

## TWO TYPES OF BEHAVIORAL CONTRAST IN DISCRIMINATION LEARNING<sup>1</sup>

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Two groups of pigeons received daily discrimination training at two values on a line-tilt continuum. S+ (VI 1) and S- (EXT) intervals alternated, and a 30-sec criterion of no responding to S- was required before S+ returned. Rates of responding to S+ showed two separate contrast effects: at an intermediate stage of training a high peak rate appeared which declined, later in training, to a stable level still in excess of the VI baseline rate. The peak rate was correlated with the total number of responses to S-, while the final rate was not; suggesting that the peak rate and final rate may not be functions of the same variable. These results were compared with performance on a red-green discrimination where the two stages were not so clear. A line-tilt discrimination was repeated with fixed length S- intervals terminated by TO, and showed the same contrast magnitude in the final rate without any peak. The peak rate was interpreted as an effect of the 'punishment' contingency where responding to S- prolongs S- for 30 sec, while the final rate was taken to be analogous to previous demonstrations of contrast.

In studies of the acquisition of a successive discrimination several different techniques of discrimination training have been employed. The basic procedure is always to reinforce a response in the presence of one stimulus (S+) and not reinforce it in the presence of a second stimulus (S-). Hence, the procedure sometimes used (e.g., Reynolds, 1961a) is a multiple variable-interval extinction schedule (MULT VI EXT) in which S+ and S- intervals are of fixed length and occur in strict alternation. Hanson (1959) randomized the presentation of his S+ and S- stimuli and inserted a 10-sec time-out (TO) between them, while Terrace (1963a) set a 3-min criterion of no responding in S- before S+ could return. All these methods produced the phenomenon termed by Reynolds (1961a) "behavioral contrast"—an increase in rate of responding to S+ as opposed to a decrease in rate of responding to S-. In these experiments the stimuli were drawn from a wavelength continuum, although effects have been obtained with orientations of the apex of a triangle (Reynolds, 1961b), and other continua.

The effects of enforcing a period of no responding at the end of S- are to lengthen considerably the pigeon's exposure to this

stimulus and to produce a large number of responses in extinction during early training (Terrace, 1963a.) The present experiments compare performance on a line-tilt discrimination with and without this procedure, and check the results against a red-green discrimination situation similar to that used by Terrace (1963a, pp. 5-6).

### METHOD

#### *Subjects*

Twenty adult homing pigeons, locally obtained and experimentally naive at the outset, were maintained at 80-85% of their free-feeding body weights. Five birds were used in each experiment.

#### *Apparatus*

Two standard experimental boxes were used. Stimuli were projected on a translucent response key in each box by In-Line Digital Display Units. The keys were 3/4-in. in diameter, and required a minimum pressure of 15 g for operation. Reinforcement consisted of 4 sec access to a grain mixture. Sessions were programmed through relays, timers and counters in an adjoining room.

#### *Preliminary Procedure*

Subjects were adapted to the box, magazine trained and trained to peck the key on a fixed

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four day schedule. Thirty reinforcements on FR 1 were given after conditioning of the key peck, and on the fifth day 60 reinforcements were given on the same schedule. Next VI training began. A schedule with mean inter-reinforcement interval of 1 min was constructed from the progression given in Fleshler and Hoffman (1962). On this schedule the probability of reinforcement as a function of the time elapsed since reinforcement is roughly constant. One hour sessions of VI 1 were programmed each day for six days. During the conditioning of the peck and the FR 1 and VI 1 schedules S+ was projected on the key. The particular stimulus used and the subsequent discrimination training varied for different groups, and are described below in each experiment.

## EXPERIMENT I

### *Procedure*

The stimulus present during preliminary training was a  $\frac{1}{8}$ -in. wide vertical ( $0^\circ$ ) illuminated line on a dark background. After the six daily sessions on VI 1, discrimination training was introduced. MULT VI 1 EXT was in effect with the  $0^\circ$  line correlated with VI and a  $45^\circ$  line correlated with EXT. The duration of the S+ interval was fixed at 2 min, but S- intervals were prolonged until 30 sec elapsed with no responding. The minimum length of an S- interval was 2 min. S+ and S- intervals alternated, and a daily session consisted of 15 presentations of each stimulus. The training procedure continued for 10 days, after which it was judged that performance had stabilized.

