DISCRIMINATIVE EFFECTS OF MASSED EXTINCTION¹

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Prior studies have reported that generalization gradients are not steepened if periods of non-reinforcement in S— follow and are not interspersed with periods of reinforcement in S+. Sharper gradients are produced by this massed-extinction procedure if it is preceded by prior discriminative training on a dimension orthogonal to the S+, S— dimension. The present study, using pigeons, found that generalization gradients along the wavelength dimension were steepened by massed-extinction sessions in 570 nm that had been preceded by: (1) discriminative training in which the S+ was a 550-nm light and the S— was a black vertical line superimposed on the 550-nm light; (2) non-differential reinforcement training with a 550-nm light and a black vertical line superimposed on the 550-nm light; (3) reinforcement training with only the 550-nm light. Massed-extinction sessions were administered until the response rate in the presence of the 570-nm stimulus was one-tenth of the mean response rate in the presence of the 550-nm stimulus during prior reinforcement training. Prior studies have used a time-dependent criterion, rather than a response-rate criterion of extinction, and this difference may be responsible for the differences in the effects of massed extinction on stimulus control.

Interspersion of reinforcement and non-reinforcement periods, each cued by stimuli from the same dimension (intra-dimensional training), is a rather typical component of discriminative training, yet relatively little is known about its contribution to the effects of discriminative training. Honig, Thomas, and Guttman (1959) found that no discriminative effects (*e.g.*, reduced responding in the S— stimulus region during generalization tests, steeper generalization gradients) could be produced by a procedure in which pigeons were first trained to key peck in the presence of a 550-nm light and subsequently exposed to sessions of non-reinforced key pecking in the presence of a 570-nm light (massed extinction). In their study, this massed-extinction procedure reduced rate of responding in the presence of all wavelength stimuli, with no greater reduction in the region of 570 nm (S—) than in other stimulus regions; nor was there any steepening of the generalization gradient. Friedman and Guttman (1965) replicated the finding of Honig *et al.* (1959), but found that the massed-extinction procedure would pro-

duce some discriminative effects if pigeons were first exposed to discriminative training, even though the relevant stimulus dimensions during that training and during massed extinction were different (inter-dimensional training). In that study, discriminative training was provided in which key pecks in the presence of a 550-nm light that transilluminated the entire key were reinforced, and key pecks in the presence of a dark cross on a background of 550-nm light were not reinforced. After 10 sessions of discriminative training, the birds were subjected to 40 min of a massed-extinction procedure in which key pecks were not reinforced in the presence of a 570-nm light. Generalization tests given on the next day revealed a reduction in responding to stimuli in the vicinity of the 570-nm stimulus. Friedman and Guttman were led to suggest that “. . . the formation of virtually any discrimination produced . . . a state of susceptibility to the specific extinction effects associated with an unrelated stimulus” (1965, p. 261). This suggestion was based primarily upon the data of birds that had received discriminative training involving exposure to a non-reinforcement component and necessarily to a second exteroceptive stimulus. It is possible that exposure to the second stimulus may have played some role in the effects of massed extinction on

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generalization gradients. Bitterman, Calvin, and Elam (1953) found that non-differential training facilitated subsequent performance in a differential reinforcement test with the same stimuli. They suggested that "some . . . differentiation may develop . . . in the course of non-differentially reinforced experience . . ." (p. 396).

The present study was undertaken to determine whether massed extinction sessions would lead to discriminative effects not only following inter-dimensional, discriminative training but also following inter-dimensional, non-differential reinforcement training.

METHOD

Subjects

Sixteen experimentally naive Silver King pigeons, 2- to 4-yr old, were maintained at approximately 80% of their free-feeding body weights through the experiment.

Apparatus

The experimental chamber was made of Plexiglas and measured 47 by 39 by 33 cm. The response panel contained a translucent Gerbrands pigeon key located 20 cm from the floor and a Lehigh Valley Electronics Co. grain feeder 15 cm below the key. A Grason-Stadler noise generator provided background noise throughout the session. A white houselight located in the upper left-hand corner of the response panel remained on throughout the session.

