**THE PEAK SHIFT IN STIMULUS GENERALIZATION:
EQUIVALENT EFFECTS OF ERRORS AND
NONCONTINGENT SHOCK¹**

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Terrace suggested that the peak shift in stimulus generalization occurs because the training stimulus not correlated with reinforcement has become aversive. This hypothesis is plausible in the light of instances where the peak shift is obtained compared with those where it fails to appear. The present experiment attempted to test implications of this hypothesis. Two groups of pigeons learned the same two-stimulus discrimination between colors by different training methods in a free-operant situation. When the discrimination was trained with many errors, a large peak shift was obtained in a subsequent generalization test of wavelength; after discrimination training with few errors, a negligible shift was observed. Half of each group then received noncontingent aversive shock during presentations of the stimulus not correlated with reinforcement in continued discrimination training. After this treatment, the errorless-shock subgroup showed a large peak shift and the error-shock subgroup tended to show a larger shift than before. Nonshocked control groups showed little change in the peak shift. It was concluded that pairing aversive shock with a stimulus not correlated with reinforcement is sufficient to produce or enhance a peak shift. In their effect on the peak shift, aversive shock and large amounts of nonreinforced responding appear to be equivalent.

The peak shift is a displacement in the mode of a postdiscrimination stimulus generalization gradient away from its expected location at S+ (the stimulus correlated with reinforcement) in a direction which also displaces it away from S- (the stimulus correlated with extinction). Since its earliest exploration (Hanson, 1959), the phenomenon has been studied extensively in the pigeon with wavelength of

light as the stimulus dimension. A peak shift typically occurs after two-stimulus discrimination training involving successive presentation of the stimuli. It does not, however, always occur after such discrimination training.

Terrace (1963a) evolved a method for teaching a discrimination with few or no "errors" (responses to S-). After such training, a peak shift did not occur; that is, the peak of the generalization gradient was at S+ (Terrace, 1964). Terrace suggested that S- functions differently when a discrimination is learned with errors than when it is learned with few or no errors. In the former case, nonreinforced responding may make S- an aversive stimulus. In the latter case, S- may be a neutral stimulus lacking motivational properties. Terrace then hypothesized that the peak shift represents a shift away from an aversive stimulus.

This hypothesis is credible in view of informal observations of behavior in the presence of S-. After errorful training, "emotional" responses (wing flapping, turning away from the pecking key, etc.) were common. After errorless training such responses did not occur (Terrace, 1963a). Also, tranquilizing drugs impaired discrimination performance only after errorful training (Terrace, 1963b). As the author argued, such drugs may render S- less aversive and with this source of re-

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sponse inhibition removed in the errorful case, S— responding resumes. In the errorless case, control of nonresponding in the presence of S— involves some other mechanism not based on aversiveness and this mechanism is not affected by these drugs. In line with this reasoning, Terrace (1966a) has shown that gradients around S— with greater-than-zero slopes, indicating response inhibition to S—, are obtained only after errorful discrimination training. After errorless training, generalization around S— does not yield this evidence of inhibitory control.

Honig (1962) found that a peak shift was not obtained after training involving simultaneous presentation of S+ and S—. A comparable experiment using successive presentations did yield a peak shift. Among the differences between these two procedures was that it required seven times as many responses to S— in the successive case to reach the same criterion of discrimination as in simultaneous presentation. Thus, it is plausible that S— became much more aversive in successive presentations because of prolonged S— responding and hence a peak shift did occur. In simultaneous presentation, the amount of S— responding may have been too low to generate much aversiveness, hence no peak shift occurred.

Guttman (1959) showed that a peak shift was obtained where "S—" was associated with a lower-frequency reinforcement schedule than S+. This implies that total extinction is not necessary to render S— aversive. Guttman's result was clarified by Terrace (1966b, p. 331 ff.) with two groups of pigeons. In the first phase of Terrace's experiment, one group (A) had a high-frequency reinforcement schedule associated with both of two stimuli; the other group (B) had a low-frequency schedule associated with the two stimuli. In the second phase of the experiment, discrimination training between these stimuli was begun for both groups with one stimulus (S1) correlated with the high-frequency schedule and the other stimulus (S2) correlated with the low-frequency schedule. Thus, while both groups underwent identical discrimination training, it meant for Group A a transition between the first and second phase from a high-frequency to a low-frequency schedule in S2 with no change in S1; for Group B, the transition was from a low-frequency to a high-frequency schedule in S1 with no change in S2. Only Group A

showed a peak shift in subsequent generalization tests. Presumably, then, a reduction of reinforcement frequency rendered S2 aversive (Group A), while an increase in reinforcement frequency during S1 did not make S2 aversive (Group B).

