THE EFFECT OF OVERTRAINING ON BEHAVIORAL CONTRAST AND THE PEAK-SHIFT¹

ABDULAZIZ DUKHAYYIL AND JOSEPH E. LYONS²

UNIVERSITY OF ARIZONA

Following initial discrimination training between two wavelength stimuli and a subsequent generalization test to the wavelength dimension, Group 1 was "overtrained" for 105 days on the original discrimination. Group 2 was "overtrained" with the original positive stimulus and a new negative stimulus, a white line. Group 3 was "overtrained" with the original negative stimulus and a new positive stimulus, the white line. Each 15 days of extended training were followed by a wavelength generalization test similar to the first test. The results suggest that there is no consistent relationship between the response rate in positive stimulus immediately before the generalization test and whether or not a peak shift occurs during the test.

In two separate but related experiments, Terrace (1966a) found that extended discrimination training eliminated both behavioral contrast and the peak-shift. Behavioral contrast is the increase in the response rate in S+ (stimulus correlated with reinforcement) above what it was before the beginning of discrimination training correlated with a reduction in the response rate in S- (stimulus correlated with extinction). The peak-shift is a change in the modal response point of a post-discrimination generalization gradient away from the S+ so as to be further removed from S-. Terrace (1968) contended that behavioral contrast (as defined above) during discrimination training is a necessary and sufficient condition to produce the peak-shift during generalization testing.

In Experiment 1, Terrace (1966a) tested pigeons for wavelength generalization after 60 days of discrimination training between a 580-nm stimulus (S+) and a 540-nm stimulus (S-). The training data revealed a gradual reduction in behavioral contrast, with a return

to baseline level occurring at about the forty-fifth day. The generalization test data disclosed quite symmetrical gradients around S+ for all birds.

In Experiment 2, four additional birds also received 60 days of discrimination training to the S+ and S-, but after each 15 training sessions these subjects received a wavelength generalization test. Terrace (1966a) maintained that the test data revealed a gradual reduction of the peak-shift until by the fourth test it had been eliminated in all four pigeons. Terrace (1966a) related these findings to those of an earlier study, Terrace (1966b), to conclude that the aversive properties acquired by S- through nonreinforced responding in its presence dissipated with extended training, thereby reducing behavioral contrast and eliminating the peak-shift. In this earlier study, generalization testing was conducted after each 12 training sessions through four generalization tests. Unfortunately, the training data were not reported for either of the studies in which repeated testing was used. Therefore, the strength of the peak-shift cannot be related to specific changes in behavioral contrast, a point critical to Terrace's analysis of the relationship between overtraining on the one hand and behavioral contrast and the peak-shift on the other.

In a more recent study, Hearst (1971) failed to find any reduction of behavioral contrast with 64 days of interdimensional discrimination training. The extended training also failed to eliminate the gradient of inhibition,

¹The data from this study are part of the thesis submitted to the Graduate School of the University of Arizona in partial fulfillment of the requirements for the Masters of Arts degree for the first author. Partial support for this study was provided by a scholarship to the first author from the College of Petroleum. (Saudi Arabia)

²Our thanks to Dr. David R. Thomas for his most helpful criticisms of the paper. Reprints may be obtained from Joseph E. Lyons, Department of Psychology, University of Arizona, Tucson, Arizona 85721.

i.e., a gradient with minimal responding at S⁻. Terrace (1966c) asserted that the gradient of inhibition covaries with behavioral contrast in much the same way that the peak-shift does in the intradimensional situation. The two pigeons in the Hearst study receiving intradimensional discrimination training failed to show a peak-shift after extended training. However, these two birds continued to show strong behavioral contrast which, according to Terrace (1968), should have produced a peak-shift. The lack of a peak-shift reflects one of two things: (1) it is possible that behavioral contrast and the peak-shift are actually independent of one another, or (2) the training conditions produced unusual behavior in these two subjects. Hearst (1971) favors this latter view.

