared that the greatest increase occurred for IRTs less than 3 sec, and that the probability of occurrence of longer IRTs was little affected. Reynolds and Limpo found that behavioral contrast was slow in developing. Here again short IRTs appeared to be effected the most.

EXPERIMENT I

The main question under investigation in the first experiment can be stated simply as follows: is discrimination training necessary for the development of inhibitory stimulus control, as measured by a generalization gradient, after training on a schedule of reinforcement which generates low rates of responding? An extension of the results of Hearst et al. (1964) suggests that a schedule which maintains a low rate of responding may, of itself, yield inhibitory generalization gradients. The results of Weisman (1969) have shown that inhibitory gradients do develop after discrimination training around the stimulus correlated with the schedule which maintained the lower response rate. Guttman's (1959) statement that a "stimulus associated with relatively weak reinforcement can become functionally negative" [p. 338] implies that discrimination training is necessary to generate inhibitory stimulus control.

Of secondary interest was the effect of a feedback stimulus, delivered immediately after each unreinforced response, on the rate of responding, particularly during discrimination training.

Method

Subjects

The subjects were 18 naive White Carneaux female pigeons, ranging in age from six to 10 years, maintained at 80 per cent of their free-feeding weight.

Apparatus

The experimental environment was a standard operant conditioning chamber, 12 X 14 X 13 in. The front panel contained three Lehigh Valley Electronics pigeon keys, 1 in. in diameter, mounted 8 1/2 in. above the floor with a horizontal separation of 3 in. Behind the center key an Industrial Electronics Engineers in-line display unit was mounted. The display cell could illuminate the center key with six orientations of a 1/8 in. wide by 7/8 in. high white line (+90°, -60°, -30°, 0°, +30°, +60°, of departure from vertical) and five wavelengths (501, 538, 555, 576, and 606 nm peak wavelength). A force of approximately 15 g was required to close the key and record a response. A rectangular opening located below the center key permitted access to grain which was raised to the feeding position and illuminated for $2 \frac{1}{2} \sec for reinforcement$. Two house lights, used only during shaping, were mounted on the front wall. A third house light (yellow) was mounted on the rear wall. Programming and recording equipment were located in an adjoining room.

Procedure

All animals were given approximately one hr of general habituation to the chamber, followed on the second and third days by manual shaping of approach to the food magazine and the pecking response to the center key. During shaping the center key was illuminated with either the white vertical line on the green (555 nm) background or the plain green (555 nm) stimulus. The stimuli alternated every 2 min.

Once at least 10 responses had been reinforced on a continuous reinforcement schedule in the presence of each stimulus, the first daily session started. During Phase I (acquisition training) the responses of all subjects were reinforced on a multiple DRL 8-sec - DRL 8-sec schedule. The white vertical line on the green background was associated with one component and the plain green stimulus with the other. Under this schedule all IRTs of 8 sec or longer are reinforced, whereas all IRTs less than 8 sec reset the timing contingency. During reinforcement the response key was not illuminated. In addition, after each unreinforced response, the key light was blacked out for 0.8 sec to provide immediate stimulus feedback for each response which activated the microswitch. The time of 0.8 sec was selected from the data of Blough (1966) which suggested that interresponse times in this area were not sensitive to the manipulation of independent variables. No other illumination was provided in the chamber.

The stimuli on the center key were presented according to one of six irregular orders (Gellerman series) for 4-min periods, and eight periods of each stimulus were given each day for a total of 16 periods. The 4-min periods were separated by 10-sec periods during which the center key was out and the yellow light in the rear of the chamber was illuminated. Responding during this 10-sec period had no scheduled contingencies. Phase I lasted for 20 daily sessions. The subjects were run on the average of six days a week.

During Phase II the 18 subjects were divided into three groups of six each. Two groups received discrimination training on a multiple schedule; multiple DRL 8-sec -DRL 64-sec for one group and multiple DRL 8-sec - Extinction (Ext) for the other discrimination group. For both groups the plain green stimulus (555 nm) was correlated with the DRL 8-sec component, while the white vertical line on the green background was correlated with either the DRL 64-sec component or the Ext component. As before, the stimuli were presented for 16 periods of 4 min duration, eight of each stimulus component. The remaining group of six subjects received DRL 64-sec only, in the presence of the white vertical line on the green background. This group received only eight 4-min periods daily. Thus, the number of periods where the stimulus was the white vertical line on the green background was the same for all three groups.

After 15 sessions of Phase II for all groups, all subjects were given a brief warmup on the next day (2 4-min periods of each schedule component for the discrimination groups and 2 4-min components for the DRL 64-sec group), followed by a generalization test in extinction. The six line-orientation stimuli were presented in each of 12 randomized blocks for a total of 72 stimulus-on presentations, each separated by 10-sec periods when no stimulus was presented and the yellow light in the rear of the chamber was illuminated. Six test stimulus sequences were used, with a different sequence for each subject in each group. The number of key-pecks during each 30-sec stimulus presentation was recorded.

The two groups given discrimination training during Phase II were then given five additional sessions as before in Phase II. On the following day generalization testing in extinction was administered along the wavelength dimension using the same procedure as for the line-orientation dimension. The five wavelength stimuli were presented in each of 12 randomized blocks for a total of 60 30-sec presentations. The data were recorded as before.

Results

Generalization Gradients

Figures 1, 2, and 3 show the individual generalization data, expressed as a function of the number of

Figure 1.--Individual generalization gradients, expressed in terms of number of responses to each of the six generalization stimuli, after exposure to the white vertical line correlated with the DRL 64-sec component during discrimination training in Phase II.



Figure 2.--Individual generalization gradients, expressed in terms of number of responses to each of the six generalization stimuli, after exposure to the white vertical line correlated with the extinction component during discrimination training in Phase II.



Figure 3.--Individual generalization gradients, expressed in terms of number of responses to each of the six generalization stimuli, after exposure to the white vertical line correlated with the DRL 64-sec contingency during non-differential training in Phase II.


responses to each of the six line-orientation stimuli, for the multiple DRL 8-sec - DRL 64-sec group, the multiple DRL 8-sec - Ext group, and the DRL 64-sec group, respectively. For the multiple DRL 8-sec - DRL 64-sec group (DRL 8-64 group), individual differences are striking. The individual gradients range from clearly excitatory (Birds 2450 and 947) to clearly inhibitory (Bird 1169). The individual gradients for the multiple DRL 8-sec - Ext group (DRL 8-Ext group), shown in Figure 2, show more uniformity. The gradients for the four birds with a level of responding above zero at all stimuli uniformly show a minimum number of responses at or near the training stimulus $(0^\circ, +30^\circ)$, and a maximum number of responses to the peripheral stimuli (+90°, +60°). The individual gradients for the DRL 64-sec group (DRL 64 group), shown in Figure 3, indicate the most individual uniformity. With the exception of Bird 387, all gradients reach a minimum at or near the training stimulus (0°, +30°) and a maximum at the peripheral stimuli.

