ON THE MINIMAL CONDITIONS FOR THE DEVELOPMENT OF A PEAK-SHIFT AND INHIBITORY STIMULUS CONTROL¹

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Failures to obtain a peak-shift and inhibitory stimulus control following massed extinction in the presence of intra- and interdimensional stimuli confirm earlier results reported by Honig, Thomas, and Guttman (1959) and by Weisman and Palmer (1969). Peak-shifts and inhibitory stimulus control were observed when any of the following procedures intervened for 3 min between massed extinction and generalization testing: (1) S+ presented, responding reinforced; (2) S+ presented, responding not reinforced; or, (3) noncontingent food presented in the presence of a dark key. Behavioral contrast was shown not to be a necessary antecedent for the occurrence of peak-shift or inhibitory stimulus control.

A wide variety of experiments have replicated Hanson's (1959) demonstration of a peak-shift in the pigeon. For example, Bloomfield (1967) obtained a peak-shift on the line-orientation continuum; Pierrel and Sherman (1960) obtained a peak-shift from rats, and Terrace (1968) obtained a peak-shift following differential reinforcement when responding to both discriminative stimuli was reinforced, albeit at different frequencies. A summary of other experiments on the peak-shift can be found in Purtle's (1973) review article.

One interesting failure to obtain a peak-shift was reported by Honig, Thomas, and Guttman (1959). In this experiment, with pigeons, each subject's exposure to S- was confined to a single interval, either 20 or 40 min in duration. Following this single presentation of S- (massed extinction), subjects were given a generalization test. The gradients obtained by Honig *et al.* differed from those obtained after successive discrimination training in two respects. The peaks were located at S+ and the overall level of responding to test stimuli was lower. A similar study, using goldfish, also

failed to obtain a peak-shift following massed extinction (Yarczower and Switalski, 1969).

The failure to obtain a peak-shift following massed extinction cannot be attributed to the relatively short exposure to S- before the generalization test. When S+ is alternated with S-, a peak-shift can be obtained after as little as 20-min total exposure to S- (Thomas, 1962).

An experiment on inhibitory stimulus control by Weisman and Palmer (1969) produced results analogous to those obtained by Honig *et al.* Weisman and Palmer first demonstrated inhibitory stimulus control following successive discrimination training between a green (S+) and a vertical line (S-). U-shaped gradients of line-orientation, with minima at S-, were obtained following successive discrimination training between two stimuli from orthogonal continua. However, following massed extinction in the presence of a vertical line, generalization gradients of line-orientation were flat, rather than U-shaped.

Why is not massed extinction in the presence of S- an effective procedure for producing either a peak-shift or inhibitory stimulus control? One obvious answer points to the absence of reinforcement following S- in the massed extinction procedures used by Honig *et al.* and by Weisman and Palmer. On the other hand, a successive discrimination procedure (by definition) ensures that presentations of S- will be followed by presentations of S+. From the point of view of traditional models of successive discrimination learning (*e.g.*, Bush and Mosteller, 1951; Hull, 1943; Spence, 1936,

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1937) a successive discrimination procedure alternates periods of excitation (occasioned by S+) with periods of inhibition (occasioned by S-). During presentations of S+, opportunities exist for the occurrence of various sources of potential excitation. These include (1) the opportunity to respond to S+ *per se*, (2) the opportunity to obtain food in the presence of S+, (3) the opportunity to consume food reinforcers, and (4) the opportunity for behavioral contrast to develop. The present experiments sought to evaluate the importance of these presumed excitatory factors in the development of the peak-shift and inhibitory stimulus control.

METHOD

General Procedure

During the first phase of the basic experimental paradigm, a pigeon was trained to respond to S+ on a variable-interval (VI) schedule of reinforcement. Following a period of massed extinction in the presence of either an intra- or an interdimensional stimulus, each subject was exposed briefly to one of the following procedures:

- (a) Presentation of S+, during which responding was reinforced.
- (b) Presentation of S+, during which responding was not reinforced.
- (c) Noncontingent reinforcement in the presence of a dark key.