The monochromatic stimuli were presented using a device described by Johnson (1966). Activation of a solenoid raised a filter holder into the path of collimated light. The light source was a GE 18A/T10 2P-6V microscope illuminator bulb operated at 17.5 amps. The collimated light passed through Bausch and Lomb interference filters (44-78 series). A Kodak filter No. 2A was used in conjunction with the Bausch and Lomb filters to eliminate secondary transmission of wavelengths below 405 nm. A shutter prohibited light from reaching the response key during timeout periods as well as before and after the session began.

Procedure

The 16 pigeons were divided into four groups of four each. All birds were magazine trained and then shaped to peck a key trans-

illuminated by a 550-nm light until each bird had earned 50 reinforcements under a fixed-ratio 1 (FR 1) schedule of reinforcement. All birds were then exposed to a variable-interval (VI) 1-min schedule of reinforcement in the presence of the 550-nm keylight each day for 10 days. Access to the food magazine was limited to 3 sec. Each stimulus period was of 1-min duration with a 5-sec timeout period, during which the keylight was off and food reinforcers were not available. Twenty stimulus periods were presented each session. The force required to activate the response key was 0.147 N.

One group of birds (ND) then received non-differential reinforcement training during which key pecks were reinforced under a VI 1-min schedule in the presence of a 550-nm light, as well as in the presence of a 3-mm wide, black vertical line superimposed on the 550-nm light. Two groups of birds (SS and SSE), distinguished by their treatment in a later stage of the study, continued under the same training conditions as the prior 10 days. A fourth group of birds (D) received differential reinforcement training in which key pecks were reinforced under a VI 1-min schedule in the presence of a 550-nm keylight and not reinforced in the presence of the black vertical line superimposed on the 550-nm keylight. Each stimulus period was of 1-min duration and was presented 20 times with a 5-sec timeout period between presentations. This phase lasted for 16 sessions, after which Groups ND, SSE, and D received extinction sessions, each one of which consisted of twenty 1-min presentations of a 570-nm keylight, during which key pecks were not reinforced. Each stimulus period was separated from the next by a 5-sec timeout period. Extinction sessions were administered until the bird had, in the presence of the 570-nm stimulus, emitted 10% or fewer responses during the entire 20-min extinction session than the mean number it had emitted to the 550-nm stimulus during the last five days of the prior training regimen.

Each bird was then given a generalization test on the day after the extinction criterion had been met. Group SS, which did not receive any extinction sessions, was tested on the day following the last day of training. Generalization tests consisted of the presentation of eight monochromatic stimuli (500, 520, 530, 540, 550, 560, 570, 580 nm). Each one was presented

six times for a total of 48 test trials. Each stimulus was of 45-sec duration with a 5-sec timeout period between presentations. The order of stimulus presentations was randomized within each block of eight stimuli with the restriction that all eight stimuli had to be presented once before a new block of stimuli was presented. Food reinforcers were not available during generalization tests.

RESULTS

Figure 1 shows the mean response rate during the 550-nm stimulus for each group for each of the 16 training sessions. A repeated measures analysis of variance indicated that there were nonsignificant differences among the groups, significant ($p < 0.001$) differences among the sessions, and a significant ($p < 0.05$) session $\times$ group interaction. During the preceding 10 sessions, in which all groups were under the same VI 1-min schedule of reinforcement, only sessions was a significant ($p < 0.001$) source of variation.

Table 1 contains the individual data of the extinction sessions. The mean amount of time required for all birds to reach criterion was

Table 1

Total responses and total time to reach extinction criterion.

Training Condition	Bird	Number of Responses to 570 nm	Time Min
Group ND (non-differential reinforcement)	3951	1226	79
	4145	1469	60
	66	657	60
	4060	2201	97
Mean		1388	74
Group SSE (single stimulus)	2803	3606	138
	3243	1657	59
	4483	5467	159
	4798	3367	103
Mean		3524	115
Group D (differential reinforcement)	3256	2599	59
	4725	2916	116
	4692	2917	60
	3521	981	97
Mean		2353	83

Fig. 1. Mean response rate in the presence of the 550-nm stimulus during training but before massed extinction. The functions are labelled as follows: D, differential reinforcement; ND, non-differential reinforcement; SS, single stimulus, no subsequent massed extinction; SSE, single stimulus.