Figure 4 shows the mean number of responses for the three groups at each of the line-orientation stimuli. A subjects by treatments (stimuli) repeated-measures AOV was performed for each group gradient. The statistical analysis of the absolute number of responses across the various stimuli revealed that there was no significant effect for the DRL 8-64 group (F < 1), no significant effect for the DRL 8-Ext group (F = 1.80, df 5/25, p > .10), but that the

Figure 4.--Group generalization gradients, expressed in terms of the mean number of responses per group to each of the six generalization stimuli, in the presence of the white vertical line. The appropriate component is underlined for each group.



effect of stimuli was significant for the DRL 64 group (F = 7.42, df 5/25, p < .001). This result, combined with inspection of the group and individual gradients, indicates that the gradient for the DRL 64 group is a U-shaped, inhibitory gradient.

A two-factor AOV with repeated measures on one factor (stimuli) was performed for comparisons between groups. Statistical comparison of the group gradients of the DRL 8-64 group and the DRL 8-Ext group indicated that there was no significant difference between groups (F = 1.13, df 1/10, p > .20), that the overall effect of stimuli was not significant (F < 1), and that the interaction of the groups and the stimuli was not significant (F = 1.26, df 5/50, p > .20). Statistical comparison of the DRL 8-64 group gradient with the DRL 64 group gradient indicated no significant difference between groups (F < 1) and no significant difference due to stimuli (F < 1). However, the interaction of the groups with the stimuli was significant (F = 3.57, df 5/50, p < .01). This result indicates that the two group gradients have a different shape. The overall conclusion is that, for the contingencies used in this experiment, discrimination training did not lead to inhibitory stimulus control while comparable training on the same schedule (DRL 64-sec) in isolation did yield inhibitory stimulus control.

Although the DRL 8-Ext group and the DRL 64 group differ procedurally by two factors, a comparison of the generalization gradients is still of some interest. The effect of the stimuli produced a statistically significant difference (F = 8.12, df 5/50, p < .001). However, neither the effect of groups (F = 2.36, df 1/10, p > .10) nor the interaction of groups with stimuli (F = 1.55, df 5/50, p > .20) yielded a significant difference.

Both the DRL 8-64 group and the DRL 8-Ext group were given a second generalization test along the wavelength dimension, the dimension correlated with the DRL 8-sec component. The general tendency for animals in both groups was for an excitatory gradient reaching a peak at the training stimulus (555 nm), with the fewest number of responses at the peripheral stimuli (501 and 606 nm). Two birds in the DRL 8-64 group were exceptions to this trend. Birds 347 and 1169 emitted the highest number of responses to the 538 nm stimulus. Nevertheless, both of these gradients were excitatory in shape.

Figure 5 shows the mean number of responses for both groups at each of the five wavelength stimuli. Both group gradients are excitatory and symmetrical. Statistical analysis of the absolute number of test responses revealed that the effect of stimuli was significant for both the DRL 8-64 group (F = 6.47, df 4/20, p < .005) and for the DRL 8-Ext group (F = 16.84, df 4/20, p < .001). Statistical

Figure 5.--Group generalization gradients, expressed in terms of the mean number of responses per group to each of the five wavelength stimuli, around the 555 nm stimulus which was correlated with the DRL 8-sec component for both groups during discrimination training in Phase II.



comparison of the group gradients with each other indicated no significant differences between the groups (F = 1.54; df 1/10, p > .10) and no significant interaction (F < 1). Of course the overall effect of stimuli was highly significant (F = 21.10, df 4/40, p < .001). These results indicate that (1) generalization around a stimulus correlated with DRL 8-sec is excitatory after discrimination training, and (2) the generalization gradient around a stimulus correlated with DRL-8 sec is not differentially affected by whether the schedule in the other component is reinforced (DRL 64-sec) or not reinforced (Ext), as long as both maintain a lower response rate.

Response Rates

Figure 6 shows the mean daily response rates of both discrimination groups for the DRL 8-sec component (S1) and the mean daily response rates of all groups for either the DRL 64-sec component (the DRL 8-64 group and the DRL 64 group) or Ext (the DRL 8-Ext group). This component is designated as S2. The points at Session 0 represent the group mean averages for the last five days (days 16 to 20) of Phase I (acquisition) training. These last five days of Phase I were chosen as the baseline rate of responding since inspection of the data indicated that the rate of responding had reached as asymptotic level and showed little day-to-day changes. Therefore, these last five days will be used as a baseline point from which to determine

Figure 6.--Daily average group response rates (responses per min) during Phase II for the component correlated with S1, the 555 nm stimulus, and for the component correlated with S2, the white vertical line. The point at "Session O" represents a group average response rate for each particular component during the last five days of Phase I.



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whether the daily response rates changed during Phase II. It is quite clear that all three groups showed a reduction in the rate of responding in the presence of S2. Considering days 1 through 15 of Phase II, one bird (#9) in the DRL 64 group exceeded the baseline rate on days 2, 5, and 6. One subject in the DRL 8-64 group exceeded this baseline rate on day 4. For all other birds every daily rate was below the average 5-day baseline rate.

Statistical comparisons of the three groups with each other were carried out using the average rate of responding per group in the presence of S2 for days 11 through 15 of Phase II. This comparison was made because the rates of responding were asymptotic by this time, and also because these days just preceded the line-orientation generalization test. The analyses indicated that the average rate of responding for both the DRL 8-64 group and the DRL 64 group differed significantly from the DRL 8-Ext group (t = 3.65, df 5, p < .02; t = 3.23, df 5, p < .05, respectively, two-tailed). However, the rate of responding for the DRL 8-64 group and the DRL 64 group were not significantly different (t = 0.37, df 5, p > .50). Therefore, the difference in the shape of the generalization gradients for these two groups cannot be attributed to a difference in asymptotic response rates.

Inspection of the daily response rates during the DRL 8-sec component (S1), shown in Figure 6, for the DRL

8-64 group and the DRL 8-Ext group during Phase II shows only small rate changes from day-to-day. For the DRL 8-64 group there is a slight rate increase for the first day compared to the previous 5-day baseline rate (mean change of 1.1 responses per minute) and for the first five days combined (mean change of 1.1 responses per minute). For succeeding days there was a very slight but gradual de-For the DRL 8-Ext group there was a drop in the crease. response rate for the first day of Phase II for all animals which averaged 2.5 responses per min, followed on the second day by an increase for all animals which averaged 2.5 responses per min. For succeeding days the response rate declined slightly and gradually. Except for the first day of discrimination training the daily average response rates for both groups were quite similar. Between days 15 and 16 the generalization test along the line-orientation dimension was given. Note that the response rates on days 15 and 16 show little change.

For statistical analysis the rates of responding were grouped into 5-day blocks, thus collapsing the data into five 5-day blocks (the last five days of Phase I and 20 days of Phase II). A two-factor AOV with repeated measures on one factor was performed using the response rates during the DRL 8-sec component for the DRL 8-64 and the DRL 8-Ext groups across the five 5-day blocks. The results showed no significant differences due to groups

(F < 1), 5-day blocks (F < 1), or the interaction of groups with treatments (F = 1.49, df 4/40, p > .10). A subjects by treatments repeated-measures analysis across the five 5-day blocks for the DRL 8-Ext group also showed no significant rate changes (F < 1). However, the same analysis for the DRL 8-64 group was significant (F = 2.98, df 4/20, p < .05). In order to determine which means differed from each other, a Newman-Keuls test was performed (Winer, p. 114). The results indicated that the only significant difference occurred between the last five days of Phase I and the first five days of Phase II (p < .05). The mean change was an increase in the rate of responding of 1.1 responses per min.