### *Results*

All birds showed the same essential characteristics of performance (Fig. 1). Three stages may be differentiated. In the first 4 to 5 days of discrimination training more than 90% of all the responses to S- were made. During this phase response rate to S+ increased steadily, apart from a drop on the first day. The second stage occurred from day 4 to 5 to day 6 to 7. Here response rates to S+ reached a peak, while responses in the extinction component were low. Finally, in the last 3 to 4 days of training, response rates to S+ fell, but remained above the baseline rate on the VI schedule for each bird.

The individual graphs in Fig. 1 show that the final rate on the discrimination preserves the ranking of the birds on the baseline VI performance, and in all cases increases about 100% on this baseline rate. This percentage is not influenced by the number of responses made to S-, but the results show a positive correlation between the peak rate to S+ and the amount of responding in EXT. Although this relationship is clear in all birds, it is particularly obvious for birds 08 and 10. They show widely different VI rates (1.0 and 0.6 responses per sec) while the number of responses made by each in the presence of S- are identical. These birds both show peak rates to S+ of 2.3 responses per sec, although bird 08's rate change to reach the peak is very much greater than that made by 10.

## EXPERIMENT II

### *Procedure*

The same conditions held here as in Exp I, but S- was now  $15^\circ$  from the vertical rather than  $45^\circ$ . Since this discrimination is more difficult, 15 days were spent in training instead of 10.

### *Results*

Right hand panels in Fig. 1 show the response rates to S+ and the total responses made to S- for each bird in this group. Many more responses were made than in Exp I. Bird 40 gave nearly 60,000 responses to S-, and birds 36 and 38 gave about 30,000 responses each. This may be compared with Exp I where the greatest number of responses to S- was 16,000. With two apparent exceptions (bird 34 and 40) the three stages shown for Exp I appear here also. Response rates to S+ rose steadily until days 3 to 4 while the greater number of responses to S- were being emitted. Then a peak rate to S+ was reached on days 5 to 6, responses in EXT falling off. Finally, a stable rate appeared to S+ and responding to S- was minimal.

The apparent exceptions, birds 34 and 40, may be considered extreme cases. Since bird 34 emitted only 6000 responses to S-, most of them on the first day of training, a small peak rate would be expected. In fact no peak is present, only the final rate which is reached on the sixth day. Bird 40, on the other hand, shows a more irregular record. A peak appears