All of the above evidence is consistent with Terrace's hypothesis, but the evidence is somewhat indirect. The present experiment attempted to shed light on the hypothesis by assessing the following implications. If, in fact, the peak shift occurs because S— is aversive, then it should be possible to produce a shift where little or no shift existed previously by associating S— with an aversive event. Also, it should be possible to augment an existing peak shift by implementing the same procedure of associating S— with an aversive event.

METHOD

Subjects

Twelve male White Carneaux pigeons were maintained at 80% of free-feeding weight throughout the experiment.

Apparatus

An experimental chamber was designed to allow projection of colors of different wavelengths on a translucent pigeon key. The chamber was 14 in. long, 12 in. wide, and 18.5 in. high. Three of the walls were clear Plexiglas. The fourth was aluminum and contained a 1-in. diameter circular opening 10 in. from the floor and 4.5 in. from the right wall. The pigeon key was located behind this opening. The same wall contained a 2.5- by 2-in. rectangular opening centered in the wall 4 in. from the floor. Presentation of a grain hopper through this opening for 4 sec constituted a reinforcement. Two 0.5-w houselights supplied dim illumination of the chamber. A female telephone jack was located high on the rear wall of the chamber. A 10-in. length of coiled cable with a male telephone jack at one end and two alligator clips at the other was used in conjunction with the female jack to deliver shock through wing bands of beaded chain (Hoffman and Fleshler, 1959).

Behind the aluminum wall was a second chamber containing the grain hopper, pigeon key, and Bausch and Lomb second-order transmission type monochromatic interference filters. These filters were mounted on a circular

slide-projector drum which was set on a horizontal shaft permitting vertical rotation so that any one of the filters could be positioned accurately in front of the key. A Bausch and Lomb Nicholas microscope illuminator was mounted just behind the filter, which was in transmitting position, and supplied a narrow beam of white light. The light passed through the filter, then through an 8.25-in. long, 1.5-in. diameter tube lined with soft black paper, and then was projected onto the back of the pigeon key.

The entire unit was housed in a metal refrigerator shell. When the shell was closed, the subjects could be observed through a wide-angle viewer installed in the refrigerator wall adjacent to the pigeon chamber. The shaft on which the slide-projector drum was mounted extended through the wall of the refrigerator shell. The experimenter could rotate the drum by a wheel attached to this shaft and thus manually program generalization tests. Stimulus changes during two-stimulus discrimination training were automated by utilizing the motors located on the outside of the shell.

The seven monochromatic filters covered a nominal range of 510 to 570 $m\mu$ (millimicrons) in 10- $m\mu$ steps. Spectrophotometric analyses disclosed that actual peak wavelengths did not deviate from nominal wavelengths by more than 2 $m\mu$ for any filter. Extra bands of light in the violet region (350 to 450 $m\mu$) were found. These were eliminated by adding a Corning K-2 auxiliary filter to the optical system. The seven filters had a mean peak transmittance of 41.6% with a range from 37 to 46%. The half-width of the filters was 10 $m\mu$ or less. A 25-w 1060-ohm potentiometer in series with the Nicholas illuminator permitted fine control of brightness from apparent dark (to the dark-adapted experimenter's eyes) to fully bright. With the illuminator at full brightness all seven filters appeared equally bright to human observers. Since the spectral luminosity function in man is similar to that of the pigeon (Blough, 1957), no attempt was made to control brightness differentially for the different filters when the potentiometer was at 0 ohms.

The experimental sequence was programmed and responses recorded by automatic switching equipment in a room adjacent to the experimental chamber.

Preliminary Training

Within four days, all subjects were trained to eat when the food hopper was presented. Then, the response key, which had been dark, was illuminated by a 550- $m\mu$ light and key-peck training by successive approximation was begun. Once a subject was key-pecking, sessions lasted 30 min per day for two or three days, depending on the stability of performance as determined by visual inspection of the cumulative record. During this time, the reinforcement schedule was changed from reinforcement for every response (CRF) to a variable-interval schedule of 1 min (VI 1-min) with a range of 15 sec to 2 min. The schedule change was effected as quickly as possible for each bird. Each subject was then randomly assigned to one of two groups of six pigeons each, an errorless or an error group.

