THE EFFECT OF DISCRIMINATION TRAINING ON RESPONSES TO A NEW STIMULUS

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Most previous research on the effect of the duration of preceding discrimination training on responding to a new stimulus has measured the responding during extinction. To reduce effects originating in the extinction procedure itself, the present study assessed the effect of discrimination training on responses to a new negative stimulus added during continued discrimination training. Pigeons were given a new negative stimulus (blue key) after 0, 1, 3, or 9 days of discrimination training with a yellow key as the positive stimulus, and both a green key and a red key as negative. Fewer responses were made to the blue key when it was introduced after nine days of discrimination training than after less discrimination training. That effect of long discrimination training agrees with reported results from extinction tests. However, the effect of briefer discrimination training in the present study differed from reported results with extinction testing. It appears that testing during continued discrimination training eliminates a distortion present in extinction tests of the effect of discrimination training on responding to a new stimulus.

The effect of discrimination training on responding to new stimuli has usually been studied in generalization tests¹ carried out while extinguishing responses during all stimuli. With this technique Hanson (1959), Honig, Thomas, and Guttman (1959), and Terrace (1964) demonstrated that discrimination training decreases responding to new stimuli near the negative stimulus (S-) as well as to S- itself. Recently, Farthing and Hearst (1968) and Hearst (1971) used extinction tests to examine the effect of different amounts of discrimination training ranging from one to 64 days. Their data showed more complex effects, namely increases in responses to new stimuli between the first and fourth training sessions, then a decrease after eight and more sessions.

Extinction of all responses need not be used during generalization tests. Testing can be carried out with the same reinforcement sched-

ule during all stimuli (Besley and Hearst, 1969), or discrimination training can be continued during the generalization tests. Pierrel, Sherman, and coworkers used the latter procedure to measure the effect of different amounts of discrimination training on responding to new stimuli. Sherman and Pierrel (1961) showed that 14 and 28 days of training on two different auditory intensities did decrease responding by rats to the S- and to new stimuli close to S-. However, when Pierrel, Sherman, and Fischman (1963) tested the earlier addition of new stimuli with the same basic procedure, they found that the difference in responding to their training stimuli was small during the first 8 hr of training. Thus, comparison of results from generalization tests made during discrimination with those made during extinction is impaired by large confounded differences both in species and in speed of discrimination due to choice of stimuli. The present study used generalization tests during discrimination training, but with pigeons and a rapidly developed discrimination, to provide results more comparable to published results from generalization tests using extinction with pigeons and rapid discriminations. Various amounts of training were used to detect complex effects such as reported by Farthing and Hearst (1968) in the first few days of training. To minimize further disturb-

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ance from the test, two training S—s (red and green) were used, and only one new stimulus (blue) was added, instead of a set of new test stimuli. The positive stimulus (S+) was yellow. In Experiment I, four different amounts of discrimination training (0, 1, 3, or 9 days) were given before introduction of the new S—. Experiment II assessed the reliability of some of the results from Experiment I by exactly replicating three of the four groups (0, 1, and 9 days).

METHOD

Subjects

Each of 56 (32 in Experiment I and 24 in Experiment II) experimentally naive, female, retired-breeder, White King pigeons was reduced to approximately 70% of its free-feeding weight, and then was fed a fixed amount of food each day in the home cage immediately after the experimental session. The amount of this after-session feeding was adjusted only to offset changes in the amount of feeding in the experimental session or to eliminate a consistent trend in weight. Birds were housed in individual cages where grit and water were always available.

Apparatus

The experimental chamber was a standard Lehigh-Valley-Electronics two-key chamber, except that a 120-v, 6-w houselight was used. Only pecks on the right key had any effect, and it was illuminated by an Industrial Electronic Engineers, Inc. (IEE), Series-10, projector. For the red, green, and yellow stimuli, the IEE filters were used, but the blue filter was replaced with two layers of transparent blue plastic to obtain a more saturated blue stimulus.

Key-peck Training

The key peck was conditioned by an adaptation of the auto-shaping procedure of Brown and Jenkins (1968). Seven-second presentations of a yellow keylight, immediately followed by 3 sec of food access, were given at varying intervals averaging 1 min. A peck on the yellow keylight immediately terminated it and produced food access (3 sec). Between these yellow-key trials the key was dark and a peck had no effect. After the fourth peck on the yellow key and the feeding that followed, the yellow key

came on and stayed on during 10 continuous reinforcements (CRF), after which the session terminated. If four pecks did not occur by the fortieth yellow-key trial, the session was terminated and another auto-shaping session with 40 pairings of the yellow key and food was given the next day. One to three auto-shaping sessions were generally required, and subjects were discarded if pecking did not develop within five sessions. One bird was discarded.