Fig. 2. Mean absolute generalization gradients for the four groups. They are labelled as follows: D, differential reinforcement; ND, non-differential reinforcement; SS, single stimulus, no subsequent massed extinction; SSE, single stimulus.

91 min, with a range from 59 to 159 min. Although the extinction session was 20 min and thus the data shown in Table 1 should have been multiples of 20 min, there were slight deviations in the actual duration of some extinction sessions.

Figure 2 shows the absolute generalization gradients for all four groups. A repeated measures analysis of variance revealed significant differences among groups ($F = 5.59$, d.f. 3, 12, $p < 0.025$), stimuli ($F = 44.72$, d.f. 7, 84, $p < 0.001$), and a significant interaction between groups and stimuli ($F = 3.90$, d.f. 21, 84, $p < 0.001$). It should be noted that the mean numbers of responses to the peak of the generalization gradients for Groups D, ND, and SSE are not elevated above the mean number of responses at the peak of the generalization gradient for Group SS.

Table 2 contains the individual data of the generalization tests. Figure 3 shows the mean relative generalization gradients of all four groups. A similar repeated measures analysis of variance revealed a significant difference

among stimuli ($F = 48.00$, d.f. 7, 84, $p < 0.001$), and a significant groups $\times$ stimuli interaction ($F = 2.15$, d.f. 21, 84, $p < 0.005$). The generalization gradients of the birds in the three groups exposed to massed-extinction periods (D, ND, SSE) are steeper than the generalization gradient of birds not exposed to massed extinction (SS).

Analyses of slope differences that use relative generalization gradients that are based upon data which consist of zero responses to stimuli on the wings of the gradient can lead to ambiguous interpretations, especially when there is an overall reduction in responding. It is possible that under these circumstances, steeper relative generalization gradients are artifacts of measurement. In order to gain a clearer picture of the relative steepness of the generalization gradients, only three values along the S+ dimension were used in the calculation of the relative generalization gradients shown in Figure 4. The number of responses emitted to 550 nm (S+) was made equal to 100% and responses to 540 nm and 560 nm were calcu-

Table 2

Responses to wavelength stimuli in generalization tests. All birds except those in Group SS were exposed to massed extinction periods before test.

Training Condition	Bird	Stimuli in nm							
		500	520	530	540	550	560	570	580
Group SS (single stimulus no massed extinction)	3889	0	112	73	285	371	216	159	139
	4141	131	91	231	414	470	379	291	313
	4518	24	87	108	121	131	122	144	128
	4581	1	82	69	142	137	196	106	117
Group D (differential reinforcement)	3256	3	18	25	331	346	104	138	63
	4725	0	36	62	168	317	7	0	9
	4692	0	6	0	78	272	163	5	0
	3521	0	1	0	94	220	0	6	1
Group ND (non-differential reinforcement)	3951	0	1	0	71	79	17	24	4
	4145	0	0	0	27	69	8	0	0
	66	0	9	8	122	128	63	22	1
	4060	4	2	0	43	91	9	1	1
Group SSE (single stimulus)	2803	0	38	10	197	157	52	46	9
	3243	1	0	20	192	135	26	8	0
	4483	0	6	14	201	252	121	31	14
	4798	0	14	7	51	110	33	4	11

Fig. 3. Mean relative generalization gradients for the four groups. They are labelled as follows: D, differential reinforcement; ND, non-differential reinforcement; SS, single stimulus, no subsequent massed extinction; SSE, single stimulus.

Fig. 4. Responses to the 540- and 560-nm stimuli plotted as a percentage of responses to the 550-nm stimulus. The mean relative generalization gradients for the four groups are labelled as follows: D, differential reinforcement; ND, non-differential reinforcement; SS, single stimulus, no massed extinction; SSE, single stimulus.

lated as percentages of it. The gradients to the left of S+ are steepest for the D and ND groups and relatively flat for the SSE group. Two of the four birds of the SSE group responded more to the 540-nm stimulus than to the 550-nm stimulus (peak shift), a result that would tend to flatten the gradient between 550 nm and 540 nm.