Discrimination Training—Errorless Group

The errorless group began discrimination training on the following day. The stimulus correlated with reinforcement (S+, 550 $m\mu$) and the one not correlated with reinforcement (S-, 570 $m\mu$) were presented alternately. A 5-sec timeout, during which the pigeon chamber was in total darkness, separated each presentation or trial.

S+ was always presented for 30 sec at full brightness with reinforcement available on the VI 1-min schedule. Duration and brightness of S- were varied in three phases. In the first phase, the key was kept dark by setting the potentiometer at 1000 ohms. The duration of S- trials began at 5 sec and was increased to 30 sec in successive 2.5-sec steps, trial by trial. In the second phase, duration was lowered to 5 sec and kept there while brightness was increased by lowering the resistance of the potentiometer from 1000 to 0 ohms. Resistance was decreased in 12 successive steps. Finally, in the third phase, full brightness of S- was maintained while duration was extended from 5 to 30 sec in 2.5-sec steps as in the first phase.

Terrace (1963c) used a similar procedure to prevent any responses from occurring in the presence of S-. However, that experiment involved a 40- $m\mu$ difference between S+ and S-. In the present case, with a 20- $m\mu$ difference, responses did occur during S-, especially in the third phase of changes. When this happened, either duration or brightness

or both were returned to values at which responding ceased and were kept there for several S— trials before proceeding with further changes. Once S— was fully bright and at full duration, the session was terminated and no further attempts were made to manipulate S— brightness or duration except during the first 5 min of the next day's session.

It was intended that full duration and brightness of S— would be attained within a single experimental session. A restriction was that the session would terminate after 60 reinforcements so that weight would not exceed 80% of free-feeding weight. For two pigeons this restriction meant that two sessions were required to arrive at the final discrimination.

On each of the five experimental days that followed errorless training, this group received 120 stimulus presentations (not including the 5 min of further S— manipulations on the first of these days) and on the five days after that, 60 stimulus presentations. On each of these 10 days, half of these trials were S+ and half were S—. They were programmed in an irregular sequence with a maximum run of three consecutive S+ or S—. Each presentation or trial lasted 30 sec and was followed by a 5-sec timeout.

Discrimination Training—Error Group

The error group did not receive discrimination training immediately after preliminary training. Rather, on each of the five following days, they received sixty 30-sec trials of S+ (550 m μ) only, with reinforcements programmed on VI 1-min and with 5-sec timeouts between each trial.

Discrimination training (S+ 550 m μ ; S— 570 m μ) began then and continued until at least 90% of total responses on each of two consecutive days occurred during S+ with the restriction that all pigeons received a minimum of five days of discrimination training. On each of these days, 60 trials per day were completed, half S+ and half S—, with the same irregular sequence as for the errorless group. S— was presented at full brightness and duration throughout discrimination training.

Except for the one or two days of errorless training (errorless group) and except for sessions beyond the minimum of five days of discrimination training (error group), the experimental design equated both groups for total

number of reinforcements before generalization testing.

Preshock Generalization Tests

On the day after discrimination training the first generalization test was given to all birds. The test series was preceded by 20 presentations of S+ and S— in an irregular sequence with reinforcements as during training. After this warm-up, further reinforcements were withheld while the seven test stimuli (including S+ and S—) were presented. Each stimulus was presented seven times mixed in with presentations of the other stimuli in a latin-square sequence. The presentations lasted 30 sec each and were followed by 5-sec timeouts during which responses were recorded and stimuli changed.

This first test was followed by one day of discrimination retraining as before the test to counteract any extinction effects during the first test. The day after that, a second generalization test was given to increase the number of observations per stimulus. This second test was identical to the first except that a different latin-square sequence was used.

Noncontingent Shock Procedure

After preshock generalization testing the two main groups were each divided into a nonshock and shock subgroup. Subjects were assigned on the basis that the mean location of the peaks in preshock gradients of the two subgroups within each main group were roughly equal. All birds, whether they were to be shocked or not, had the feathers on the underside of the base of each wing plucked, exposing flesh. Standard, chrome-plated, beaded chain was wrapped twice around the base of each wing and remained in place for the rest of the experiment. The chain was fastened tightly enough to ensure contact with the flesh. In all subsequent experimental sessions all subjects wore the coiled cable described in the Apparatus section. One end was connected to the chains through the alligator clips and the other end was plugged into the female jack at the back of the chamber.