Thus, the relationship between overtraining, behavioral contrast, and the peak-shift, is unclear at this time. The present study sought to determine the effect of extended training on behavioral contrast and, in turn, to investigate the relationship between behavioral contrast and the peak-shift. To accomplish this, pigeons were given extended discrimination training (120 days) and eight different generalization tests (one after each 15 days of training). Note that the present training period was much longer than that used by either Terrace (1966 *a,b*) or Hearst (1971). This was done to allow ample time for the effects of extended training on the response rate in S⁺ and the peak shift to occur.

A second purpose of the present study was to determine the necessary and sufficient conditions to produce the "overtraining effect", *i.e.*, a reduction in behavioral contrast concurrent with the elimination of the peak-shift. In particular, we investigated the role of overtraining on S⁺ and S⁻ individually, each paired with a new stimulus and compared these results with those obtained with a standard overtraining condition.

METHOD

Subjects

Fifteen experimentally naive adult pigeons were maintained at 70 to 75% of their free-feeding weight throughout the experiment.

Apparatus

Two commercially available Grason-Stadler pigeon chambers (model no. 1100PB), with

associated automatic scheduling and recording equipment, were used. Industrial Electronics Engineers Inline display cells provided the stimuli, which included nine different wavelengths (501, 511, 538, 548, 555, 566, 576, 589, and 606 nm, *cf.*, Lyons and Klipec, 1971) as well as two white lines at different angular orientations (90° and 60°), both on a black background. Masking noise was supplied to both chambers by a Grason-Stadler White Noise Generator (model 901b).

Procedure

Subjects were trained to peck the response key, then allowed to obtain 50 continuous reinforcements (CRF) for key pecking on the first day. Reinforcement consisted of 3-sec access to the food hopper, which contained a mixed grain pigeon feed. On Days 2 and 3, each bird was given an additional 50 reinforcements on CRF for key pecking. During the next two sessions, the CRF schedule was changed to a variable-interval (VI) 15-sec, (Day 4) and VI 30-sec (Day 5). The stimulus-on periods were 50 sec in duration and each was separated from the next by a 10-sec blackout of the stimulus and "houselight". Fifteen such periods were presented during the fourth and fifth sessions. Throughout this preliminary training, the stimulus on the pecking key was the 555-nm light.

On Day 6, the number of stimulus-on periods was increased to 30 and the reinforcement schedule was changed to VI 1-min. For 15 of these periods, the stimulus on the key was the 555-nm light while, for the remaining 15 periods, the stimulus on the key was a 538-nm light. The stimuli were alternated in a quasi-random sequence with the restriction that no more than two S⁺ or S⁻ periods could occur in succession. The VI 1-min schedule of reinforcement was in effect in the presence of both stimuli. Five days of nondifferential training were given to each bird. This training provided the baseline response rate to the 555-nm stimulus against which the effect of discrimination training between the 555 nm and the 538 nm could be judged.

Discrimination training then began with responses in the presence of the 555-nm stimulus (S⁺) reinforced on the VI 1-min schedule and extinction in effect in the presence of the 538 nm (S⁻). Fifteen S⁺ periods were randomly alternated, with the above mentioned

restriction, with 15 S— periods during each training session. Stimulus-on periods continued to be 50 sec in length and each was separated from the next by the 10-sec blackout. Training continued in this manner until a criterion of 10 responses to S+ for each response to S— was met.

On the day after criterion performance was achieved, each bird was given a generalization test along the wavelength dimension (Test 1). The test stimuli consisted of the nine wavelengths previously mentioned. The nine test stimuli were randomized within a series and five different random sequences were presented to each subject. All testing was conducted in extinction and each test was preceded by a 5-min warm-up consisting of three S+ periods alternated with two S— periods.