DISCUSSION

The present study was undertaken to determine whether any discriminative effects of massed extinction in S−, which have been reported to be absent following S+ only training, but present after prior discriminative training on a dimension orthogonal to S+, S−, could be induced after exposure to non-differential reinforcement. In the course of the study, it was found that some discriminative effects of massed extinction could be produced after non-differential reinforcement and after differential reinforcement, and also following S+ only training, the latter finding being in apparent disagreement with the results reported by earlier investigators. The Honig *et al.* (1959) and Friedman and Guttman (1965) studies used 10-sec timeout periods between stimulus presentations but a 5-sec timeout period was used in the present study. This difference would appear to be small and not likely to have led to differences in the effectiveness of the massed-extinction procedure. How-

ever, it is still possible that under the conditions of the present study, the timeout period provided enough of an opportunity for discriminative training that it rendered the massed extinction treatment effective for all three groups. An important difference in procedure between the present and earlier studies concerns the criterion of massed extinction. The criterion in the present study required that the bird emit 10% or fewer responses in the presence of the massed-extinction stimulus (S−) than it had in the presence of the S+ stimulus. The mean amount of time required for all the birds exposed to massed-extinction sessions was 91 min. The amount of exposure to massed extinction in both the Honig *et al.* (1959) and the Friedman and Guttman (1965) studies was 40 min for all birds and was not dependent upon response rate. The original study (Hanson, 1956) that apparently led to studies on the effects of massed extinction in S− made use of a response rate criterion to determine at what point generalization tests should be administered. The criterion was one of "... no responding in five successive minutes of S− within one 10 min block ..." (1956, p. 9). The S+ was a 550-nm light and the data from the group of birds given 570 nm as the S− reveal that the total time required to meet the criterion ranged from 60 to 165 min, and the mean for the six birds was 98 min. The discriminative effects that Hanson (1956, 1957, 1959) described were reduced responding to stimuli 570 nm and longer and increased responding to stimuli in the region 530-550 nm. These effects were produced after considerably greater exposure to S− than that given by either the Honig *et al.* (1959) study or the Friedman and Guttman (1965) study. The present results, and those of a previous study (Yarczower and Switalski, 1969), support the suggestion that interspersed S+ and S− trials is not a necessary condition for the production of certain discriminative effects of S+, S− training; a reduction in responding in the region of the S− stimulus and a sharpening of control by the S+ stimulus.

The number of responses emitted at the peak of the generalization gradient may be elevated beyond the number emitted after training with only S+ (Nevin, 1973). It is unclear from a review of the literature to what extent the elevated peak is in fact a reliable product of discriminative training. The fre-

quent reporting of relative generalization gradients only, and the lack of appropriate controls for the amount of S+ training received by subjects given discriminative training, preclude a definitive statement about the elevation in peak responding. Of the studies that contain data suitable for such an analysis, there are as many that reveal reliable rate increases to the peak stimulus as there are that do not. Two studies report the occurrence of an elevated peak response rate (Hanson, 1961; Thomas and Williams, 1963), which was the result of training with three stimuli; in the former case, two S—s and one S+ were used and in the latter case, two S+s and one S— were used. In addition to these studies, the data reported by Rudolph and Honig (1972, see Table 1), when converted to absolute scores, reveal higher peak rates for each of the 10 birds given discriminative training than for the three birds given only S+ training. Wildemann and Holland (1973) also reported data (see Table 2, Figures 1, 2) which, when converted to absolute scores, revealed higher peak rates for each bird given discriminative training ("Delayed Traditional Subjects") than for birds given only S+ training. However, in that same study, when S— was introduced soon after S+ had been introduced ("Early Traditional Subjects"), only two of the five birds had peak rates higher than the five birds of the control group. Jenkins and Harrison (1962) and Yarczower, Gollub, and Dickson (1968) reported data that revealed clear reductions in peak responding as a function of discriminative training. In one of two studies by Terrace for which comparisons can be made, the data reveal overlap in peak responding between the three birds that received S+ only training and those that received discriminative training with errors (Terrace, 1964). In the other study (Terrace, 1968), comparisons between the data of birds that reflected peak shifts with those that did not, also revealed overlap in peak responding (compare Figure 1 with Figure 2 and Figure 4 with Figure 5). Grusec (1968) showed that generalization gradients of birds given near-errorless discriminative training did not reveal peak shifts. If non-contingent shocks were administered subsequently in the presence of the S—, then generalization gradients revealed a peak shift. The gradients also reveal a reduction in peak responding for two of the three birds that

received that treatment. The present data revealed either no increase in peak responding or, in many instances, a decrease in the response rate to the peak stimulus.