Shock was delivered to the appropriate birds through the cable from a variable transformer without external series resistance. Each shock lasted 0.33 sec and the output voltage on the transformer was set at the lowest level which yielded a slight but noticeable startle reaction

in each bird. For the most part, once the appropriate shock level was determined, it remained there throughout the noncontingent shock sessions. Occasionally, the level for a given animal was changed up or down at the beginning of a session depending on the bird's reaction in order to maintain a slight but noticeable startle reaction. Measurements made after the experiment was completed showed that the animals had received between 0.7- and 1.0-ma shocks. This range included the few changes in shock level.

No shocks were delivered on the first session after preshock generalization testing but all birds wore the cable so that they would habituate to it. On each of the next 16 days, shocks were delivered during S- trials to the appropriate birds. On the first three days of the 16-day sequence, 5 to 8 shocks were administered during the last eight S- periods. The actual number was determined by visual observation of each animal. The minimum number was administered only if the shock led to generalized behavioral suppression. On each of the last 13 days, an average of 15 shocks were delivered, completely determined by an automated timing device. These shocks were programmed on a variable-interval schedule with no contingency between behavior and shock. On the average, one shock occurred during every second S-, always within the first 20 sec of the 30-sec trial. In all other respects, these sessions were like those which preceded preshock generalization tests, with 60 stimulus presentations, half S+ and half S-, programmed in an irregular sequence. In cases where the shock stimulus resulted in generalized suppression, so that a bird would not key-peck during an S+ within the 30-sec trial length, that S+ period was lengthened until responding resumed.

Postshock Generalization Tests

On the seventeenth day after introducing shock, all subjects were again tested for stimulus generalization. The test was preceded by a 20-trial warm-up, as in preshock generalization tests. Shocked animals received a single shock on the second S- only. Reinforcement and shock were then discontinued and the same seven stimuli were presented as in preshock tests but with a different latin-square sequence.

After the first day of postshock generalization tests, there was one day of retraining

with reinforcement during S+ and shock in S- to counteract extinction effects during the first test. Then a final day of generalization testing took place, identical to the previous one but with a changed latin-square sequence.

RESULTS

Discrimination Training and Preshock Generalization Results

No subject in the errorless group learned the discrimination without responses during S-. During the one or two days of errorless training, total responses during S- ranged from 5 to 111 among the birds. The errorless group also made occasional responses in the presence of S- during the 10 days of training preceding preshock generalization tests (responses ranged from 9 to 343). However, if responses in the presence of S- during these 10 days (average rate of 0.04 to 1.5 responses per min) are compared with responses in the presence of S+ during the same period (range of 8000 to 20,000, average rate of 36 to 89 responses per min), relatively few S- responses are seen.

"Behavioral contrast" (Reynolds, 1961) was shown by the error group as soon as discrimination training began. Mean rates during S+ over the five days of discrimination training were 1.5 to 2.7 times the mean rates during S+ for the preceding three days of S+ only training. It might be argued that this reflects the usual increase in rate over time during variable-interval schedules toward the beginning of training, rather than behavioral contrast. However, the same upward shift can be seen by comparing S+ response rate on the first day of discrimination training with that of the preceding day; mean rates increased by factors of 1.1 to 2.6. This increase between two successive days differentiated by the introduction of S- was consistent for all error animals. Rate changes between any other two successive days before preshock generalization tests (excepting the first two days of S+ only training when the animals were stabilizing on the reinforcement schedule) were not consistent and were of small magnitude. Thus, this sudden, consistent rate increase may be attributed to the introduction of S-.

Two birds in the error group attained the criterion of 90% of responses during S+ on

two successive days within the minimum allowed of five sessions of discrimination training. The other four birds needed 6, 7, 8, and 12 days to reach criterion (Birds 7, 8, 10, and 9, respectively). Total responses by the error group during S— before preshock generalization tests ranged from 600 to 6000. There was no overlap in total S— responses between this group and the errorless group.

The responses to each of the seven stimuli during the two sessions of preshock generalization tests were summed for each bird. The open-circle curves in Fig. 1 and 2 show the total responses in the presence of each stimulus during these preshock tests for each animal. All animals in the errorless group (Fig. 1) show maximal responding to 550 m μ , the S+. Birds 2, 3, and 4 also show rather elevated responding to 540 m μ . In the error group (Fig. 2), Birds 7, 9, and 10 show a peak shift with maximal responses to 540 m μ . The other three birds (8, 11, and 12) show maximal responding during S+ but with 540 m μ commanding only slightly fewer responses than 550 m μ .