To assess the effects of these procedures, generalization gradients were first obtained from subjects whose total experience before a generalization test occurred in the presence of S+. These control procedures were studied in Experiment I.

The effects of brief periods of S+ and/or reinforcement following massed extinction were studied in Experiments II and III.

In Experiment II, a minimum of 2 hr of massed extinction was arranged. However, each response to S- stopped the S- timer for 45 sec. In Experiment III, the duration of massed extinction was fixed at 2 hr.

Subjects

Sixty-two experimentally naive White Carneau male pigeons were maintained at 80

$\pm 3\%$ of their free-feeding weights throughout the experiment. The ages of subjects ranged from six months to 1 yr.

Apparatus

Each experiment was conducted in a standard operant-conditioning apparatus (Ferster and Skinner, 1957). The center of a single circular key, 2.54 cm in diameter, was located 21.27 cm above the floor. The bottom of the opening to the food hopper (4.76 cm square) was located 6.35 cm above the floor. The micro-switch from which key pecks were recorded required a minimum force of 15 g (0.15 N) to be activated. The houselight was on at all times during experimental sessions except during food presentations, which were each of 4.4-sec duration.

The response key was transilluminated by light from an optical system consisting of a high-intensity point source (a Westinghouse #1493, 2.75-A, 6.5-V bulb), a collimating lens, and a solenoid-operated two-compartment filter box. The filter box could move from side to side in a manner that enabled stimuli in either the right-hand or the left-hand compartment to be presented by remote command. During generalization testing, when it was necessary to select from more than two stimuli, a filter-flipper unit (Johnson, 1966) was added to the optical system between the light source and dual filter box. The filter-flipper unit could be programmed to present any one of 15 different stimuli.

Monochromatic stimuli were generated by passing collimated light through Bausch and Lomb second-order interference filters that were corrected for secondary peaks. The peak values of these interference filters were 490, 510, 520, 530, 540, 550, 560, 570, 580, 590, 600, 610, 630, 650, and 670 nm; the half-width band pass of each filter was less than 12 nm. Their transmittances ranged between 26% and 37%; luminances ranged between -0.28 and -0.64 log ft-lamberts.

In those procedures concerned with intra-dimensional stimulus control, S+ was a homogeneous field of monochromatic light whose dominant wavelength was 570 nm. In the intra-dimensional experiments on massed extinction (Experiments II and III, Groups 2A, 3A, 4A, 5A, 6A, 7A, 8, and 9), S- was a homogeneous field of monochromatic light whose wavelength was 550 nm. The luminances of S+ and

S- were respectively -0.33 and -0.45 log ft-lamberts.

In those procedures concerned with interdimensional stimulus control, S+ was a white vertical line (0°), 0.32 cm wide, on a black background. In the interdimensional experiments on massed extinction (Experiments II and III, Groups 2B, 2C, 3B, 4B, 5B, 6B, and 7B), S- was a homogeneous field of monochromatic light whose dominant wavelength was 570 nm. The brightness of the white line was matched, by eye, to the brightness of the 570-nm stimulus. To achieve this apparent equal brightness, a 0.3 neutral density filter was added to the filter that generated the white line.

Generalization Test

Following intra- and interdimensional training, each subject was tested for wavelength generalization. Following intradimensional training, the generalization test consisted of four different sequences of the 15 test stimuli described above. Following interdimensional training, the generalization test consisted of four different sequences of 16 stimuli each (15 different wavelengths and S+). The generalization test given to Group 2C subjects of Experiment II did not include S+.

Each test stimulus was presented for 1 min and was followed by a 2-sec timeout period (TO), during which the key was dark. Responding was not reinforced during any of the generalization tests.

Preliminary Training

Before the generalization test, responding was reinforced nondifferentially in the presence of S+. In Experiment I, generalization testing followed nondifferential training directly. In Experiments II and III, a particular experimental treatment intervened between nondifferential training and the generalization test. Throughout both phases of training, the key was darkened for 2 sec (TO) at the end of each minute during which S+ was presented. These TOs were used to prepare the birds for generalization testing, during which the 2-sec TO was used for changing filters. Responses were never reinforced during TO.