Reinforcement Rates

Table 1 shows the 5-day average number of reinforcements per 100 min for days 1 through 15 for the groups that responded on the DRL 64-sec component in the presence of S2. Both individual and group averages are shown. For the DRL 8-64 group the reinforcement rate increased over the three 5-day blocks, although some individual exceptions occurred. For the DRL 64 group, the mean average reinforcement rate increased to its maximum value during days 6 to 10 and remained at about that level for days 11 to 15. Note that both groups have equal reinforcement frequencies for the 11-15 day block.

| Reinforcements Per 100 Minutes | | | | | | | |
|--|----------|-----------|-------------|--|--|--|--|
| Subjects | Days 1-5 | Days 6-10 | Days 11-15 | | | | |
| Multiple DRL 8-sec - <u>DRL 64-sec</u> | | | | | | | |
| 382 | 3.4 | 2.5 | 4.4 | | | | |
| 2,450 | 3.1 | 3.1 | 5.6 | | | | |
| 1,169 | 2.5 | 2.5 | 4.5 | | | | |
| 540 | 3.7 | 8.1 | 6.2 | | | | |
| 347 | 1.8 | 5.6 | 8.1 | | | | |
| 947 | 4.4 | 5.0 | 6.8 | | | | |
| Mean | 3.2 | 4.5 | 5.9 | | | | |
| DRL 64-sec | | | | | | | |
| 387 | 2.5 | 10.0 | 10.0 | | | | |
| 9 | 1.2 | 3.1 | 1.9 | | | | |
| 637 | 5.0 | 9.3 | 9.3 | | | | |
| 542 | 5.6 | 7.6 | 6.2 | | | | |
| 635 | 1.2 | 3.7 | 6.2 | | | | |
| 97 | 5.6 | 2.5 | 1.9 | | | | |
| | | | | | | | |
| Mean | 3.5 | 6.0 | 5.9 | | | | |
| Total Mean | 3.3 | 5.3 | 5.9 | | | | |

A two-factor AOV with repeated measures on one factor (three 5-day blocks) was carried out for comparisons between groups. The blocks effect was significant (F = 6.39, df 2/20, p < .001). There was no significant effect due to groups (F < 1) or the interaction of groups with blocks (F < 1).

Table 2 shows the 5-day average number of reinforcements per 100 min for the five 5-day blocks (days 16 to 20 of Phase I and days 1 to 20 of Phase II) for the component correlated with S1, the green (555 nm) stimulus, for the DRL 8-64 group and the DRL 8-Ext group. Again, both group averages and individual averages are shown as well as the combined average for both groups. The overall trend (combined group average) is for an initial decrease followed by a monotonically increasing rise in reinforcement frequency. This is also characteristic of the group averages for the DRL 8-64 group, while the DRL 8-Ext group did not show the initial drop. Note that within either group there are some animals whose reinforcement rate varies from the group average. Statistical comparison of the groups across the 5-day blocks indicated no significant differences due to groups (F < 1), blocks (F < 1), or the interaction of groups with blocks (F < 1).

Discussion

The data from this experiment lead to several conclusions. First of all, on the basis of the generalization

TABLE 2.--Reinforcements per 100 min for the five 5-day periods (days 16 to 20 of Phase I and days 1 to 20 of Phase II) for the multiple DRL 8-sec - DRL 64-sec group and the multiple DRL 8-sec - Ext group during the DRL 8-sec component (S2).

| Reinforcements Per 100 Minutes | | | | | | | |
|--|--|---|---|---|--|--|--|
| Subjects | Phase I Days 16-20 | Phase II Days 1-5 | Phase II Days 6-10 | Phase II Days 11-15 | Phase II Days 16-20 | | |
| Multiple <u>DRL 8-sec</u> - DRL 64-sec | | | | | | | |
| 382 2,450 1,169 540 347 947 Mean | $ \begin{array}{r} 164.2 \\ 418.1 \\ 125.3 \\ 240.9 \\ 306.4 \\ 121.0 \\ \end{array} $ | 208.3 180.9 123.9 212.1 203.2 135.2 177.2 | 205.9 245.9 141.7 251.1 208.4 157.3 201.7 | 213.7 295.7 217.9 251.9 173.2 148.1 216.8 | 268.5322.7128.5252.6220.1135.022.12 | | |
| Multiple <u>DRL 8-sec</u> - Ext | | | | | | | |
| 193 592 564 17 1,174 450 Mean | 382.9 145.9 182.0 154.8 195.6 82.0 190.5 | $ \begin{array}{r} 297.0 \\ 187.1 \\ 214.0 \\ 253.5 \\ 233.2 \\ 57.7 \\ \hline 207.1 \\ \end{array} $ | 351.4158.2230.6235.7334.267.3229.5 | 334.3281.5119.990.0421.592.9223.4 | 377.4 307.8 133.1 115.7 400.8 89.2 237.3 | | |
| Total Mean | 210.0 | 192.2 | 215.6 | 220.0 | 229.3 | | |

data of the DRL 64 group, it appears that discrimination training is not a necessary prerequisite for the production of inhibitory stimulus control. The data indicate that some positive reinforcement schedules, at least long DRL schedules, can produce inhibitory stimulus control. These animals did, however, show a reduction in the rate of responding from a previously established rate of responding.

Secondly, a reduction in the rate of responding during discrimination training does not always lead to inhibitory stimulus control. This is most evident from the data of the DRL 8-64 group, where only one out of six subjects showed a clear inhibitory gradient. This was the case even though all six birds clearly showed a rate reduction and discrimination between the two schedules.

The fact that the DRL 64 group produced an inhibitory generalization gradient while the DRL 8-64 group did not can only be attributed to the fact that the DRL 64 subjects were not given discrimination training. The groups did not differ with respect to asymptotic response rates on the DRL 64-sec component, they were not significantly different with respect to reinforcement rate, and they did not differ with respect to the total number of responses emitted during the generalization test.

The fact that the DRL 8-64 group did not show clear inhibitory stimulus control around the stimulus correlated with the DRL 64-sec component is somewhat

paradoxical since the DRL 64 group did. The literature suggests that discrimination training should heighten inhibitory stimulus control when compared to a nondiscrimination procedure. Just the opposite was found in this experiment. One possible explanation suggests itself from the generalization data of the DRL 8-Ext group. While several investigators (Honig et al., 1963; Terrace, 1964; Farthing & Hearst, 1968) have shown clear inhibitory gradients around a stimulus correlated with extinction after VI - Ext training, the extinction gradients for the DRL 8-Ext group were equivocal with respect to shape. Two animals failed to response enough to show any gradient. All animals emitted a low number of responses during the generalization test. The same number of presentations of six line-orientation stimuli was used in this experiment as was used by Farthing and Hearst in a generalization test after 16 sessions of VI 1-min - Ext training. They obtained clear inhibitory stimulus control around the stimulus correlated with extinction (a 1/8 in. black line on a white field). But their six subjects emitted three times as many total responses as the DRL 8-Ext subjects in the present experiment (1535 vs 452). This suggests that possibly the alternation of the DRL 8-sec schedule with either the DRL 64-sec schedule or extinction created a ceiling effect. The "maintained" rate of responding in this experiment was approximately nine responses per min while the VI 1-min

schedule used by Farthing and Hearst maintained an average rate of responding of 70 responses per min. This does not negate any conclusions drawn with respect to the DRL 64 group. The animals in this group did not have any "reference" rate of responding, at least for 15 days, and thus there was no other conditioned low rate.