A sensitive measure of location of the peak is to treat the generalization gradient as a frequency distribution and to calculate the gradient mean in m μ 's. Such treatment takes into account characteristics of the entire gradient. Figures 1 and 2 show the location of the gradient mean for each of the preshock gradients as a vertical dashed line.

Since there were more stimuli at wavelengths lower than S+ than there were at higher wavelengths, it would be expected that, regardless of training method, the location of the gradient mean would be shifted away from S+ toward lower wavelengths. A control group receiving nondifferential (S+ only) training was not included in the present experiment. Thus, there is no baseline for determining what the gradient mean would have been after nondifferential training. Using the gradient mean statistic, however, the two experimental groups may be compared as to degree of displacement away from S+.

The error group's gradient means (Fig. 2) range from 538.1 to 544.2 m μ while the errorless group's (Fig. 1) range is from 544.5 to 549.7 m μ . Thus, the two groups do not overlap in location of the peaks, with the error group consistently displaced further away from S+ than the errorless animals. Since the

groups are clearly separated, it is not necessary to decide whether, for instance, Bird 2 (gradient mean 544.5 m μ) does show peak shift, or whether Bird 12 (gradient mean 544.2 m μ) fails to show it. It can be concluded that the errorless training procedure had the reliable effect of locating the gradient mean close to S+ (group mean location of peak 547.3 m μ) while error training reliably produced a greater displacement away from S+ (group mean location of peak 541.7 m μ).

A Spearman rank correlation coefficient showed a high and statistically significant correlation between number of errors and location of gradient mean ($\rho = 0.86$, $p < 0.001$) when all 12 animals were taken into account. However, this correlation, in part, reflects the success of the experimental procedures in producing the major outcome discussed above. More impressive would be high correlations within each group considered separately. But within-group correlations were weak (error, $\rho = 0.31$; errorless, $\rho = 0.54$) and fell short of significance, partly because of the small number of subjects. Thus, there is a slight but unconvincing suggestion that the degree of displacement from S+ is greater the larger the absolute number of S— responses.

Noncontingent Shock and Postshock Generalization Results

Key-peck performance was not impaired by introducing the beaded chain and shock cable; nor did the cable interfere with movement. For the remainder of the experiment, four of the six nonshock birds maintained a response rate equal to or higher than that preceding preshock generalization tests. The other two birds, one in the error, the other in the errorless group, tended to respond at lower rates than before. No explanation for this decline is apparent.

The primary effect of shock was to produce great variability in performance of shocked subjects. Except on rare occasions, average response rates were consistently lower than before preshock generalization tests and varied irregularly for any given bird both within a session and from day to day. Any one animal sometimes showed stable performance for several sessions followed by sessions of irregular and erratic performance for no discernible reason. In one case, a notable change in re-

Fig. 1. Total responses to each stimulus in preshock and postshock generalization tests for the errorless subgroups and location of gradient means for each curve. Also shown are gradient change scores in $m\mu$ (preshock gradient mean minus postshock gradient mean) for each bird (on the left of each curve).

Fig. 2. Total responses to each stimulus in preshock and postshock generalization tests for the error subgroups and location of gradient means for each curve. Also shown are gradient change scores in $m\mu$ (preshock gradient mean minus postshock gradient mean) for each bird (on the left of each curve).

sponse topography occurred during four of the 16 shock sessions. Generalized suppression occurred fairly frequently for all subjects. This within and between-subject variability lasted throughout the 16 days of shock with no signs

of disappearing. These irregularities obscured any "behavioral contrast" effects which might have been expected either as increases in average S+ rate as compared with preshock rate or as S+ rate increases following a shocked S-

trial in comparison with rate after a non-shocked S— trial.

Five of the six errorless birds made very few responses to S— during these 16 days (totals of 0, 1, 6, 8, and 23 responses). The other bird, in the errorless-shock subgroup, made 230 responses to S—, but 90% of these occurred in two nonconsecutive days. The error group responded considerably more to S—, with the nonshock subgroup (347, 1706, and 1323 total S— responses) exceeding the shock subgroup (28, 99, and 106 total S— responses).