On the first day in the experimental chamber, each subject was (1) trained to peck the key by the method of successive approximations, (2) given several continuous reinforce-

ments (CRF), and (3) introduced to a 15-sec variable-interval schedule of reinforcement with timeout (VI 15-sec TO). Beginning with the second day, during which responding was reinforced on a VI 15-sec TO schedule, all sessions of the nondifferential phase were terminated after the twenty-fifth reinforcement.

On both the third and fourth days of training, responding was reinforced on a VI 30-sec TO schedule. On the fifth day, and during the subsequent 19 nondifferential sessions, responding was reinforced on a VI 1-min TO schedule. In subsequent descriptions of the procedure, the first day of VI 1-min TO training is referred to as Session 1 and the sequence of 1-min of VI 1-min followed by TO is referred to as a cycle of VI 1-min TO.

EXPERIMENT I

This experiment was conducted to provide baseline gradients of intra- and interdimensional generalization. After 20 sessions of nondifferential reinforcement, generalization gradients were obtained from each of the groups studied. The experimental procedures are outlined in Table 1. During the 20 sessions of nondifferential reinforcement, Group 1A subjects received reinforcement for responding to 570 nm; Group 1B subjects received reinforcement for responding to a white vertical line on a black background.

Table 1
Experiment II

S+:	Group 1A	Group 1B
	570 nm	White Vertical Line
Massed Extinction:	No	No
Intervening Treatment:	No	No
Generalization Test:	Intra- dimensional S+ included	Inter- dimensional S+ included
N:	4	6
Subjects:	B-484	B-385
	B-486	B-387
	B-489	B-396
	B-490	B-397
		B-400
		B-427

RESULTS

Baseline rates of responding to S+ and the generalization gradients of each subject are shown in Figure 1 (Group 1A) and Figure 2 (Group 1B), respectively. In each case, responding on the VI 1-min TO baseline had stabilized by the end of the 20 sessions. Figure 1 shows that gradients of wavelength generalization tend to be symmetrical around S+. Figure 2 shows that when responding along the wavelength continuum is assessed directly after nondifferential training in the presence of an orthogonal stimulus (a vertical line), there is little systematic tendency to respond to any test stimulus from the wavelength continuum. Except for Subject B-427, there was a slight preference for stimuli in the 550 to 530-nm region of the wavelength continuum. This preference was similar but smaller than that reported by Selekman (1973), who measured the tendency to respond to stimuli from the wavelength continuum following nondifferential training in the presence of a white light.

EXPERIMENT II

METHOD

This experiment sought to determine the effect of massed extinction on inter- and intra-dimensional stimulus control where a correction procedure was used to ensure that, at the

end of massed extinction, the rate of responding to S- was reduced to zero. The experimental groups and the procedures followed in Experiment II are outlined in Table 2. In each case, Session 21 began with three cycles of VI 1-min TO, followed by massed extinction, either in the presence of 550 nm (intra-dimensional groups) or 570 nm (interdimensional groups). These cycles are referred to as *A* in the description of the results. No TOs were scheduled during extinction. If no responding occurred to S-, massed extinction lasted 2 hr. Under the correction procedure, however, each response during massed extinction stopped the 2-hr timer for 45 sec. Thus, massed extinction could not terminate until a period of 45 sec without a response had elapsed.

Groups 2A, 2B, and 2C (generalization test follows directly after massed extinction). Group 2A subjects experienced massed extinction in the presence of 550 nm following nondifferential training in the presence of 570 nm. Group 2B and 2C subjects experienced massed extinction in the presence of 570 nm following nondifferential training in the presence of a white vertical line. In the session that followed massed extinction, each subject was given a generalization test. For Group 2A and 2B subjects, S+ was included among the test stimuli of the generalization test. S+ was omitted from the test stimuli of the generalization test given to Group 2C.