If, however, it does appear that an elevated peak is the result of interspersed S+, S— training, then it may very well be the only by-product of discriminative training for which interspersed S+, S— training is necessary. Indeed, if an elevated peak in the generalization gradient is the result of behavioral contrast induced during discriminative training, then, according to Amsel (1971), interspersed S+, S— is a condition necessary for the occurrence of behavioral contrast. According to Amsel, contrast is an increase in the response rate in S+ precipitated by the frustrative aftereffects of non-reinforcement in the S— stimulus period. These frustrative aftereffects are time dependent and presumably are not present when S+ and S— periods are not interspersed.

REFERENCES

- Amsel, A. Positive induction, behavioral contrast, and generalization of inhibition in discrimination learning. In H. H. Kendler and J. T. Spence (Eds.), *Essays in neobehaviorism*, New York: Appleton-Century-Crofts, 1971. Pp. 217-236.
- Bitterman, M. E., Calvin, A. D., and Elam, C. B. Perceptual differentiation in the course of nondifferential reinforcement. *Journal of Comparative and Physiological Psychology*, 1953, **46**, 393-397.
- Friedman, H. and Guttman, N. Further analysis of the various effects of discrimination training on stimulus generalization gradients. In D. I. Mostofsky (Ed.), *Stimulus generalization*. Stanford, Calif.: Stanford University Press, 1965. Pp. 255-267.
- Grusec, T. The peak shift in stimulus generalization: equivalent effects of errors and noncontingent shock. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 435-441.
- Hanson, H. M. *The effects of discrimination training on stimulus generalization*. Unpublished doctoral dissertation, Duke University, 1956.
- Hanson, H. M. Discrimination training effect on stimulus generalization gradient for spectrum stimuli. *Science*, 1957, **125**, 888-889.
- Hanson, H. M. Effects of discrimination training on stimulus generalization. *Journal of Experimental Psychology*, 1959, **58**, 321-334.
- Hanson, H. M. Stimulus generalization following three-stimulus discrimination training. *Journal of Comparative and Physiological Psychology*, 1961, **54**, 181-185.
- Honig, W. K., Thomas, D. R., and Guttman, N. Differential effects of continuous extinction and discrimination training on the generalization gradient. *Journal of Experimental Psychology*, 1959, **58**, 145-152.
- Jenkins, H. M. and Harrison, R. H. Generalization

- gradients of inhibition following auditory discrimination learning. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 435-441.
- Johnson, D. F. A device for rapid presentation of monochromatic stimuli. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 335-336.
- Nevin, J. A. Stimulus control. In J. A. Nevin (Ed.), *The study of behavior*. Glenview, Illinois: Scott, Foresman, 1973. Pp. 115-152.
- Rudolph, R. L. and Honig, W. K. Effects of monochromatic rearing on spectral discrimination learning and the peak shift in chicks. *Journal of the Experimental Analysis of Behavior*, 1972, 17, 107-111.
- Terrace, H. S. Wavelength generalization after discrimination learning with and without errors. *Science*, 1964, 144, 78-80.
- Terrace, H. S. Discrimination learning, the peak shift, and behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 727-741.
- Thomas, D. R. and Williams, J. L. A further study of stimulus generalization following three-stimulus discrimination training. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 171-176.
- Wildemann, D. G. and Holland, J. G. The effect of the blackout method on acquisition and generalization. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 73-80.
- Yarczower, M., Gollub, L. R., and Dickson, J. F. Some effects of discriminative training with equated frequency of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 415-423.
- Yarczower, M. and Switalski, R. Stimulus control in the goldfish after massed extinction. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 565-570.

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