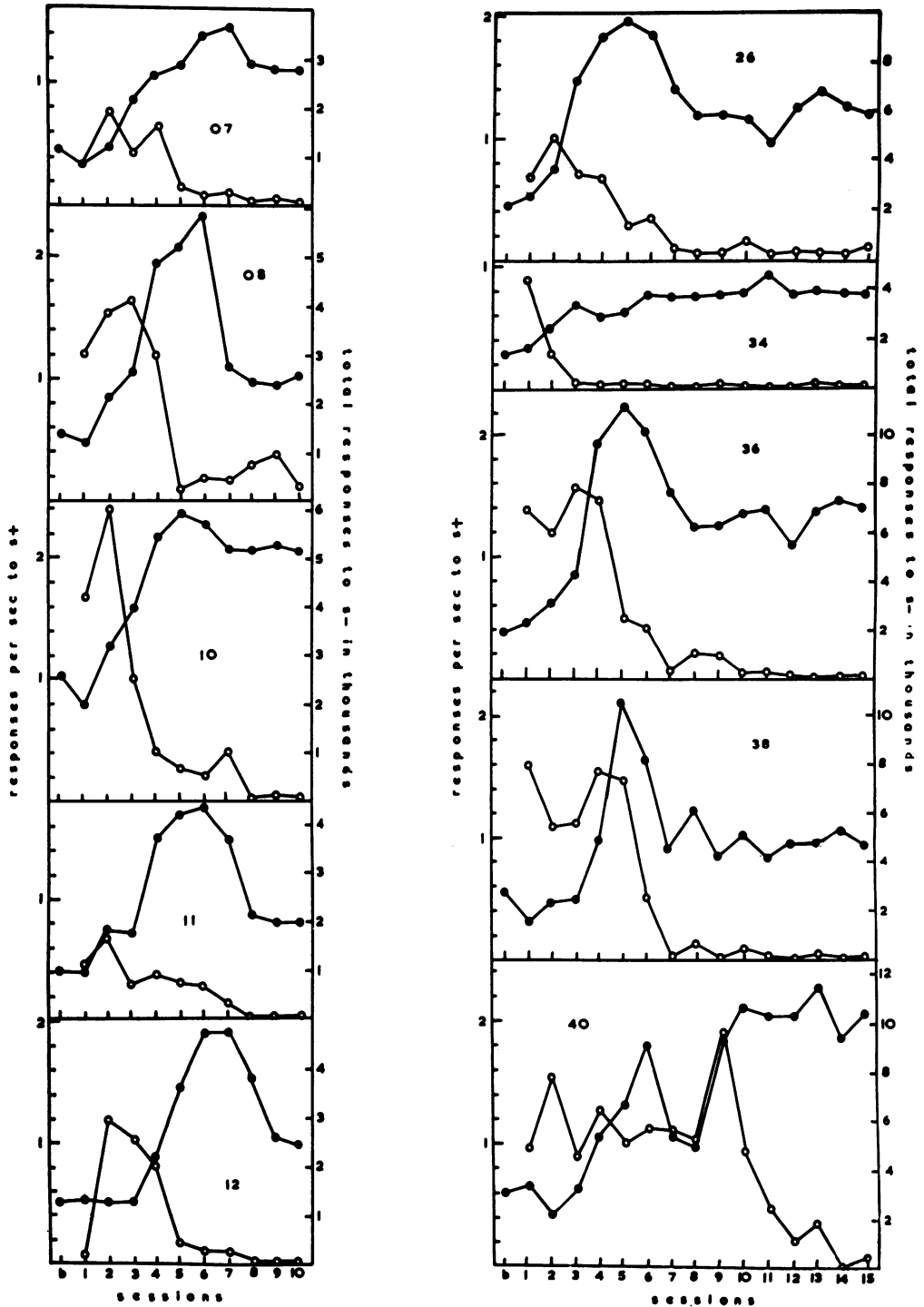


Fig. 1. Left hand panels show birds from Exp I and right hand panels birds from Exp II. Filled circles represent response rates to S+ and open circles total responses to S- for each bird on each day of training. Note that S- scales in left and right hand panels differ. Point "b" is the VI baseline response rate obtained by averaging performance on the last three days before discrimination training.

on day 6, then a decline on days 7 and 8, and finally an increase to a high response rate. Since all other birds in Exp I and II show the peak rate only when responding to S- has begun to decline, it is assumed that bird 40 does not show this peak until the end of training, when its responses to S- reach a low level for the first time. This means that the peak rate is in this case identical with the final rate. Since this almost occurs with bird 10 in Fig. 1, the interpretation does not seem implausible.

EXPERIMENT III

Procedure

A different method of training was used. To replace the enforced period of no responding at the end of S-, a fixed TO of 15 sec was used to separate S+ and S- presentations. A line-tilt discrimination was used, as in the previous experiments, with S+ 0° and S- 45°. Two birds were run on 5 min durations of S+ and S+, and three birds on 1 min durations of these stimuli. Seventeen daily sessions were programmed. Birds receiving 1 min presentations of stimuli were given 30 periods of S+ alternating with 30 of S-; whereas those on 5 min periods were given six presentations of each stimulus in each session.

Results

Figure 2 shows no difference between the performance of the 1 min and 5 min groups. Both show a steady, almost linear, increase in responding to S+, and a similar decrease in responding to S-. A stable final performance is reached by the 14th day, and the birds preserved their ranking on the initial VI performance in their final rates. There is no evidence of the second stage in S+ performance identified in the first two experiments, only the initial steady rise in responding to S+ and the stable final rate. This type of performance is the typical one which was previously obtained by Reynolds (1961a, 1961b) and Hanson (1959).

EXPERIMENT IV

Procedure

The same conditions were used as in Exp I and II, except that the stimuli were red (S+) and green (S-) illumination on the response key. S+ and S- intervals alternated, and the 30-sec period of no responding to S- was required before S+ returned. Thirteen daily sessions were run, each consisting of 15 presentations of both S+ and S-. Five birds were