Table 2
Experiment II. Correction Procedure

		Group								
		2A	2B	2C	3A	3B	4A	4B	5A	5B
S+:	570 nm	0° white line	0° white line	570 nm	0° white line	570 nm	0° white line	570 nm	0° white line	570 nm
S-:	550 nm	570 nm	570 nm	570 nm	550 nm	570 nm	550 nm	570 nm	550 nm	570 nm
Massed Extinction:	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intervening Treatment:	No	No	No	S+/S ^R	S+/S ^R	S+/S ^{R̄}	S+/S ^{R̄}	S̄+/S ^R	S̄+/S ^R	S̄+/S ^{R̄}
Generalization										
Test:	S+ included	S+ included	S+ omitted	S+ included	S+ included	S+ included	S+ included	S+ included	S+ included	S+ included
N:	3	4	4	4	3	3	3	4	3	
Subjects:	B-501	B-429	B-399	B-510	B-302	B-514	B-332	B-538	B-328	
	B-502	B-430	B-428	B-515	B-310	B-522	B-338	B-541	B-339	
	B-504	B-431	R-1	B-518	B-320	B-523	B-362	B-590	B-346	
		B-432	R-9	B-519				B-591		

GROUP 1A: CONTROL GROUP
S+ (570 nm) → GENERALIZATION TEST

Fig. 1. Individual and group average rates of responding to S+; generalization gradients of Group 1A.

GROUP 1B: CONTROL GROUP S+ (0°) → GENERALIZATION TEST

Fig. 2. Individual and group average rates of responding to S+; generalization gradients of Group 1B.

Groups 3A and 3B (reinforced responding following massed extinction). Following massed extinction, each Group 3A and 3B subject was allowed to respond to three presentations of S+, in the presence of which responding was reinforced on a VI 1-min TO schedule. A maximum of six reinforcements would be earned under this condition. During the next session, a test of wavelength generalization was administered to each subject.

Each of the experimental procedures employed for Groups 3A, 3B, 4A, 4B, 5A, and 5B was instituted immediately after massed extinction at the end of Session 21 as follows: two 1-min cycles occurred, each preceded by TO. These cycles are referred to as *B* in the description of the results. At the start of Session 22, a single 1-min warm-up cycle (followed by TO) of any of three experimental procedures was in effect. This cycle is referred to as cycle *C*. The generalization test commenced immediately after the TO that followed cycle *C*.

Groups 4A and 4B (presentation of S+/no reinforcement). At the end of massed extinction, each subject in these two groups was presented with three 1-min cycles S+. Responding to S+ was not, however, reinforced. During the next session, a test of wavelength generalization was administered to each subject.

Groups 5A and 5B (blank key and noncontingent reinforcement). Following massed extinction, these subjects were given as many as six noncontingent reinforcements in the presence of a blank key. During the 3 min in which this condition was in effect, no stimulus was presented on the key and responding was not reinforced. Noncontingent reinforcements were presented on a variable-time 1-min (VT 1-min) schedule. During the following session, a test of wavelength generalization was administered to each subject.

RESULTS

The main result of Experiment II can be summarized as follows. No peak-shifts could be discerned in any of the generalization gradients obtained directly after massed extinction. Peak-shifts were observed in all gradients obtained after any of three experimental treatments that followed massed extinction (reinforced responding to S+, nonreinforced re-

sponding to S+, and noncontingent reinforcers in the presence of a blank key). Given that a peak-shift occurred, its magnitude did not appear to be systematically related to the different treatments that followed massed extinction. It was also shown that a peak-shift could be obtained, even though contrast did not occur during the training that followed massed extinction.

Inhibitory stimulus control was not obtained if the generalization test was administered directly after massed extinction. Inhibitory stimulus control was obtained following massed extinction if, before the generalization test, S+ (with or without reinforcement) was presented for a brief period of time, or if a few noncontingent reinforcers were presented in the absence of S+. Contrast did not appear to be a necessary condition for the occurrence of inhibitory stimulus control.