Following the first generalization test, Group 1 was overtrained on the original discrimination (555 nm S+; 538 nm S—) for 105 days. Following each 15 days of overtraining, each bird received a wavelength generalization test similar to Test 1. The overtraining for Group 2 was with the 555-nm S+ and a white vertical line as S—, while for Group 3 the S+ was the white line and the S— was the 538-nm stimulus. Following each 15 days of overtraining for these latter two groups, a wavelength generalization test was administered to each subject. Thus, all three groups received eight

wavelength generalization tests with test conditions the same for each test.

RESULTS

Figure 1 presents the total responses to the 555-nm (S+) stimulus for the birds in Group I. Note that behavioral contrast (here defined as an increase in response rate over baseline) occurred in all birds, *i.e.*, each bird made more responses to 555 nm during discrimination training than during nondifferential training. However, there was no consistent pattern of responding to the S+ among the five subjects. Based on Terrace's (1966 *a,b*) work, one would predict a rapid rise in the rate during S+, followed by a gradual decline as discrimination training progressed. This occurred in only one bird (A6). Clearly, this was not the case for the other four subjects in Group 1.

Figure 2 presents the generalization gradients for Group 1.³ Observe that on Test 8, three of the five birds (A19, A20, and A7) continued to show the peak-shift. Recall that all three birds also showed behavioral contrast before this test. Subject A8 failed to show the

³Note that the gradients are not drawn with a linear scale. This was done primarily for convenience and ease of reading. However, the same general picture would emerge if the gradients were drawn on a linear scale.

Fig. 1. Number of responses to the 555 nm (S+) as a function of extended training on the *mult* VI 1-min (555 nm) EXT (538 nm) schedule. The arrows indicate the number of responses to S+ on the day before each test.

Fig. 2. The eight wavelength generalization gradients for the five birds in Group I overtrained on the wavelength discrimination.

peak-shift on Test 8, but this bird continued to display strong behavioral contrast before the test. Bird A6 made very few responses during Test 8, making it impossible to judge the shape of the gradient.

Taken together, the training and test data for Group I raise serious questions concerning Terrace's interpretation of the effect of extended discrimination training on behavioral contrast and the peak-shift. The data also show

that the presence (or absence) of behavioral contrast during training is not a reliable predictor of the peak-shift during test. For example, Bird A19 failed to demonstrate a peak-shift on Tests 3, 5, and 6; before Test 6, strong behavioral contrast occurred, whereas there was no contrast before Tests 3 and 5.

Training produced a high response rate before each test for Birds A20, A7, and A8, yet these subjects failed to show the peak-shift during many of the generalization tests. For Bird A20, no peak-shift occurred on Tests 6 and 7, whereas for A7 neither Tests 2, 3, or 5 produced a peak-shift. The failures for A8 occurred on Tests 3, 7, and 8. For Bird A6, behavioral contrast disappeared before Test 3, yet this bird showed a peak-shift on both Tests 4 and 5, neither of which were preceded by behavioral contrast during training. Thus, the birds from Group 1 failed to show any consistent relationship between behavioral contrast and the peak-shift.

Figure 3 depicts the responses to S+ for the birds in Group 2. Bird A21 shows a rapid increase in responding to S+ at the beginning of discrimination training followed by a gradual decline with extended training. However, the remaining four birds in this group show a marked oscillation in the response rate to S+ as training progresses, such that

little can be said about the relationship between the response rate to S+ during training and the peak-shift for the birds in Group 2.

Figure 4 reveals the generalization test data for Group 2. Note that two of the five birds (A9 and A11) showed a peak-shift during the eighth test. This is most interesting because Subject A9 failed to produce a peak-shift during Test 1, which followed the initial wavelength discrimination training. The original discrimination training did, however, produce behavioral contrast. Bird A9 also showed a peak-shift on Tests 4 and 7. The remaining four birds (A21, A22, A10, and A11) showed peak-shifts on Test 1 as well as on later tests.