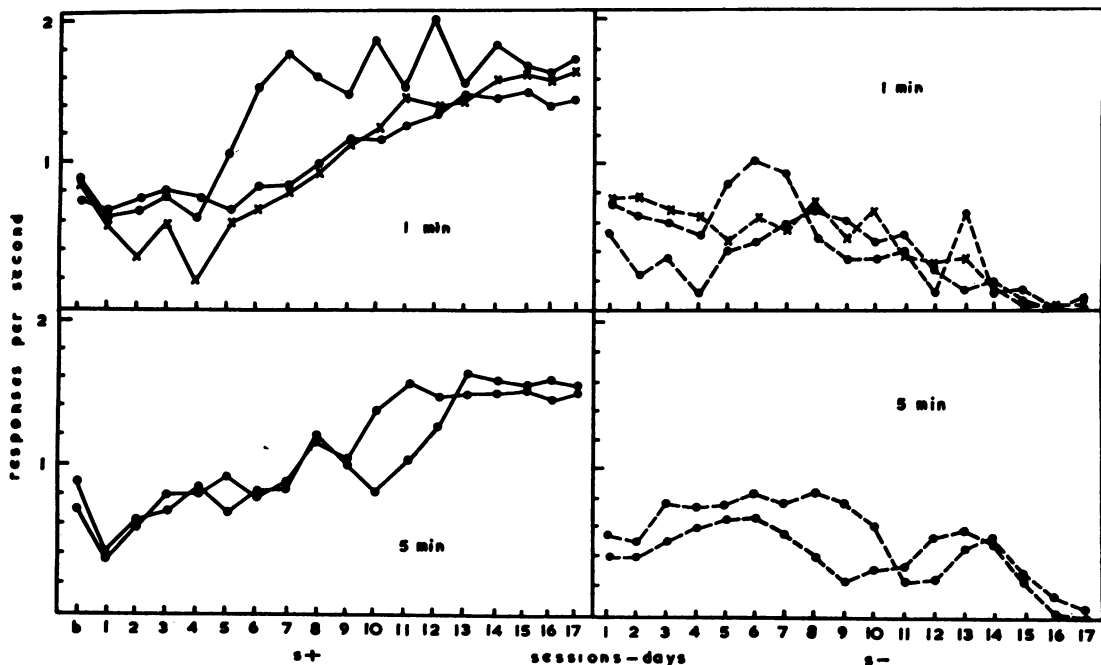


Fig. 2. Exp III. Left hand panels show response rates to S+ for 1 min and 5 min S+ intervals on each day of training; right hand panels show response rates to S- for these two groups.

used again, after the six days of preliminary training described.

Results

Practically all responses to S- occurred on the first day, and no graph is shown. Responses numbered between 1000 and 3000. Figure 3 shows the responses to S+ for each day of training. All birds show a small peak in S+ rate in early training followed by a few days at a lower rate. Bird 33 has a peak on day 4, 39 on day 2, and the others on day 1. After the decline in S+ rate, higher final rates appear in all birds except 33. This bird shows a negatively accelerated decline to the final rate (days 6-13, filled squares). Except for the reversal of 33 and 35, the birds are ranked in the same order on their final rates as on their initial VI rates.

Essentially the same condition was used by Terrace (1963a, p. 14 'late constant' group), and his birds show a similar peak on the first day of discrimination training. The smallness of this peak compared with the normal variability in response rates from day to day would result in its neglect, if it were not for the data in Fig. 1, where the existence of the phenomenon is clearly demonstrated.

DISCUSSION

Several features of these discrimination performances are worth attention. The upper graph in Fig. 4 shows each bird from Exp I and II plotted against axes of peak rate to S+ and total responses to S- over the whole training.

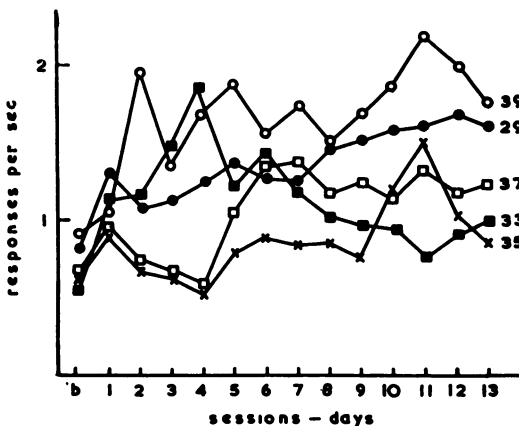


Fig. 3. Exp IV. Response rates to S+ for each bird are shown for each day of training. S- responding extinguished substantially on the first day, and no graphs are shown.