Subjects trained on the intradimensional discrimination (S+: 570 nm *versus* S-: 550 nm) tended to make more responses to S- than did subjects trained on the interdimensional discrimination (S+: vertical line *versus* S-: 570 nm). Likewise, the duration of S- under the correction procedure was longer for subjects trained on the intradimensional discrimination than was the case for subjects trained on the interdimensional discrimination. The data that support these conclusions follow.

The interdimensional gradients obtained along the S- (wavelength) dimension were evaluated by calculating the slopes of the gradients above S- (570 to 670-nm segment) and below S- (490 to 570-nm segment). The average values of these slopes, along with the degree to which these average values differ significantly from zero, are shown in Table 3. A linear regression analysis was used to calculate the best fit of data points to the line $y = a + bx$. A *t*-test was used to test the hypothesis that $b = 0$. In those instances, when it was determined that the hypothesis $b = 0$ could not be rejected, it was concluded that the gradients showed a lack of inhibitory stimulus control. In those instances, when it was determined that the hypothesis $b = 0$ was untenable, it was concluded that the gradients showed the presence of inhibitory stimulus control. Specific results are noted in the text when the data from individual groups are presented.

Table 3

Slope and significance of average generalization gradients for groups with interdimensional S+ and S-.

Group	Slope of 490-570 Segment	t	Slope of 570-670 Segment	t
1B	0.287	0.73	-0.184	0.46
2B	-0.100	0.25	0.309	0.80
2C	0.195	0.49	0.173	0.43
3B	-0.868	4.25*	0.711	2.49*
4B	-0.836	3.72*	0.700	2.41
5B	-0.882	4.60*	0.722	2.56*
6B	0.287	0.73	0.616	1.91
7B	-0.195	0.49	0.157	0.39

* $p < 0.05$

(a) *Control groups (Groups 2A, 2B, and 2C).* The subjects of these groups were given a generalization test of wavelength immediately after massed extinction. The baseline

Table 4

Durations of S- and number of responses during massed extinction (correction groups).

Group Number	Subjects	Duration (Min)	Number of Responses to S-
2A	B-501	193	464
	B-502	182	618
	B-504	205	319
2B	B-329	144	65
	B-347	189	84
	B-360	169	318
	B-361	150	274
2C	B-399	252	1201
	B-428	139	38
	R-1	161	311
	R-9	177	245
3A	B-510	290	865
	B-515	315	914
	B-518	146	512
	B-519	187	431
3B	B-302	175	706
	B-310	171	159
	B-320	259	1140
4A	B-514	118	524
	B-522	183	315
	B-523	260	674
4B	B-332	153	169
	B-338	143	307
	B-362	265	2292
5A	B-538	229	375
	B-541	401	1142
	B-590	366	2562
	B-591	173	448
5B	B-328	176	1101
	B-339	160	274
	B-346	124	13

rates of responding during VI 1-min TO and subsequently obtained generalization gradients of Groups 2A, 2B, and 2C are shown in Figures 3, 4, and 5, respectively. The durations of S- and the number of responses to S- of each subject of Groups 2A, 2B, and 2C (as well as those of the other groups) are shown in Table 4. Figures 3 to 5 illustrate that responding on the VI 1-min TO baseline had stabilized by the end of 20 sessions. Figure 3 reveals that the gradients of wavelength generalization tended to be symmetrical around S+.

On the average, no inhibitory stimulus control, with respect to wavelength, was observed in a subject whose key pecking was extinguished in the presence of 570 nm. This was true whether or not S+ was omitted from the sequence of test stimuli (*cf.* Figures 4 and 5). The gradient of one subject of Group 2B (B-431) was U-shaped with a minimum at S- (570 nm). However, preferences of other subjects, *e.g.*, for 540 nm and 600 nm (Subject B-429), for 600 nm (Subject B-430), and for 560 nm (Subject B-432) resulted in an essentially flat average gradient for this group. (The gradients for Group 2C subjects all appear essentially flat. The slopes (see Table 3) of neither half of Group 2B and 2C gradients differed significantly from zero.) It seems reasonable, therefore, to conclude that the gradients obtained from Groups 2B and 2C show no evidence of inhibitory stimulus control.