One problem with this explanation is that the total number of responses for the DRL 8-64 group and the DRL 64 group did not differ significantly during generalization testing, although the total was slightly higher for the DRL 64 group. A more hypothetical explanation may be that inhibitory stimulus control around a given stimulus indicates that the particular stimulus is aversive. Further, a stimulus is only aversive in a relative sense as Guttman (1959) suggested. Applying this explanation to the present data, the DRL 64-sec schedule and extinction were not particularly aversive when contrasted with a DRL 8-sec schedule, a schedule which maintains a rather low rate of responding when compared to most other reinforcement schedules. For the DRL 64 group there was no other conditioned low rate stimulus in the animals' immediate past history. Therefore, any aversiveness conditioned to the DRL 64-sec schedule would not be dissipated by reference to another low rate schedule. A logical extension of this hypothesis would be that increasing the rate of responding in the presence of S1 would lead to greater inhibitory stimulus

control in S2, provided that S2 rates are approximately equal.

The generalization gradients around the stimulus correlated with the DRL 8-sec component were clearly excitatory. This is in contrast to the results of Hearst et al. (1964) who found that the generalization gradients around a DRL 6- or 10-sec stimulus were essentially flat. The present gradients were taken after discrimination training and after a prior generalization test, two operations which tend to sharpen stimulus control. The significant point is that a DRL schedule can lead to excitatory stimulus control.

As previously mentioned, behavioral contrast refers to a change in the rate of responding in the constant component of a multiple schedule in a direction away from the change in the rate of responding in the other component (Reynolds, 1961a). Terrace (1968) concluded that "reducing the rate of responding to a discriminative stimulus by extinction, by changing from a VI 1-min to a VI 5-min schedule of reinforcement, by a DRL schedule, or by electric shock punishment are functionally equivalent in that in each case, (behavioral) contrast and the peak shift result [p. 737, my parentheses]." The results of the present experiment indicate that some of these operations do not always produce behavioral contrast. For the DRL 8-Ext group behavioral contrast in the DRL 8-sec component did not occur, even

though there was a clear and immediate reduction in the response rate in the extinction component. For the DRL 8-64 group a significant rate increase was found for the first five days of discrimination training compared to the five baseline days. But this rate increase averaged only 1.1 responses per min and did not persist past the first five days of Phase II as would normally be the case. Reynolds and Limpo (1968) found that behavioral contrast developed gradually over 15 days and was greatest for days 11 through 15, when the constant component was a DRL 35-sec schedule. Considering the low magnitude and the brevity of the rate change for the DRL 8-64 group, the rate increase of this group during the DRL 8-sec component is uncharacteristic of the normal contrast phenomenon. The general lack of behavioral contrast in this experiment suggests that a reduction in the rate of responding in one component does not always lead to an increased rate of responding in the constant component.

EXPERIMENT II

The procedure used in the first experiment was somewhat unusual in that each unreinforced response was followed by darkening the response key for 0.8 sec (feedback). This was done because past experiments had indicated that (1) short IRTs (less than 0.8 sec) were not under stimulus control (Blough, 1963, 1966), and (2) short IRTs accounted for the major part of the rate increase during discrimination training when a DRL schedule was the constant component (Reynolds & Limpo, 1968; Reynolds & Catania, 1961). Experiment II was undertaken (1) to determine the effect of this feedback on the rate of responding, particularly during discrimination training, and (2) to determine the possible effect of feedback on the generalization gradients.

Method

Subjects

The subjects were 18 naive White Carneaux female pigeons, ranging in age from six to 10 years, maintained at 80 per cent of their free-feeding weight.

Apparatus and Procedure

All aspects of the apparatus and procedure of this experiment were identical to the first with one exception. After each unreinforced peck the key light remained illuminated. The key light was darkened only during reinforcement and during the 10 sec between 4-min periods.

To briefly summarize the procedure, all animals were given 20 days of training on a multiple DRL 8-sec -DRL 8-sec schedule (Phase I). Then the birds were divided into three groups of six each (Phase II). One group received 15 days of multiple DRL 8-sec - DRL 64-sec training, the second group 15 days of multiple DRL 8-sec - Ext training, and the third 15 days of DRL 64-sec training. The DRL 64-sec schedule and extinction were correlated with the white vertical line on the green background. After the 15th day of Phase II all animals were given a generalization test along the line-orientation dimension as in Experiment I. The two discrimination groups were then given five additional days of Phase II training, followed on the next day by a generalization test along the wavelength dimension.

Results

Generalization Gradients

Figures 7, 8, and 9 show the individual generalization data, expressed as a function of the number of responses to each of the six line-orientation stimuli, for

Figure 7.--Individual generalization gradients, expressed in terms of number of responses to each of the six generalization stimuli, after exposure to the white vertical line correlated with the DRL 64-sec component during discrimination training in Phase II.



Figure 8.--Individual generalization gradients, expressed in terms of number of responses to each of the six generalization stimuli, after exposure to the white vertical line correlated with the extinction component during discrimination training in Phase II.

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Figure 9.--Individual generalization gradients, expressed in terms of number of responses to each of the six generalization stimuli, after exposure to the white vertical line correlated with the DRL 64-sec contingency during non-differential training in Phase II.



the multiple DRL 8-sec - DRL 64-sec group, the multiple DRL 8-sec - Ext group, and the DRL 64-sec group, respectively. For the multiple DRL 8-sec - DRL 64-sec group (DRL 8-64 group), two birds show excitatory gradients (Birds 109 and 2618) while the other four birds show either flat (Bird 17) or inhibitory gradients. The individual gradients for the multiple DRL 8-sec - Ext group (DRL 8-Ext group) are similar to the gradients of the corresponding group in Experiment I. Again, two birds (275 and 242) emitted too few responses for any conclusions to be drawn about a gradient. The gradient for one bird is excitatory (Bird 29), while the remaining gradients are inhibitory. The individual gradients for the DRL 64-sec group (DRL 64 group) show the most variability. Two of the gradients are excitatory (Brids 185 and 3821), two are flat (Birds 298 and 23), one is inhibitory (Bird 658), and the sixth is nonsymmetrical.

Figure 10 shows the mean number of responses for the three groups at each of the line-orientation stimuli. It is clear by inspection that neither the DRL 8-64 nor the DRL 64 group gradients are inhibitory. The DRL 8-Ext group gradient is flat with a very slight inflection for the $\pm 90^{\circ}$ stimulus. A subjects by treatments (stimuli) repeatedmeasures AOV was performed for each group gradient. The statistical analysis of the absolute number of responses across various stimuli revealed no significant effect for

Figure 10.--Group generalization gradients, expressed in terms of the mean number of responses per group to each of the six generalization stimuli, in the presence of the white vertical line. The appropriate component is underlined for each group.



either the DRL 8-64 group (F < 1), the DRL 8-Ext group (F = 1.45, df 5/25, p > .20), or the DRL 64 group (F < 1).