Another interesting result from Group 2 is that the seventh test produced a peak-shift in three of the five birds, one more than occurred on any other test except Test 1. Thus, the seventh and eighth tests produced more peak-shifts than Tests 2, 3, 4, 5, and 6 combined, suggesting that the lack of a peak-shift in early testing is no guarantee that later testing will fail to show a peak-shift.

The training data for Group 3 are presented in Figure 5. Note that all subjects showed behavioral contrast before Test 1. However, the training data after the first test represent the response rates to a new S+ (the white line) and it is difficult to determine the presence or

Fig. 3. Number of responses to the 555 nm (S+) as a function of extended training with the 555 nm (S+) and the vertical line (S-). The arrows indicate the number of responses on the day before each test. The number of responses on the day following the first test reflects the effect of the introduction of the new S-, the vertical line, on the rate to S+, the 555-nm light.

Fig. 4. The eight wavelength generalization gradients for the five birds in Group 2 overtrained with the 555 nm (S+) and the vertical line (S-). Test 1 followed the initial wavelength discrimination training.

absence of behavioral contrast without a base-line response rate to the white line against which comparisons can be made. Therefore, no attempt will be made to evaluate the effect

of extended training on the response rate during S+ for Group 3 other than to point out that for Birds A23 and A14, the rate during S+ remained consistently high throughout

Fig. 5. Number of responses to the 555 nm (S+) to the first arrow followed by the number of responses to the vertical line (S+) after the first arrow. The arrows indicate the number of responses to S+ before each generalization test.

training, while there was considerable variability in the rate for Subjects A24, A13, and A12.

The generalization gradients for Group 3 appear in Figure 6. An examination of the gradients for Test 8 discloses that four of the five birds overtrained on the S- were still showing the peak-shift. Bird A23 failed to show the peak-shift on Test 1 but showed it on the last seven tests, demonstrating again that the lack of a peak-shift on any one generalization test does not predict the lack of a peak-shift on later tests, as Terrace (1966 *a,b*) suggested.

The mean response rates per day to the S- before each generalization test are presented in Table 1. Notice that most birds maintained a very low level of responding in S-, *i.e.*, fewer than 20 responses per day, from about the thirtieth discrimination training session on. Moreover, there does not seem to be any relationship between responding in S- and the peak-shift. For example, Bird A8, the only subject that responded substantially to S- throughout training, failed to show a peak-shift on Tests 3, 5, 7, and 8, even though each of these tests was preceded by a relatively high response rate in S-. A careful examination of Table I also reveals that many peak-shifts occurred following a very low response rate in S-, as well as a relatively high rate in S-.

Thus, it appears that neither the response rate in S+ nor the rate in S- consistently predicts the peak-shift.

The generalization test data from the three groups suggest that overtraining on the S+ in the absence of the original S- has a greater tendency to reduce the peak-shift than does extended training with the S-. In fact, of the 35 peak-shifts that could have occurred on Tests 2 through 8 for each group, Groups 1 and 3 had 21 and 23 respectively, while for Group 2 the number was only nine. An analysis of variance of these data confirmed that there were fewer peak-shifts for the birds in Group 2 than in the other two groups ($F_{2,12} = 6.6, p < 0.05$).

DISCUSSION

The present results are clearly contrary to Terrace's (1966 *a,b*) suggestion that extended discrimination training reduces behavioral contrast and eliminates the peak-shift. The data from Group 1 reveal that four of the five birds were still showing behavioral contrast and three of the five were showing the peak-shift after approximately 115 days of discrimination training between the two wavelengths. Recall that in the Terrace work, discrimination training terminated after only 60 days. Thus, almost twice as much overtraining in

Fig. 6. The eight wavelength generalization gradients for the birds in Group 3 overtrained with the vertical line (S+) and the 538 nm (S-). Test 1 followed the original wavelength discrimination training.

the present study failed to produce the over-training effect reported by Terrace. Nor was a consistent relationship found between the presence of behavioral contrast and the peak-shift, other than on Test 1, where all birds

showed behavioral contrast and 13 of 15 birds showed the peak-shift.