Discrimination Training and Testing

The four stimuli were presented for 20-sec intervals separated by 12-sec interstimulus intervals during which the key was dark but the houselight remained on. Key pecks during the yellow stimulus (S+) were reinforced with 3 sec of food access on a variable-interval 30-sec schedule (VI 30-sec). Responses were never reinforced during the red, green, or blue stimuli (S—). Responses in the last 5 sec of the interstimulus interval delayed presentation of the next colored stimulus until after 5 sec without a response.

Discrimination training began on the day after the key-peck training. All birds received the yellow S+, red S—, and green S— throughout. The 0-day group had no discrimination training before the blue S— was introduced on the first day of discrimination training. The 1-day group had one day of discrimination training before the blue S— was introduced at the beginning of the second session; the 3-day group had the blue S— from the fourth session on, and the 9-day group had it from the tenth session on. Each bird was tested for three sessions after the blue S— was introduced. The 3-day group was omitted in Experiment II.

In the first session of discrimination training, each key peck during S+ was reinforced up to the end of the S+ presentation during which the third reinforcement of the session occurred. The next nine reinforcements occurred on a VI 15-sec schedule, and thereafter on a VI 30-sec schedule. The first S— occurred after the S+ with the fifth reinforcement on VI 15-sec. At first, each S— was followed by an S+, but after three S—s had occurred, the S— frequency was increased during the next 25 stimuli until each color had the same frequency. During this first session, each S— occurred 25 times except for the 0-day group (with the blue stimulus on the first session), where each S— occurred 22 times. Due to vari-

ation in the response rate during the first few reinforcements, the first-session S+ presentations varied between 28 and 35. The S- colors were given in a regular order until the frequencies of all colors were equal. Then, the colors were given in a random order except that all three (or four if blue had been introduced) were presented before any color was repeated.

During all later sessions, each color occurred 24 times. Thus, 72 stimuli were given in later sessions when blue was absent, and 96 when blue was present.

RESULTS AND DISCUSSION

Figure 1 shows the distribution of the total responses made to the new blue S- by different birds during the first session that blue was presented. The four different distributions show the effect of introducing the blue S- after different amounts of discrimination training. The solid blocks represent birds in Experiment I and the open blocks represent birds in Experiment II. The 9-day distribution appears substantially different from the others, because only in it did all birds make fewer than seven responses to the new S-. In each of

Fig. 1. Frequency distributions of responses to the new blue S- made by different birds on the first day the blue S- was present. The four distributions show the effect of different durations (days) of preceding discrimination training. Solid squares show Experiment I subjects, and open squares show Experiment II subjects. Open squares for subjects in Experiment II were plotted above those already plotted for Experiment I, therefore the ordinate gives the total number of subjects in both experiments that made a particular number of responses. A total of 16 subjects was tested at each duration except only eight were tested at three days.

the other groups, some birds made many more responses. For both experiments, Hartley's $F_{\max}$ test (Winer, 1962) showed a significant effect of the duration of discrimination training on the response variances ($p < 0.01$).

Figure 2A shows the means and medians of the same data, the responses to the blue S- during the first session blue was presented, as a function of the days of preceding discrimination training. The large connected solid circles and triangles show the means for Experiments I and II respectively, and the small unconnected circles and triangles show the medians. Kruskal-Wallis analyses of variance (Siegel, 1956) showed a significant effect of discrimination training ($p < 0.05$ for Experiment I, $p < 0.01$ for Experiment II). Mann-Whitney U tests (Siegel, 1956) among the groups of Experiment I showed significant differences between the 9-day group and the 1-day group ($p < 0.001$), and between the 9-day group and the 3-day group ($p < 0.024$; all tests are two-tailed unless otherwise stated). Other group differences failed to reach significance.

Experiment II was carried out to assess further the reliability of the increase produced by one day of training. The triangles in Figure 2A show that the increase was replicated, but it again failed to reach significance. A Mann-Whitney U test between the pooled 0-day and 1-day groups of the two experiments also just failed to reach significance ($U = 85.5$, $U = 83$ significant at 0.05 level, one-tailed). The differences between the 9-day group and both the 0-day and 1-day groups in Experiment II were significant ($p < 0.02$ and $p < 0.001$). Unlike the responding to blue on its first day, the responding to blue on its second and third days was near zero in all groups in both experiments; consequently, differences between groups disappeared.