A two-factor AOV with repeated measures on one factor (stimuli) was performed for comparisons between groups. Statistical comparison of the DRL 8-64 group and the DRL 8-Ext group indicated that there was a significant effect due to groups (F = 9.16, df 1/10, p < .025), but no significant effect due to stimuli (F < 1) or to the interaction of groups and stimuli (F < 1). Statistical comparison of the DRL 8-64 group gradient with the DRL 64 group gradient indicated no significant differences due to either groups, stimuli, or the interaction of groups and stimuli (all F values less than 1). Comparisons between the DRL 8-Ext group and the DRL 64 group showed no significant difference due to groups (F = 4.43, df 1/10, .05),no significant effect due to stimuli (F < 1), and no significant interaction (F < 1). Therefore, the only significant difference found in the generalization data was that the DRL 8-Ext group emitted significantly fewer responses during the generalization test than did the animals in the DRL 8-64 group.

Both the DRL 8-64 group and the DRL 8-Ext group were given a second generalization test along the wavelength dimension, the dimension correlated with the DRL 8-sec component. Again, the general tendency was for an excitatory gradient reaching a peak at the training stimulus (555 nm),

with the fewest number of responses at the peripheral stimuli (501 and 606 nm). Two birds in the DRL 8-64 group and one bird in the DRL 8-Ext group showed a slight deviation from this pattern with a maximum number of responses at either 538 or 576 nm.

Figure 11 shows the mean number of responses for both groups at each of the five wavelength stimuli. Both group gradients are excitatory and symmetrical. Statistical analysis of the absolute number of responses during generalization revealed that the effect of stimuli was significant for both the DRL 8-64 group (F = 9.79, df 4/20, p < .001) and the DRL 8-Ext group (F = 15.69, df 4/20, p < .001). Statistical comparison of the group gradients with each other indicated no significant difference due to groups (F < 1) and no significant interaction (F < 1). Of course the overall effect of stimuli was highly significant (F = 23.73, df 4/40, p < .001).

Response Rates

Figure 12 shows the mean daily response rates of both discrimination groups for the DRL 8-sec component (S1) and the mean daily response rates of all groups for either the DRL 64-sec component (the DRL 8-64 group and the DRL 64 group) or Ext (the DRL 8-Ext group). This component is designated as S2. The points at Session O represent the group mean average for the last five days (days 16 to 20) of Phase I (acquisition) training. These last five days of

Figure 11.--Group generalization gradients expressed in terms of the mean number of responses per group to each of the five wavelength stimuli, around the 555 nm stimulus which was correlated with the DRL 8-sec component for both groups during discrimination training in Phase II.


Figure 12.--Daily average group response rates (responses per min) during Phase II for the component correlated with S1, the 555 nm stimulus, and the component correlated with S2, the white vertical line. The point at "Session O" represents a group average response rate for each particular component during the last five days of Phase I.



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Phase I were chosen as the baseline rate of responding since inspection of the data indicated that the rate of responding had reached an asymptotic level and showed little day-to-day change. Therefore, these last five days will be used to determine whether the daily response rates changed during Phase II.

As in Experiment I it is clear that all three groups showed a reduction in the rate of responding in the presence of S2. Considering days 1 through 15 of Phase II, three birds in the DRL 8-64 group exceeded the baseline rate on one day each, and one bird in the DRL 64 group exceeded the baseline rate on one day. All other individual daily response rates were below the average 5-day baseline.

Statistical comparisons of the three groups with each other were carried out using the average rate of responding per group in the presence of S2 for days 11 through 15 of Phase II. These comparisons were made because the rates of responding were asymptotic by this time, and also because these days just preceded the line-orientation generalization test. The analysis indicated that the average rate of responding for the DRL 8-64 group differed significantly from the DRL 8-Ext group (t = 3.65, df 5, p < .02, two-tailed). These two groups also differed significantly in the total number of responses emitted during the line-orientation generalization test. Neither the average response rates of the DRL 8-64 group nor the

response rates of the DRL 8-Ext group differed significantly from the DRL 64 group (t = 1.18, df 5, p > .10; t = 2.49, df 5, p > .05, respectively, two-tailed).

Inspection of the daily response rates during the DRL 8-sec component (S1), shown in Figure 12, for the DRL 8-64 group and the DRL 8-Ext group during Phase II shows an increase in the rate of responding. With the exception of the first day for the DRL 8-64 group, every daily average response rate for both groups during Phase II is higher than the baseline rate. In general the rates of responding tended to increase across the 15 days of Phase II with the largest change occurring during the first five days, although there was considerable day-to-day variability. For days 11 through 15 the average increase from the baseline was 2.0 responses per minute for DRL 8-64 group and 2.6 responses for the DRL 8-Ext group.

For statistical analysis the rates of responding were grouped into 5-day blocks, thus collapsing the data into five blocks (the last five days of Phase I and 20 days of Phase II). A two-factor AOV with repeated measures on one factor was performed using the response rates during the DRL 8-sec component for the DRL 8-64 and the DRL 8-Ext groups across the five 5-day blocks. The results showed no significant effect due to groups (F < 1) and no significant interaction between groups and 5-day blocks (F < 1). However, the effect of the 5-day blocks was significant

(F = 4.27, df 4/40, p < .01). In order to determine which 5-day means differed from each other, a Newman-Keuls test was performed. The results indicated that each 5-day mean during Phase II was significantly higher than the baseline (p < .01 for each comparison). In addition, the mean for days 16 through 20 was found to be significantly higher than the mean for days 1 through 5 of Phase II. All other comparisons were not significant (p < .05). This result indicates that, for this experiment, discrimination training in general led to behavioral contrast; i.e., an increase in the rate of responding in the constant component.

Reinforcement Rates

Table 3 shows the 5-day average number of reinforcements per 100 min for days 1 through 15 for the groups that responded on the DRL 64-sec component in the presence of S2. Both individual and group averages are shown. For the DRL 8-64 group the reinforcement rate increased to its maximum value during the second 5-day block, and then showed a slight decrease for days 11 through 15. For the DRL 64 group the mean average reinforcement rate decreased during days 6 through 10 when compared to days 1 through 5. The reinforcement rate then increased to its maximum for days 11 through 15. For both groups there are large individual differences in magnitude and in pattern across the three 5-day blocks.

| Reinforcements Per 100 Minutes | | | | | | | | | |
|--|----------|-----------|---------------------|--|--|--|--|--|--|
| Subjects | Days 1-5 | Days 6-10 | Da ys 11- 15 | | | | | | |
| Multiple DRL 8-sec - <u>DRL 64-sec</u> | | | | | | | | | |
| 508 | 6.2 | 8.1 | 7.9 | | | | | | |
| 216 | 5.6 | 5.0 | 3.0 | | | | | | |
| 109 | 1.9 | 2.5 | 1.9 | | | | | | |
| 17 | 4.3 | 9.3 | 13.7 | | | | | | |
| 2,618 | 5.6 | 12.1 | 8.7 | | | | | | |
| 19 | 7.0 | 6.2 | 5.6 | | | | | | |
| Mean | 5.1 | 7.2 | 6.8 | | | | | | |
| DRL 64-sec | | | | | | | | | |
| 23 | 13.1 | 8.1 | 11.2 | | | | | | |
| 185 | 5.0 | 5.0 | 5.0 | | | | | | |
| 3,821 | 3.7 | 3.7 | 6.2 | | | | | | |
| 110 | 3.1 | 6.2 | 6.8 | | | | | | |
| 298 | 5.0 | 5.7 | 7.0 | | | | | | |
| 658 | 4.3 | 3.7 | 9.3 | | | | | | |
| | | | | | | | | | |
| Mean | 5.7 | 5.4 | 7.6 | | | | | | |
| Total Mean | 5.4 | 6.3 | 7.2 | | | | | | |

A two-factor AOV with repeated measures on one factor (three 5-day blocks) was carried out for comparisons between groups. There was no significant effect due to groups (F < 1), blocks of days (F = 2.23, df 2/20, p > .10), or the interaction of blocks with groups (F = 1.44, df 2/20, p > .20).