In studying behavioral contrast, it is important to provide an adequate baseline of response rate during nondifferential training. As

Table 1

The mean per day response rates per daily session to S— before each generalization test for the three groups.

Text # Subject #	1	2	3	4	5	6	7	8
Group 1								
A19	377	7.46	0	2.0	1.2	2.0	0	1.0
A20	217.1	94.6	21.5	2.9	3.7	1.4	1.3	0
A6	121.4	6.1	0	4.6	1.5	2.3	8.5	13.3
A7	198.4	2.7	0	0	0	0	0	0
A8	509.7	16.5	157.1	83.3	25.2	52.0	108.5	88.2
Group 2								
A21	296.3	0	5	0	0	0	0	0
A22	183.8	4.7	0	0	0	0	0	0
A9	234.0	29.4	8.5	2.6	0	0	0	0
A10	187.4	9.8	0	1.9	1.8	35.2	6.8	0
A11	393.8	1.5	0	0	0	0	0	4.3
Group 3								
A23	288.8	27.3	7.0	5.6	4.5	7.5	5.7	5.5
A24	192.2	34.6	100.8	2.7	1.0	1.7	1.5	5.7
A14	703.4	185.8	15.7	5.1	2.7	22.9	20.1	12.8
A13	516.5	104.5	0	0	0	4.7	0	34.4
A12	170.2	10.4	0	0	0	0	29.2	9.4

Hearst (1971) pointed out, it is difficult to determine just how much training is necessary. Hearst felt seven days were adequate. In the present study, it was felt that five days of nondifferential training would be enough to demonstrate the basic increases in response rate that constitute behavioral contrast. The authors felt that the relationship between behavioral contrast and the peak-shift could be demonstrated without extended nondifferential training, as long as there was sufficient training to demonstrate the presence of contrast during initial discrimination training. We feel the data justify this approach because contrast occurred in all subjects with initial discrimination training. It remains unclear, however, whether or not the initial increase in the response rate to S+ was due exclusively to the behavioral contrast that accompanied the discrimination training. It is possible that part of the increase in response rate was due to a failure to establish a stable rate of responding in S+ during the five days of nondifferential training. If this were the case, however, the response rate in S+ would stabilize after additional discrimination training and the rate to S+ could subsequently reflect the presence of contrast. In that event, if overtraining reduces contrast, extended training would produce a response rate in S+ lower than the asymptotic level but above the level of responding maintained by

S+ with nondifferential training. The rate increase above baseline would reflect the increase in the response rate to S+ that occurred as the rate stabilized. The reduction of the rate below asymptote would reflect the disappearance of contrast. In no way would the predictions based on Terrace's model be affected because the model predicts specific changes in behavioral contrast and in the peak-shift with extended training that would have occurred after the rate to S+ stabilized. This means that: (1) the response rate to S+ during the training before a generalization test that shows a peak-shift should be higher than the rate to S+ before a test that does not show a peak-shift; (2) the rate in S+ should reach some upper bound and then decrease to some stable level with extended training; (3) with the decrease in response rate to S+, the probability of obtaining a peak-shift should also decrease. It is possible that this discussion is academic, since five days of nondifferential training were adequate for the only bird in Group 1 (A6) showing the effects of extended training predicted by Terrace's model. In fact, for this bird, extended training reduced the rate in S+ below the rate obtained with nondifferential training.

In summary, we feel that the five days of nondifferential training were sufficient to establish an adequate base rate in S+. But if the

rate to S+ continued to increase for some number of discrimination training sessions it would reach asymptote rather quickly and the prediction based on Terrace's model would be unaffected by this change. In any event, it is doubtful that the lack of a stable baseline early in training could have produced the variety of different effects on the rate to S+ obtained in the present study.