Despite erratic performance of shock subgroups, all animals yielded stable and orderly generalization gradients in the postshock tests. The total responses to each stimulus in these tests are presented as closed-circle curves in Fig. 1 and 2. Solid vertical lines in these figures locate the gradient mean of each postshock gradient. Presenting preshock gradients and gradient means in the same figures permits visual comparisons between preshock and postshock gradients.

The main point of interest is in differences between preshock and postshock gradients. A convenient measure of gradient change is preshock gradient mean minus postshock gradient mean. Thus, a positive number represents the magnitude in $m\mu$ of an increased peak shift and a negative number, the magnitude of a decreased shift. These gradient change scores are shown on the left-hand side of each bird's gradients.

Only small and inconsistent gradient changes are seen in the errorless-nonshock subjects (left column of Fig. 1). Birds 1 and 3 show slight increases in peak shift, primarily due to lowered relative responses to S+, while Bird 2 shows a slightly decreased peak shift due to elevated relative S+ responses.

The errorless-shock subgroup (right column of Fig. 1), however, shows consistent and comparatively large increases in the peak shift. In all three cases, maximal responding in postshock gradients is to 540 $m\mu$ where it had been to 550 $m\mu$ in preshock gradients. There is no overlap in the distribution of gradient changes between the shock and nonshock errorless subgroups. It can be concluded that continued discrimination training (errorless-nonshock) produced little gradient change with the peaks remaining near S+. Associating shock with S—, however, was sufficient to produce a marked peak shift where it was negligible before.

Another way to look at gradient changes in the errorless subgroups is to compare gradient means in these subgroups in postshock gradients with gradient means for the error birds in preshock gradients. The error and errorless groups did not overlap in the range along the continuum which contained their gradient means. Continued discrimination without shock left the postshock gradient means of the errorless-nonshock subgroup within the same range as their initial gradients. Adding shock, however, pushed two of the gradients (Birds 4 and 5) into the range previously occupied exclusively by the preshock gradient means of the error group. Bird 6, while showing a marked gradient change (going from 549.4 to 545.1 $m\mu$) did not leave the initial errorless range. Except for Bird 6, then, shock after errorless training had an effect on the peak shift comparable to the effect of error training without shock.

Turning now to the error subgroups, two of the error-nonshock animals (left column of Fig. 2) show a decrease in peak shift (Birds 7 and 8). This change is pronounced for Bird 7 but only slight for Bird 8. The other animal in this group (Bird 9) shows a moderate increase in shift. Thus, this subgroup shows inconsistency in gradient change. All that can be said about this subgroup, as well as about the errorless-nonshock subgroup, is that continued discrimination training without shock produced no reliable gradient changes. The error-nonshock postshock gradient means remain within the continuum range occupied by preshock error gradient means.

The error-shock subgroup (right column of Fig. 2) does show a consistent pattern with all three animals exhibiting an increased peak shift in gradient change. This increase was small for Bird 10 but pronounced for Birds 11 and 12. Even with the very inconsequential change for Bird 10, all error-shock postshock gradient means are displaced further away from S+ than any gradient mean in preshock tests for the error group. In other words, the three largest peak shifts obtained in the entire experiment were in postshock gradient means of the three error-shock birds. Thus, it appears that associating shock with S— where a peak shift was previously shown to exist has the effect of producing a still greater peak shift. This conclusion, however, will be tempered by subsequent analyses presented below.

Statistical analyses support the bulk of conclusions drawn above. An analysis-of-variance based on gradient means in preshock generalization tests showed a significant effect of training procedure ($F(1,8) = 13.5$, $p < 0.01$). Not surprisingly, then, the errorless-error variable produced statistically reliable differences. In this analysis, the shock-nonshock variable was included even though this experimental treatment had not been applied before preshock tests. Lack of significant differences attributable to this variable shows that no bias was introduced as a result of assigning birds to shock treatment subgroups ($F(1,8) = 0.24$). The interaction of the two variables was not significant ($F(1,8) = 0.23$).

A similar analysis of postshock gradient means showed that training technique continued to differentiate the groups ($F(1,8) = 28.9$, $p < 0.001$) and that the shock procedure produced reliable differences ($F(1,8) = 21.9$, $p < 0.01$). Interaction was insignificant ($F(1,8) = 1.7$) showing that the effect of shock was independent of original training method.