Table 4 shows the 5-day average number of reinforcements per 100 min for the five 5-day blocks (days 16 to 20 of Phase I and days 1 to 20 of Phase II) for the DRL 8-sec component correlated with S1 for the DRL 8-64 group and the DRL 8-Ext group. The reinforcement rates for the DRL 8-64 group were monotonically decreasing across the five blocks of days, while the reinforcement rate for the DRL 8-Ext group decreased and then increased. This was also the case for the combined mean reinforcement rate. Again, within either group, there were some animals whose reinforcement rate varied from the group average.

Statistical comparison of the groups across the 5-day blocks again indicated no significant differences due to either groups (F = 1), blocks (F = 1.11, df 4/40, p > .20), or the interaction of groups with blocks (F = 2.53, df 4/40, p > .05). Thus, even though there was a significant increase in the rate of responding during the DRL 8-sec component for the discrimination groups in this experiment there were no significant changes in the reinforcement rate, although there was a slight drop initially. The largest decrease in reinforcement rate occurred between the

Reinforcements Per 100 Minutes Phase I Phase II Phase II Phase II Phase II Subjects Days Days Days Days Days 16-20 1-5 6-10 11-15 16-20 Multiple DRL 8-sec - DRL 64-sec 508 129.7 92.8 118.1 117.5 136.5 216 226.8 226.3 201.9 163.0 78.4 109 376.6 352.8 284.2 266.3 288.3 17 297.8 70.4 59.6 111.8 85.5 2,618 292.0 267.7 212.6 234.6 233.6 19 284.9 349.4 332.8 367.5 336.8 215.2 184.1 251.3 208.7 223.4 Mean Multiple DRL 8-sec - Ext 275 316.8 338.6 243.1 256.2 361.9 245 304.5 306.7 309.4 374.7 240.4 242 121.8 148.4 173.4 125.9 88.1 833 274.5 239.3 227.9 241.7 287.4 757 216.6 211.0 310.9 345.7 335.2 29 107.6 126.0 88.9 61.6 44.8 232.2 216.9 260.5 224.6 203.9 Mean Total 241.8 210.0 212.8 222.3 Mean 224.0

TABLE 4.--Reinforcements per 100 min for the five 5-day periods (days 16 to 20 of Phase I and days 1 to 20 of Phase II) for the multiple DRL 8-sec - DRL 64-sec group and the multiple DRL 8-sec - Ext group during the DRL 8-sec component (S2).

baseline days and days 6 through 10. For 10 out of 12 animals the average reinforcement rate was lower for days 6 through 10 when compared to the five baseline days.

Feedback and Generalization Gradients

The overall effect of feedback can best be seen by comparing the subjects in Experiment I (feedback) with those in Experiment II (no feedback). In addition, the overall effect of the schedule contingencies in S2 were of im-Therefore, a three-factor AOV with repeated portance. measures on one factor (stimuli) was carried out for each of the three possible comparisons for the generalization gradients along the line-orientation dimension. The results of comparing the DRL 8-64 groups with the DRL 8-Ext groups in both experiments are shown in Appendix A. This analysis indicated that the only significant difference was due to the schedule contingency (p < .01). This means that the DRL 8-Ext groups emitted fewer responses during the generalization test than the DRL 8-64 groups. There was no significant effect due to feedback or stimuli, and no significant interactions.

The results of the statistical comparison of the DRL 8-64 groups with the DRL 64 groups in both experiments are shown in Appendix B. In view of the past analyses it is not surprising that the results yielded no significant effects due to feedback, schedule contingencies, stimuli, and no significant interactions.

The DRL 64 groups were also compared with the DRL 8-Ext groups in both experiments. This statistical comparison (Appendix C) indicated a significant effect due to the schedule contingency (p < .05). This result indicates that the DRL 8-Ext groups emitted significantly fewer responses during the generalization test than the DRL 64 groups. The overall effect of feedback and of stimuli was not significant. Of the four interactions, only the Feedback X Stimuli interaction was significant (p < .05). This result, combined with inspection of the data and previous results, indicates that the gradient for these two feedback groups is inhibitory and of different shape than the combined gradient for the no-feedback groups. Further analysis indicated that this interaction was primarily due to the difference in the gradients of the DRL 64 groups. Statistical comparison of the DRL 64 feedback gradient with the DRL 64 no-feedback gradient showed no group effect (F < 1), no treatment effect (F < 1), but a significant groups and treatments interaction (F = 2.66, df 5/50, p < .05). On the other hand, the same comparison for the two DRL 8-Ext groups yielded a significant treatments effect (F = 2.89, df 5/50, p < .05), but no significant group (F < 1) or interaction effect (F < 1).

The generalization gradients along the wavelength dimension were also analyzed in a similar manner. A 2 X 2 X 5 (repeated measures) AOV indicated that there was

a significant effect due to feedback (p < .005, Appendix D). This indicates that the feedback groups (Experiment I) emitted fewer responses during the generalization test along the wavelength dimension than did the no-feedback groups. As would be expected there was a significant effect due to stimule (p < .001), indicating an excitatory generalization gradient. The only other significant effect was due to the interaction of feedback with stimuli (p < .05). At first glance this result suggests that the combined gradients for the feedback vs. no-feedback groups have a different shape, but this is a matter of interpretation. The statistical analysis measures the mean difference in the number of responses across the five wavelength stimuli. The analysis indicates that at least two of these means are different. Psychologically, the important datum is the per cent of each groups total responses emitted at each point. Table 5 shows both the total number of responses and the per cent of each groups total responses for the feedback and no-feedback groups, as well as the difference, across the five wavelength stimuli. It is clear that the difference in the number of responses differs across the five wavelength stimuli, but the percentages do not. Therefore, the shape of the two gradients do not differ.