Figure 1 shows that nine days of training with red and green S-s increased from 25% to 63% the proportion of birds that made only zero or one response during the first day of exposure to the blue stimulus, and none of the 9-day birds made over six responses. This change, plus the significant decrease in responses from zero to nine days, suggests that this technique increases the yield of birds with "errorless" discrimination. The present procedure involves fewer variables and is easier to program than the fading technique because it employs only a single set of con-

Fig. 2. Circles show Experiment I; triangles show Experiment II results. Large points show means and small points show medians. A: Responses to blue S- on the first day blue was presented. B: Responses to red S- and green S- on the first day blue was presented. C: Responses to yellow S+ on first day blue was presented. All three measures are shown as a function of the number of days of preceding discrimination training, though note that each point in A is for the first day of exposure to that stimulus (blue S-) while in B and C the days of preceding exposure to those stimuli (red, green, and yellow) vary, and are given on the abscissa. Note also the different scales for the three ordinates.

ditions, while fading involves several different conditions and a schedule for their presentation. It remains to be determined how the properties of an "errorless" discrimination produced by the present procedure compare with the properties obtained without preceding discrimination training or with the fading procedure (Terrace, 1966).

The literature and the present data indicate that discrimination training has two possible effects on responding to a new stimulus, a decremental effect from longer training, and possibly an augmenting effect of brief training. Consider the decremental effect of longer training first. Studies using generalization tests during extinction have shown clearly that discrimination training eventually decreases responses to a new stimulus when the training S- is between the new stimulus and the S+ (Hanson, 1959; Honig, Thomas, and Guttman, 1959; Terrace, 1964). The present tests during discrimination training agree with those results because we found a similar decrease in responses to a new stimulus after nine days of training. Due to the circular hue continuum (Boring, 1942; Geldard, 1953), both the present training S-s (red and green) were between the new stimulus (blue) and the training S+ (yellow). The above limitation to cases where the training S- is between the new stimulus and the training S+ is made because extinction tests have given different results for other relations. When the training S+ is between the new stimulus and the training S-, a peak shift (e.g., Hanson, 1959) can increase responding to certain new stimuli.

Farthing and Hearst (1968) reported on the effects of discrimination training on inhibitory gradients about S-. Their training S+ was a plain white key and the training S- was a vertical black line on a white field. They tested with various line tilts during extinction, so the blank S+ was orthogonal to the dimension of the generalization test stimuli instead of being on that dimension as in the preceding studies. With these different relations, they also found that responding to their new stimuli decreased between four and 16 days of preceding discrimination training (their Figure 1), and Hearst (1971) showed a further decrease after 64 days of training.

Now, consider the possible augmenting effect of briefer discrimination training. A single day of discrimination training produced an

increase in responses to the new S— in both the present experiments, though the difference failed to reach significance. Since discrimination training began after few reinforcements (about 22 before the first S— presentation) the initial increase may be related to the initial increase of S+ responding. This suggestion agrees with previous studies which have shown that training on S+ alone increases the responses to a new S— (Skinner, 1938; Margolius, 1955; Terrace, 1963; Hearst and Koresko, 1968; Taus and Hearst, 1968). Figure 2C shows that a single day of discrimination training increased S+ responses (Experiment I, $p < 0.05$, two-tailed; Experiment II, $p < 0.05$, one-tailed). In Figure 2C, one point is plotted for each group with that point showing the mean responses during S+ on the first day the blue S— was present for that group. Within-subject data confirm this increase: 47 of the 56 birds used in both experiments showed an increase in S+ response rate from the first to the second day of training ($p < 0.0001$, sign test).

Figure 2B shows that the responses to both the red and green training S—s decreased monotonically, except for a small, nonsignificant rise ($p > 0.8$) in green responses after one day of training in Experiment II. (Figure 2B is like 2C in that it plots mean responses to the training S—s from each group on the day that the blue stimulus was introduced.) Within-subject data confirm this decrease (red S—, 45/56 birds, $p < 0.0001$; green S—, 40/56 birds, $p < 0.002$). Addition of the curves in Figure 2B to those in Figure 2C, with suitable weighting, produces a curve quite similar to Figure 2A. Thus, if the Figure 2A increase in responses to a new S— after one day of training is reproducible, it could be related to the simultaneous increase in S+ responses seen in Figure 2C, and the Figure 2A decreases due to longer training could be related to the decrease in responses to the training S—s seen in Figure 2B.