A third analysis-of-variance based on gradient change scores showed that the shock variable had a significant effect in producing gradient change ($F(1,8) = 9.5$, $p < 0.05$) but that the original training method bore no reliable relationship to gradient change ($F(1,8) = 0.3$). In other words, gradient changes were attributable solely to the shock-nonshock conditions. Once again, the interaction was not significant ($F(1,8) = 0.5$), showing that gradient change produced by shock was independent of original training method.

Within the errorless condition, there is no overlap in the gradient change scores between the nonshock and shock subgroups and these scores differ reliably from one another ($t(4) = 4.55$, $p < 0.01$, one-tailed test). This confirms the main finding that shock associated with S— produces a marked peak shift where negligible shift was present immediately after errorless training. A similar analysis comparing the nonshock and shock subgroups within the error condition approaches but falls short of statistical significance ($t(4) = 1.98$, $0.05 < p < 0.10$, one-tailed test). Thus, on statistical grounds, there is reason to doubt that after error training, shock had a reliable effect beyond that of continued training without shock. Failure to disclose a significant difference is due to the much greater variability of

gradient change scores in the error subgroups than in the errorless ones and is also due to a bad overlap in scores (in view of the small number of subjects) between Bird 9 of the nonshock and Bird 10 of the shock subgroup. Hence, despite the compelling graphical evidence, not as much confidence can be placed in the second main finding, that shock enhances a peak shift produced by error training, as can be placed in the effect of shock after errorless training.

DISCUSSION

In the initial part of the present experiment the errorless training procedure was not completely successful in preventing responses from occurring during S—. Terrace (1966b, p. 307 ff.) reported a tendency for errorless performance to become disrupted once appreciable responding to S— began. In the present case, probably due to the success of the correction procedure used during errorless shaping, discrimination performance was not greatly affected despite occasional bursts of S— responses, even when these occurred in later stages of the experiment. The present results suggest that "errorless" versus "error" training produces differences in S— response tendency along a continuum. Similarly, using the gradient mean statistic to locate the peak of the stimulus generalization gradient also treats the peak shift as a matter of degree along a continuum.

Viewed in this way, the preshock results confirm the findings of Terrace (1964). After errorless training, there was only a slight peak shift with gradient means relatively close to S+. After error training a relatively large peak shift was found in the generalization gradients. Subsequently, noncontingent shock was associated with S— for half of each group in continued discrimination training. Nonshocked animals showed inconsistent changes in the peak shift in postshock generalization gradients while shocked animals showed a consistent increase in the peak shift with the errorless-shock subgroup producing the most reliable changes. Thus, pairing shock with S— was sufficient to yield a large peak shift after errorless training had produced a small one. Also, shock tended to increase the magnitude of a large peak shift which had been produced by error training.

The experimenter's interpretation of these findings agrees with Terrace's. With regard to the training method variable, the peak shift is small or absent after errorless training because the relative absence of nonreinforced responding has not rendered S— an aversive stimulus with inhibitory properties. After error training, the large magnitude of S— responding has made S— aversive and inhibitory.

One might presume that the more responding to S—, the more aversiveness would be generated and the greater would be the degree of the peak shift. If this presumption is true it suggests a reinterpretation of Hanson's (1959) principal finding that the peak shift is greater with smaller differences between S+ and S—. It may be that these differences in degree of peak shift are attributable not to the stimulus difference *per se*, but, rather, to greater difficulty of discrimination with smaller stimulus differences, which, in turn, results in more nonreinforced S— responses. Hanson did find, in fact, that time to criterion of discrimination (hence, presumably, number of S— responses) was greater with smaller differences between S+ and S—. However, with stimulus differences greater than 10 m μ , there were only slight differences in time to criterion. Hence, the presumption does not receive strong support. Similarly, in the present study, the weak and insignificant correlations within the two main groups between preshock gradient means and absolute number of S— responses during preshock training is suggestive but not convincing. Further research on the relation between amount of nonreinforced responding and the degree of peak shift is needed.

With regard to the shock variable, the present interpretation is the same as for the training method variable. The peak shift phenomenon is affected by an unconditioned aversive shock stimulus presented during S—, in a manner similar to the effect of error training. In the one case, after errorless training, a peak shift was produced by shock. In the other

case, after error training, a peak shift tended to increase in magnitude due to shock. It is plausible, then that the critical variable responsible for the peak shift and its magnitude is aversiveness associated with the S—, produced either by nonreinforced responding or by presenting a shock stimulus. This may be added to a growing list of similarities between the effects of extinction (frustrative nonreinforcement) and aversive shock compiled by Wagner (1966).

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