In summary, the feedback variable generally had little effect on the gradients along the line-orientation dimension. Only the combined effect of the DRL 64-sec

| TABLE | 5Th | e tota | al nu | mber | of | respo | nses | and | the | per | cent | of |
|-------|--------|--------|-------|-------|------|-------|------|------|-------|-------|--------|----|
| each | groups | total | resp | onses | s at | each | of | the | five | wave | elengt | :h |
| | stimul | i for | the | feed | ack | and | no-f | eedb | ack s | stimu | ıli. | |

| | Number of Responses | | | | | | |
|-------------|---------------------|--------|------------|----------|--------|--|--|
| | 501 nm | 538 nm | 555 nm | 576 nm | 606 nm | | |
| Feedback | 172 | 407 | 591 | 428 | 214 | | |
| No-Feedback | 297 | 655 | 889 | 660 | 247 | | |
| Difference | 125 | 248 | 298 | 232 | 37 | | |
| | | Per (| Cent of Re | esponses | | | |
| Feedback | 09 | 22 | 33 | 24 | 12 | | |
| No-Feedback | 11 | 24 | 32 | 24 | 09 | | |
| Difference | 02 | 02 | 01 | 00 | 03 | | |

contingency in isolation and feedback produced a reliable single-group inhibitory gradient. Feedback led to fewer responses during the generalization test along the wavelength dimension but no difference in the shape of the gradients. With respect to schedule contingencies, the Ext component for the DRL 8-Ext groups led to fewer responses during generalization testing than for either the DRL 8-64 group or the DRL 64 group.

Feedback and S1 Response Rates

The determination of the effect of feedback on the rate of responding in the DRL 8-sec component (S1) was a primary reason for Experiment II. Since the response rates during the DRL 8-sec component for the DRL 8-64 groups and for the DRL 8-Ext groups did not differ from each other in Experiment I or Experiment II, the data were collapsed into two groups: feedback (F) and no feedback (NF). Figure 13 shows the daily mean response rates for days 6 through 20 of Phase I and days 1 through 20 of Phase II for the feedback subjects and the no-feedback subjects. The vertical lines indicate +1 standard error of the mean for each point. It is obvious that the no-feedback group maintained a higher rate of responding, since every daily rate is higher for this group than for the feedback group, and the daily pairs of standard errors never overlap. It is also apparent that the response rate variability is greater for the no-feedback group. For every daily comparison but

(F) Figure 13.--The average daily response rates for the feedback groups and the no-feedback (NF) groups combined during the DRL 8-sec component for days 6 to 20 of Phase I and days 1 to 20 of Phase II. The vertical lines at each point represent \pm 1 standard error of the mean for each group.



one the standard error was greater for the no-feedback . group.

Of particular interest was the effect of discrimination training (Phase II) on the rate of responding in the S1 component. The curve for the feedback group shows a slight rise on day two of discrimination training from the baseline level, followed by a general slow and slight decrease in the rate. The curve for the no-feedback group shows a sharper increase in the rate of responding at the onset of discrimination training, followed by a slower but general increase in the rate of responding. Between days 15 and 16 of Phase II, the line-orientation generalization test was administered. It can be seen from Figure 13 that this generalization test was followed on the next day by a sharp increase in the rate of responding for the no-feedback subjects but little change for the feedback group.

Statistical comparisons between the feedback and no-feedback groups were not carried out due to the difference in variability. But previous analyses showed that the feedback subjects showed no significant response rate changes (Experiment I) while the no-feedback subjects showed a significantly higher rate of responding for each of the four 5-day periods of Phase II compared to the last five days of Phase I. The conclusion is that the nofeedback subjects showed behavioral contrast while the feedback subjects did not.

Figure 14 shows the per cent of the total number of responses which had IRTs of 0.8 sec or less for the feedback and no-feedback groups for days 6 through 20 of Phase I and days 1 through 20 of Phase II. Daily standard errors for each group are also shown. The difference in the per cent of bursts is quite clear. Also, the difference in variability is large and stable. After day 10 of Phase I each daily standard error for the feedback group is smaller than for the no-feedback group. For Phase II the standard error of the no-feedback group is about five times that of the feedback group.

There is little change in the per cent of 0.8 sec IRTs for the feedback group. After day 10 of Phase I the range of values was from a maximum of 3.3 per cent to a minimum of 1.8 per cent. In contrast, the per cent of 0.8 sec IRTs shows much more day-to-day variability for the nofeedback group. The per cent shows an irregular decrease during Phase I to a minimum at day 20. This is followed by an increase during Phase II. During Phase II the per cent of 0.8 sec IRTs varied between 30 and 36 per cent. This percentage is very similar to the percentage increase in the rate of responding of the no-feedback group over the feedback group. The data suggest that the majority of the difference in the rate of responding of the feedback and no-feedback groups is accounted for by the per cent of 0.8 sec IRTs.

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Figure 14.--The average daily per cent of the total responses with IRTs of 0.8 sec or less for the feedback (F) and the no-feedback (NF) groups combined during the DRL 8-sec component for days 6 to 20 of Phase I and days 1 to 20 of Phase II. The vertical lines at each point represent \pm 1 standard error of the mean for each group.





Discussion

The generalization data along the line-orientation dimension in Experiment II were similar to the data obtained in Experiment I for the DRL 8-64 group and the DRL 8-Ext group. Although the removal of feedback led to a higher rate of responding in the DRL 8-sec component, there was no significant difference in the total number of responses emitted during the generalization test for either group, and neither group gradient was inhibitory. At the end of Experiment I it was suggested that one possible reason for the flat generalization gradients around a stimulus correlated with either a DRL 64-sec schedule or extinction after discrimination training was the low rate of responding maintained in the constant (DRL 8-sec) component. In Experiment I the response rate in the DRL 8-sec component for these groups was between 8.5 and 9.0 responses per min, whereas in Experiment II it was between 14.0 and 15.0 responses per min just prior to the generalization test. Therefore, the present data do not support the hypothesis that it is primarily the rate of responding in the constant component, given similar response rates in the other component, which determines whether or not an inhibitory generalization gradient is obtained in the other component. On the other hand, a rate of 15 responses per min is still a comparatively low rate for pigeons since they can emit responses at the rate of 100 per min. A more adequate test

of this hypothesis could be achieved by using a yoked design. For example, one subject would respond on a DRL 8-sec schedule. Each time this animal obtained a reinforcement, its yoked-control would also receive a reinforcement for the next response. In other words the yoked animal would not have to delay between responses. This procedure should generate different rates of responding but nearly equal rates of reinforcement. During discrimination training the subjects would remain yoked during the constant component but would respond independently during the other component (either DRL 64-sec or extinction). Such a procedure would yield data which might directly indicate the role the rate of responding in the constant component plays in determining the occurrence of inhibitory stimulus control in the other component.

The group and individual gradients of the DRL 64 group in Experiment I were clearly inhibitory whereas in Experiment II they were not. Since the only difference between groups was the feedback variable, the conclusion is that feedback leads to greater stimulus control. Feedback does not always lead to greater stimulus control, however. The feedback procedure did not lead to greater stimulus control for the DRL 8-64 group or the DRL 8-Ext group on either the line-orientation dimension or the wavelength dimension. But these groups were given standard discrimination training whereas the DRL 64 group was not. Possibly

feedback exerts its greatest effect only when discrimination training has not occurred.

The data presented in Figures 13 and 14 indicate that providing explicit feedback for each unreinforced response can produce strong effects on the rate of responding. In general feedback led to a lower rate of responding, and it appeared that the majority of the rate reduction was due to the reduction in the per cent of 0.8-sec IRTs. More importantly, subjects given feedback did not show behavioral contrast, while subjects run under the standard procedure (no feedback) did show behavioral contrast. The magnitude and time-course of the increase in the rate of responding for the no-feedback group agreed closely with the data obtained by both Reynolds and Catania (1961) and Reynolds and Limpo (1968). In conclusion, the response rate data show that behavioral contrast does not always result when the rate of responding is reduced during discrimination training by either a DRL schedule or extinction. It may be that this conclusion only holds when a DRL schedule is the constant component. The data also suggest that behavioral contrast may be accounted for to a large extent by an increase in short IRTS, IRTs which Blough (1963, 1966) has shown are not under schedule control. In order to determine the generality of these findings, providing feedback to subjects responding on a multiple VI - Ext schedule is indicated.