(b) *Groups 3A and 3B (massed extinction followed by 3 min of reinforced responding to S+).* Rate functions and generalization gradients for Groups 3A and 3B are shown in Figures 6 and 7. In this and in subsequent descriptions of the results, contrast will be assessed mainly by comparing the rate of responding during cycle A (S+ baseline) with the rate of responding during cycle B (S+ presentations immediately following massed extinction). In many cases, contrast can also often be seen in comparisons of the rate of responding during cycle A with the rate of responding during cycle C (cycle preceding the generalization test). However, in the absence of systematic data on the reliability of contrast as assessed during the first cycle of a session occurring 24 hr after massed extinction, it seems wise to focus on rates during cycles A and B as the main bases for evaluating whether contrast occurred.

Fig. 3. Individual and group average rates of responding to S+ before massed extinction (left-hand portion) and generalization gradients of Group 2A (right-hand portion). Consult text for explanation of Point A.

Following massed extinction, all Group 3A subjects showed a contrast effect. This can be seen by comparing the rates of responding to S+ during either cycles B and C with the base-line rate of responding (cycle A). Peak-shifts

can be seen in the gradients of each of the subjects of Group 3A.

A contrast effect can also be seen in the rate functions of all Group 3B subjects. Each of these subjects also exhibited inhibitory stim-

Fig. 4. Individual and group average rates of responding to S+ before massed extinction (left-hand portion) and generalization gradients of Group 2B. The number above each gradient represents the number of test responses to S+ (0°). Consult text for explanation of Point A.

GROUP 2C (CORRECTION PROCEDURE)
 MASSED EXTINCTION → GENERALIZATION TEST
 (S+ OMITTED)

Fig. 5. Individual and group average rates of responding to S+ before massed extinction (left-hand portion) and generalization gradients of Group 2C (right-hand portion). Consult text for explanation of Point A.

GROUP 3A (CORRECTION PROCEDURE)
MASSED EXTINCTION → REINFORCED RESPONDING
IN THE PRESENCE OF S+

Fig. 6. Individual and group average rates of responding to S+ before and after massed extinction (left-hand portion); generalization gradients of Group 3A. Consult text for explanation of Points A, B, and C along the abscissa.

GROUP 3B (CORRECTION PROCEDURE)
 MASSED EXTINCTION → REINFORCED RESPONDING
 IN THE PRESENCE OF S+

Fig. 7. Individual and group average rates of responding to S+ before and after massed extinction (left-hand portion); generalization gradients of Group 3B. Consult text for explanation of Points A, B, and C along the abscissa. The number above each gradient represents the number of test responses to S+ (0°).

ulus control. It should be noted, however, that the gradients of Subjects B-320 and B-310 were somewhat shallow. Both segments of the gradient obtained from Group 3B had slopes significantly different from zero. (See Table 3.)

(c) *Groups 4A and 4B (massed extinction followed by nonreinforced responding to S+)*. The results obtained from these groups are essentially the same as those obtained from Groups 3A and 3B. As shown in Figures 8 and 9, all Group 4A subjects showed a contrast effect during cycles B and C. All Group 4B subjects showed contrast during either cycle B or C. A contrast effect did not appear during cycle C, the warm-up cycle preceding the generalization test of Subject B-338. Peak-shifts are apparent in all three of the gradients obtained from Group 4A (Figure 8). Figure 9 shows that inhibitory stimulus control was apparent in all three gradients obtained from Group 4B, though it was less pronounced for B-362 and B-338 than for B-332. On average, the subjects of this group produced shallow, albeit reliable, gradients of inhibitory stimulus control. The slopes obtained from Group 4B were significantly different from zero in the lower set of test stimuli (490 to 570 nm). (See Table 3.)