and total number of responses to S-. The lower graph shows peak rate to S+ plotted against base line VI rate for the same birds. There is a correlation between responses to S- and peak rate to S+, and in fact the points on the upper graph make a good fit to a curvilinear relationship for the 0°/45° discrimination. Although there seems to be a trend in the lower part of Fig. 4 for high VI rate to go with higher peak rate, no curve fits the points at all well. The data from Exp II in the upper graph (open circles) are less clear also. Bird 34 showed no peak at all, with about 6000 responses to S-. This bird's performance is consistent with the hypothetical relationship drawn in Fig. 4, since it entails only that the line should not cut the abscissa below the

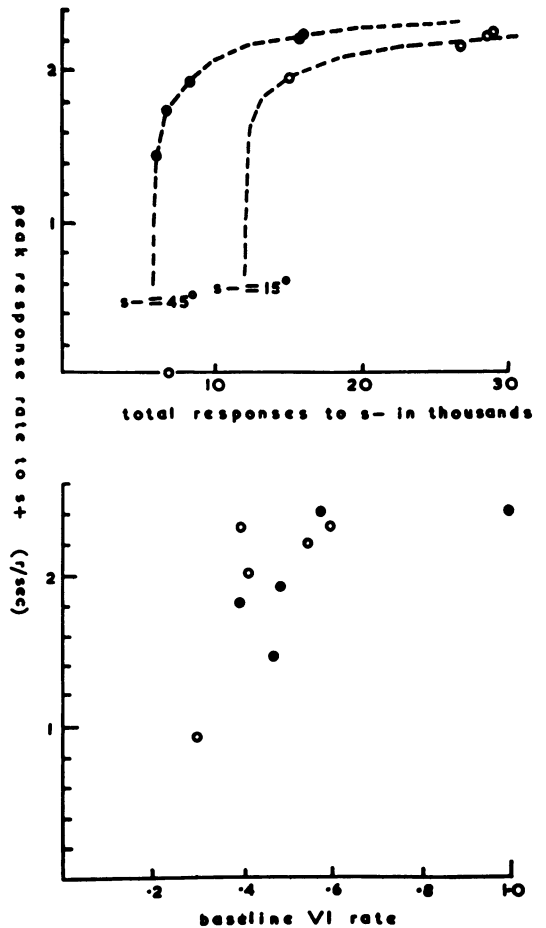


Fig. 4. Filled circles show birds from Exp I and open circles birds from Exp II. The upper graph shows a plot of the 10 birds against axes of peak rate to S+ and total responses to S- over the whole training. The lower figure shows the same birds against axes of peak rate to S+ and baseline VI rate (point "b" in Fig. 1).

point 6. It appears that a family of curves might be produced by varying difficulty of discrimination, so that more responses to S- are required to produce an equivalent peak rate to S+ in a more difficult discrimination. The validity of the curvilinear relation in general is supported by other work now being carried out by the author.

In Exp I, III and IV the birds all maintain the same ranking on final rates as in the preliminary VI training (with the exceptions noted in Exp IV). But this does not hold for Exp II, and it is not certain that this apparent connection between baseline VI rate and final rate to S+ after discrimination training can be replicated. However, the percentage increase in rate obtained in Exp I is in all cases 100%, whereas Exp II produced increases of between 100% and 300%. This difference suggests that the final rate to S+ tends to be a fixed proportion of the initial VI rate for a given separation of S+ and S- on the line-tilt continuum. A similar result appears in Hanson's (1959) data, where groups of pigeons were trained at four S+/S- differences on a wavelength dimension.

Whether final rates to S+ are determined only by the initial VI rate and the difficulty of discrimination, it is clear that they are not determined by the number of responses made to S-. Birds making many responses in extinction do not necessarily show high final rates, nor are low final rates contingent upon few extinction responses. However, as shown in Fig. 4, the peak rate of S+ is a function of the amount of responding in the presence of S-. So it is difficult to argue that the final contrast effect is a function of the same variables as the peak contrast effect, and it seems justified to call these phenomena two types of contrast.