It should be pointed out that no bird showed a peak-shift on all tests; however, the initial failure to show a peak-shift was, in all cases, followed by a peak-shift on a later test. This refutes the notion that once the peak-shift disappears, its loss is permanent—an assumption implied by Terrace's theory. We also found that, in many cases, peak-shifts from later tests were much stronger than those obtained with early testing, a finding also different from that reported by Terrace.

The inconsistent nature of the peak-shift, with it occurring on some tests but not on others, may have produced the Terrace (1966 *a,b*) results. This is an especially cogent possibility in light of the fact that for Group 1, only eight of the 15 peak-shifts that could have occurred on Tests 3, 4, and 5 (the tests made after from 40 to 75 days of training) actually occurred. Thus, with training time very close to the 48 or 60 days of overtraining used by Terrace (1966 *a,b*), about half of the birds in the present study failed to show a peak-shift. The failure of the eight birds from the two Terrace studies to show the peak-shift is therefore not entirely inconsistent with the present data. However, the failure to replicate Terrace's data on behavioral contrast and its relationship to the peak-shift is clear. In fact, of the seven peak-shifts that occurred on Tests 3 through 5, two (those from Birds A19 and A6) occurred in the absence of behavioral contrast, *i.e.*, the response rate in S+ returned to its prediscrimination rate before the test. The remaining five peak-shifts (those from A8, A7, and A20) all occurred with behavioral contrast present before the tests. But these same birds failed to show a peak-shift on other tests where behavioral contrast was also present before test (*e.g.*, Test 7 for Bird A20, Tests 2, 3, and 4 for Bird A7 and Tests 3, 5, 7, and 8 for Bird A8).

The data from Group 2 suggest that overtraining on the S+ is more effective in eliminating the peak-shift than overtraining on the

S—, as Terrace (1966 *a,b*) claimed. Recall that this training produced fewer than half the peak-shifts obtained with either training condition that contained the original wavelength S—. Clearly, extended exposure to the S— is not effective in eliminating the peak-shift.

The training procedure for Group 3 produced the most peak-shifts (23) with four birds still showing a peak-shift on Test 8. As was the case with Group 1, no subject in Group 3 showed a peak-shift on all tests, yet the initial lack of a peak-shift was followed, in all cases, by at least one peak-shift in later testing. Thus, the data from all three groups show conclusively that the lack of a peak-shift early in training cannot be taken as *prima facie* evidence of the permanence of the disappearance of the peak-shift.

The overall results strongly refute Terrace's (1966 *a,b*) hypothesis that extended training gradually reduces behavioral contrast and, concurrent with that reduction, eliminates the peak-shift. The present results are consistent with the Hearst (1971) findings mentioned earlier, *i.e.*, the presence of behavioral contrast immediately before a generalization test does not guarantee a peak-shift. There were procedural differences between our work and the Hearst (1971) work on the one hand and Terrace's (1966 *a,b*) work on the other. One such difference was that Terrace (1966 *a,b*) used a "withhold" procedure during training, *i.e.*, the presentation of S+ was withheld until the bird had stopped responding in S— for at least 30 sec. Hearst (1971) suggested that this methodological difference might have produced the disparate results between his work and that of Terrace. It is possible that this procedural difference also produced the differences in the results from our Group 1 and the Terrace work, especially in the light of the fact that Bloomfield (1966, 1972) has shown that the withhold procedure produces different effects on contrast than does a non-withhold procedure. It may be that the overtraining effect reported by Terrace (1966 *a,b*) is limited to the specific procedure he used. Other training procedures such as the one used here fail to show a reduction of behavioral contrast or the peak-shift as a function of extended exposure to S—. In fact, the present study suggests that overtraining in the presence of S+ is most effective in eliminating the peak-shift.

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Received 17 January 1973.

(Final Acceptance 10 April 1973.)