(d) *Groups 5A and 5B (massed extinction followed by noncontingent responding in the presence of a blank key)*. As shown in Figures 10 and 11, contrast could not be observed in the rate function of any subject in either group. This is not very surprising because the

key was not lit during cycles B and C, nor was responding required. Figure 10, however, shows that a peak-shift can be observed in each gradient obtained from Group 5A. Similarly, Figure 11 shows that inhibitory stimulus control was established in each subject of Group 5B. Both segments of the gradient for this group were significantly different from zero. (See Table 3.)

EXPERIMENT III

Table 5 outlines the procedures followed in Experiment III. These procedures differ from those followed in Experiment II only in that the duration of each massed extinction period of Experiment III was fixed at 2 hr; i.e., no correction procedure was used. Also, some of the experimental treatments used during Experiment II were not repeated in Experiment III in testing for interdimensional stimulus control.

(a) *Control groups (Group 6A and 6B)*. Neither control group received any of the three experimental procedures that followed massed extinction for the other groups of Experiment III. After three cycles of VI 1-min TO, at the beginning of Session 21, a 2-hr period of massed extinction ensued. For Group 6A, massed extinction occurred in the presence of 550 nm; for Group 6B, massed extinction occurred in the presence of 570 nm. During the next session (Session 21), each subject in these groups was tested for wavelength generalization.

Table 5
Experiment III. No Correction Procedure

	Group					
	6A	6B	7A	7B	8	9
S+:	570 nm	0° white line	570 nm	0° white line	570 nm	570 nm
S-:	550 nm	570 nm	550 nm	570 nm	550 nm	550 nm
Massed Extinction:	Yes	Yes	Yes	Yes	Yes	Yes
Intervening Treatment:	None	None	S+/S ^R	S+/S ^R	S+/S ^{R̄}	S̄+/S ^R
Generalization Test:	S+ included	S+ included	S+ included	S+ included	S+ included	S+ included
N:	3	4	4	3	3	4
Subjects:	B-448 B-449 B-452	B-329 B-347 B-360 B-361	B-461 B-462 B-463 B-464	B-303 B-304 B-315	B-472 B-473 B-477	B-453 B-478 B-479 B-481

GROUP 4A (CORRECTION PROCEDURE)
 MASSED EXTINCTION → NONREINFORCED RESPONDING TO S+

Fig. 8. Individual and group average rates of responding to S+ before and after massed extinction (left-hand portion) and generalization gradients of Group 4A. Consult text for explanation of Points A, B, and C along the abscissa.

Fig. 9. Individual and group average rates of responding to S+ before and after massed extinction (left-hand portion); generalization gradients of Group 4B. Consult text for explanation of Points A, B, and C along the abscissa. The number above each gradient represents the number of test responses to S+ (0°).

GROUP 5A (CORRECTION PROCEDURE)
 MASSED EXTINCTION → NONCONTINGENT REINFORCEMENT
 IN THE PRESENCE OF A BLANK KEY

Fig. 10. Individual and group average rates of responding to S+ before and after massed extinction (left-hand portion); generalization gradients of Group 5A. Consult text for explanation of Points A, B, and C along the abscissa.

Fig. 11. Individual and group average rates of responding to S+ before and after massed extinction (left-hand portion); generalization gradients of Group 5B. The number above each gradient represents the number of test responses to S+ (0°).

Experimental Groups (Massed Extinction Without Correction Procedure → Experimental Treatment):

(b) *Groups 7A and 7B (massed extinction followed by reinforced responding in the presence of S+).* Groups 7A and 7B are the analogs of Groups 3A and 3B of Experiment II.

(c) *Group 8 (massed extinction followed by presentation of S+ during which responding was not reinforced).* Group 8 is the analog of Group 4A of Experiment II.

(d) *Group 9 (massed extinction followed by noncontingent reinforcement in the presence of a blank key).* Group 9 is the analog of Group 5A of Experiment II.

RESULTS

With only minor differences, the results of Experiment III parallel those of Experiment II. No peak-shift is obtained if a generalization test follows directly after massed extinction that occurs in the presence of an intradimensional stimulus. These results replicate a similar finding by Honig *et al.* (1959).