The fact that providing feedback for each unreinforced peck greatly reduced the number of 0.8-sec IRTs suggests that pigeons, at least on DRL schedules, do not completely learn or discriminate criterion responses (activation of the microswitch behind the response key) from non-criterion responses. One consistent behavior which this investigator has observed is that subjects responding on a DRL schedule, where no extra feedback is provided, often approach the response key and peck at it many times in rapid succession. This was clearly the case for the no-feedback subjects in the present experiment. The important point is that the subjects often pecked at the key without hitting it. There can be no mistake that this occurred since it was frequently observed that the subject pecked at the key several times in rapid succession, and the last of these responses was reinforced. It was precisely this observation in previous work, combined with Blough's (1963, 1966) data and suggestions, which prompted the manipulation of feedback in the present experiment. The pecking behavior of the subjects given feedback was quite different. After the first few days of training pecks at the key were virtually 100 per cent accurate. In other words, almost all pecking motions toward the key activated the microswitch. This was easily determined through observation since each criterion peck was followed by darkening of the response key for 0.8 sec.

These observations complement the recorded data. As Figure 14 shows, approximately 30 per cent of all responses of the no-feedback subjects had IRTs of 0.8 sec. This is not at all unusual for pigeons on a DRL schedule. For the feedback subjects IRTs of 0.8 sec or less accounted for only about 2 per cent of the total responses after about 10 days of acquisition training.

These data and observations suggest the possibility that behavioral contrast may, in part, be due to incomplete learning of the appropriate response, and that discrimination training leads to sharper discrimination of the appropriate, reinforced response. One possible hypothesis is that discrimination training not only leads to stimulus differentiation, but also to response differentiation. The data from the present experiments indicate that, when feedback is provided for the criterion response, response differentiation preceded the onset of discrimination training. When this had occurred, behavioral contrast did not result.

One way to test the hypothesis that response differentiation contributes to behavioral contrast would be to establish two completely different operants in the presence of two different sets of stimuli within the same subject. Then, extinction of one response should have little effect on the other response. If this hypothesis is correct, no contrast should result. On the other hand, using the

dimension of response similarity, the more similar the two responses, the greater will be the amount of behavioral contrast when one response is extinguished. REFERENCES

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APPENDICES

APPENDIX A

| Source of Variance | SS df | | MS | F | p | |
|-----------------------|----------|-----|---------------|------|------|--|
| Between Ss | 32320.23 | 23 | | | | |
| A (Feedback) | 272.25 | 1 | 272.25 | <1 | | |
| B (Schedule) | 8993.37 | 1 | 8993.37 | 8.68 | <.01 | |
| AB | 2336.11 | 1 | 2336.11 | 2.26 | >.10 | |
| Error | 20718.50 | 20 | 1035.88 | | | |
| Within Ss | 6704.33 | 120 | | | | |
| C (Stimuli) | 225.14 | 5 | 45.03 | <1 | | |
| AC | 90.34 | 5 | 18.07 | <1 | | |
| BC | 369.38 | 5 | 73.88 | 1.26 | >.20 | |
| ABC | 134.30 | 5 | 26.8 6 | <1 | | |
| Error | 5885.17 | 100 | 58.85 | | | |

TABLE A-1.--Summary table for the analysis of variance for the DRL 8-64 groups, with and without feedback, and the DRL 8-Ext groups, with and without feedback, for the generalization gradients along the line-orientation dimension.

APPENDIX B
| Source of Variance | SS | df | MS | F | p |
|-----------------------|----------|-----|---------|------|------|
| Between Ss | 30398.31 | 23 | | | |
| A (Feedback) | 305.39 | 1 | 305.39 | <1 | |
| B (Schedule) | 106.78 | 1 | 106.78 | <1 | |
| AB | 2241.30 | 1 | 2241.30 | 2.16 | >.10 |
| Error | 27744.84 | 20 | 1038.24 | | |
| <u>Within Ss</u> | 10812.33 | 120 | | | |
| C (Stimuli) | 116.97 | 5 | 23.39 | <1 | |
| AC | 493.61 | 5 | 98.72 | 1.09 | >.20 |
| BC | 297.39 | 5 | 59.48 | <1 | |
| ABC | 818.53 | 5 | 163.71 | 1.80 | >.10 |
| Error | 9085.83 | 100 | 90.86 | | |

TABLE B-1.--Summary table for the analysis of variance for the DRL 8-64 groups, with and without feedback, and the DRL 64 groups, with and without feedback, for the generalization gradients along the line-orientation dimension.

APPENDIX C



| Source of Variance | SS | df | MS | F | p |
|-----------------------|----------|-----|-----------------|------|------|
| Between Ss | 31083.23 | 23 | | | |
| A (Feedback) | 950.70 | 1 | 950.70 | <1 | |
| B (Schedule) | 7140.25 | 1 | 7140.25 | 6.21 | >.05 |
| AB | 1.00 | 1 | 1.00 | <1 | |
| Error | 22991.28 | 20 | 1149.56 | | |
| Within Ss | 6816.33 | 120 | | | |
| C (Stimuli) | 300.39 | 5 | 60.80 | 1.16 | >.20 |
| AC | 633.47 | 5 | 12 6. 69 | 2.41 | <.05 |
| BC | 110.92 | 5 | 22.18 | <1 | |
| ABC | 520.16 | 5 | 104.03 | 1.98 | >.05 |
| Error | 5251.39 | 100 | 52.51 | | |

TABLE C-1.--Summary table for the analysis of variance for the DRL 64 groups, with and without feedback, and the DRL 8-Ext groups, with and without feedback, for the generalization gradients along the line-orientation dimension.

APPENDIX D

| Source of Variance | SS | df | MS | F | p |
|-----------------------|----------|----|---------|-------|-------|
| Between Ss | 22040.80 | 23 | | | |
| A (Feedback) | 7300.80 | 1 | 7300.80 | 10.27 | <.005 |
| B (Schedule) | 128.13 | 1 | 128.13 | < 1 | |
| АВ | 388.80 | 1 | 388.80 | < 1 | |
| Error | 14223.07 | 20 | 711.15 | | |
| Within Ss | 50373.20 | 96 | | | |
| C (Stimuli) | 32322.91 | 4 | 8080.73 | 42.98 | <.001 |
| AC | 1901.11 | 4 | 475.28 | 2.53 | <.05 |
| BC | 535.95 | 4 | 133.99 | < 1 | |
| ABC | 574.29 | 4 | 143.57 | < 1 | |
| Error | 15038.93 | 80 | 187.99 | | |
| | | | | | |

TABLE D-1.--Summary table for the analysis of variance for the DRL 8-64 groups, with and without feedback, and the DRL 8-Ext groups, with and without feedback, for the generalization gradients along the wavelength dimension.