The Farthing and Hearst (1968) study seems to be the only published study of the effect of discrimination training that tested short enough training durations to detect an early increase. Although their study was designed to show the effect of discrimination training on inhibitory gradients, their thorough reporting of results provides valuable information about extinction during generalization tests. Their

extinction tests did show a large increase in responding to the test stimuli and *even a small increase to their training S—* (their Figure 1) between one and four days of discrimination training. However, they had given nine days of S+ training before beginning discrimination training. Consequently, their increase seems to have a different explanation than the cumulative effect of reinforcements in the early stages of conditioning, which was appropriate for the increase we found. It is strange for three days of discrimination training to produce no decrease in responding to the S— when generalization tests after one and four days of discrimination training are compared. This result becomes even more strange when, as shown in their Figure 4, the discrimination training results do show the expected large decrease in responses to the *same stimulus* between one and four days of discrimination training. Compare those results more closely. After one day of discrimination training, the response rate during S— in the generalization test was considerably lower (six or seven responses per minute from Figure 1) than the rate during the same stimulus in the discrimination training the day before (about 23 responses per minute from Figure 4), and lower than the responses during the same stimulus made on the same day by birds in other groups continued on discrimination training (average about 16 responses per minute, Figure 4). Thus, the responding during the S— in the context of a generalization test where responses to all stimuli were extinguished, was much lower than responding to the same stimulus in the context of discrimination training that continued a moderate level of reinforcement. The clear explanation for this decrease is extinction resulting from the change from moderate levels of reinforcement in the VI 1-min and discrimination procedure to no reinforcement during the 56-min generalization test.

After two days of discrimination training, the S— rate during the generalization test still was lower than during discrimination training, but after 4, 8, and 16 days of training the S— rates were similar under the two conditions. After eight or 16 days, the responding was so low that further response depression would be hard to detect. However, responding after four days of training was still high enough to reveal such depression; why did no

drop occur in the extinction test? The well-known partial reinforcement effect (PRE), the increase in extinction responding after partial reinforcement (reviews: Robbins, 1971; Lewis, 1960) explains this reduced sensitivity to extinction after four days of discrimination training. The discrimination training gave VI 1-min on only half the stimulus presentations and gave extinction on as many as three S—s in a row; hence, it provided an appreciably lower and more variable overall reinforcement frequency than the preceding VI 1-min training with only S+. The longer exposure to the lower reinforcement frequency would be expected to slow the extinction during the generalization test. More direct evidence comes from the demonstration by Jenkins (1961) that discrimination training increased extinction responding. Consequently, the faster extinction in the tests after one and two days than after four days of discrimination training eliminates from the function the decline in responses to S— between one and four days and replaces it with the slight rise. However, that rise is then an artifact of the extinction present in the test procedure, rather than a direct effect of discrimination training. The new test stimuli show a much greater rise than the training S—. This analysis is supported by the present results, which did not employ extinction during the test and showed no rise in the new test stimulus between tests after one and after three days of training. In more general terms, when the magnitude of a disturbance due to the testing technique depends on the variable under study (duration of discrimination training) then changes in the disturbance change the shape of the function, not just its absolute level. The finding that inhibitory gradients after one and two days of discrimination training are flatter than after longer training may also be partly due to the more abrupt extinction after one and two days training than after longer training.

In the present experiment, introduction of the blue stimulus did not result in any change in S+ presentations or in total daily reinforcements, and it increased S— presentations only from 48 to 72. Only one new stimulus was introduced and it was farther from S+ than either training S—. The responding during the yellow S+ and the red and green training S—s showed no evidence of any disturbance when the blue S— was introduced. Hence, it is

thought that the present results show the effect of discrimination training on responding to a new S— with less contamination from effects of the test procedure than previous results. Pierrel and Sherman (1960) reported a disruption of discrimination performance when they introduced new S—s close to the S+ during continued discrimination training. Thus, the present outcome is probably due in part to the choice of stimuli and other conditions as well as continuation of discrimination training during generalization testing.

Can the number of new stimuli be increased to obtain a more detailed picture of generalization without resorting to separate groups, with each group receiving only one new stimulus? That question seems to be an experimental one, which can be answered by measuring whether a multiple test-stimulus procedure can be found whose results agree sufficiently well with a single test-stimulus procedure that minimizes test disturbance.

In summary, the present study with testing during continued discrimination training confirms certain results from extinction tests, those that have shown that long discrimination training decreases responding to new S—s. Yet, Farthing and Hearst found more responding to new S—s after four days of training than after one day of training. There is evidence that their increase may be due to the extinction during their test. The present tests without extinction show no increase between one and three days of discrimination training. A small increase between zero and one day of training was found in both the present experiments, but it fell short of significance. If reproducible, that increase may result from the cumulative effect of S+ reinforcements, because an increase in S+ responding had a similar time course, and few reinforcements occurred before discrimination training. That explanation is not likely for the Farthing and Hearst increase, because nine days of S+ reinforcement preceded their discrimination training.

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