#### *Behavioral Contrast*

The contrast effect obtained by Reynolds (1961a, 1961b) is a stable effect appearing in the final performance after several days of training. It may thus be assumed that this is analogous to the contrast obtained in the third stage of performance in Exp I, II and IV above. In Exp III this type of contrast is simply shown in the final rate, there being no intermediate peak rate to S+. Contrast magnitude seems not to be related to the number of responses given in EXT, since the four experiments show no relation between the final con-

trast effect on S+ and the number of responses to S-. Terrace (1963a, p. 24) makes the lesser claim that unreinforced responding in one component of a multiple schedule increases rate of responding in the other component. However, Reynolds (1961a) has shown that MULT VI TO produces a similar magnitude of contrast as MULT VI EXT. In TO virtually no responses are made, thus no responses go unreinforced; but contrast is still produced. Terrace's procedure of reducing the initial intensity and duration of S- also prevents responses to S-, but here no contrast appears. Since pecking to S- should occur by generalization from the training received on S+, it may be argued that some competing behavior in the presence of S- must occur in both Reynolds' MULT VI TO and Terrace's "early progressive" training on S-.

As Terrace (1963a, p. 26) notes, withdrawal of the bird's head at the onset of S- may have been reinforced by the return of S+. If S+ is taken as a conditioned reinforcer, then in Terrace's situation this stimulus is effectively contingent upon a definite response to S- (head withdrawal). But in MULT VI TO, the competing behavior is already present, since pigeons tend not to peck in total darkness. Perhaps, then, TO can be regarded as a "restraint" procedure, to be contrasted with "early progressive" S- training which actually establishes competing behavior by a conditioned reinforcer. From this viewpoint, contrast may be linked to the absence of any conditioned or unconditioned reinforcement in one component of a multiple schedule. On this interpretation contrast would be expected in MULT VI EXT and in MULT VI TO, but not in Terrace's "early progressive" training nor in MULT VI DRO (Reynolds, 1961a) where reinforcement is made contingent upon not pecking.

The results from Exp I and II raise another question:—why does the intermediate and transitory peak rate to S+ appear? A possible answer is suggested by an experiment of Brethower and Reynolds (1962). They shocked pigeons in one component of MULT VI 3 VI 3, and found that the rates of responding in the unpunished component rose proportionately to the intensity of the electric shock. Considering this evidence, the present procedure of enforcing 30 sec of no responding at the end of S- can be interpreted as a 'punishment'

situation in which a further 30 sec of extinction was made contingent upon a response from 90-120 sec after the onset of S- and then upon each response following an IRT less than 30 sec. 'Punishment' is qualified because to call this a punishment situation assumes that there are functionally similar elements in non-reinforcement and response-contingent shock. But this hypothesis is not implausible (see Terrace, 1963b; Amsel, 1958, 1962, 1965). Brethower and Reynolds (1962) show that the magnitude of punishment determines the amount of contrast shown in the rates to S+. It may be argued that the aversive properties of an extension in S- duration vary with the amount of responding to S-, since the more the bird responds, the more S- is prolonged. Then the result plotted in Fig. 4 would be expected. Birds showing most total responses in extinction would show most contrast at some point in their S+ response rates. A comparison of performance to S+ in Fig. 1 and Fig. 3 demonstrates that the 30-sec criterion of no responding must be responsible for the peak rate to S+, and the interpretation given in terms of a punishment contingency will explain this difference.

More weight is added to this interpretation by considering the experiment by Reynolds (1961a) which used a MULT VI DRO schedule. One feature of the DRO component resembles the procedure used here in Exp I and II. In Reynolds' DRO procedure the bird is reinforced for not pecking by direct operation of the magazine if no key-peck has occurred for time  $t$ . If S+ is regarded as a conditioned reinforcer, then the no-responding criterion used here makes a conditioned reinforcer contingent upon not pecking, since S+ returns if no response has occurred for time  $t$  (30 sec). However Reynolds' procedure differs in not delaying the return of the VI component of the schedule if responses of pecking occur in DRO. So there is no punishment contingency, and, as would be expected, the birds show no contrast effects—no contrast due to punishment, and no contrast due to extinction.

This punishment contingency explains the differences between the performance of the red/green and the line-tilt discrimination groups. The red/green discrimination birds (Fig. 4) show a small peak only in early training, followed by a decline and a rise to the final rate. Here the punishment contingency can operate only weakly, since responding to S- is substantially extinguished on the first day. The peak is thus a small one. The decline from the peak rate to a level below the final rate before performance stabilizes indicates that the final contrast effect due to the extinction component does not appear for several days. This decline does not appear in Exp I and II because the peak rate is high and extends over days 4 to 6, thus effectively masking the growth of the second and final contrast effect.

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