Contrast was not always obtained in those instances in which S+ was presented for a brief period of time following massed extinction. A peak-shift did occur in all instances in which one of the three experimental procedures followed massed extinction. The occurrence of inhibitory stimulus control following massed extinction in which a correction procedure was not used, however, appeared to be less reliable. Intradimensional discrimination training occasioned more responding to S— than did interdimensional training. Supporting data for these conclusions are presented below.

(a) *Groups 6A and 6B (generalization test immediately following massed extinction).* Rate functions and generalization gradients for Groups 6A and 6B are shown in Figures 12 and 13. The number of responses to S— by each subject of Groups 6A and 6B (as well as those of the other groups) are shown in Table 6.

As mentioned previously, the only way in which a contrast effect can be assessed in the performance of Group 6A and 6B subjects is to compare the rate of responding to S+ during the generalization test with the rate of responding to S+ during baseline training. The rate of responding to S+ during the gen-

Table 6

Number of responses to S— during massed extinction (noncorrection groups. Duration of S—: 120 min)

Group	Subjects	Number of Responses
6A	B-448	867
	B-449	573
	B-452	949
6B	B-329	1258
	B-347	160
	B-360	336
	B-361	615
7A	B-461	156
	B-462	1892
	B-463	875
	B-464	1462
7B	B-303	732
	B-304	479
	B-315	388
8	B-472	1164
	B-473	906
	B-477	798
9	B-453	531
	B-478	690
	B-479	734
	B-481	880

eralization test can be determined by dividing the number of responses to S+ by four. The data shown in Figures 12 and 13 do not indicate a contrast effect; note, however, that a comparison of rates of responding to S+ during baseline training and during a generalization test is not a common measure of contrast.

The peaks of two of three Group 6A subjects were located at S+. The one exception was B-448, whose peak was located at 560 nm—the stimulus between S— and S+. Thus, in no instance were peak-shifts observed in the gradients obtained from Group 6A subjects. As shown in Figure 12, massed extinction appears to produce only a slight change in responding to the test stimuli from the wavelength continuum. With the slight exception of the gradient obtained from Subject B-361, no evidence of inhibitory stimulus control is apparent in the gradients obtained from Group 6B. The conclusion of lack of inhibitory stimulus control is confirmed by the t-test of the slope of Group 6B's gradient. (See Table 3.)

(b) *Groups 7A and 7B (reinforced responding to S+ following massed extinction).* Rate functions and generalization gradients for each subject of Groups 7A and 7B are shown in Figures 14 and 15, respectively. Only two of

Fig. 12. Individual and group average rates of responding to S+ before massed extinction (left-hand portion) and generalization gradients of Group 6A (right-hand portion). Consult text for explanation of Point A.

the four Group 7A subjects showed contrast during the cycles of S+ that followed massed extinction (B-464 and B-463). A peak-shift, however, could be observed in all of the gra-

dients obtained from this group. Two of the three Group 7B subjects show clear evidence of contrast (B-303, B-304). When responding during cycle C was compared to

GROUP 6B (NONCORRECTION PROCEDURE)
MASSED EXTINCTION → GENERALIZATION TEST

Fig. 13. Individual and group average rates of responding to S+ before massed extinction (left-hand portion) and generalization gradients of Group 6B. Consult text for explanation of Point A. The number above each gradient represents the number of test responses to S+ (0°).

Fig. 14. Individual and group average rates of responding to S+ before and after massed extinction (left-hand portion); generalization gradients of Group 7A. Consult text for explanation of Points A, B, and C along the abscissa.

GROUP 7B (NONCORRECTION PROCEDURE)
 MASSED EXTINCTION → REINFORCED RESPONDING
 IN THE PRESENCE OF S+

Fig. 15. Individual and group average rates of responding to S+ before and after massed extinction (left-hand portion); generalization gradients of Group 7B. Consult text for explanation of Points A, B, and C along the abscissa. The number above each gradient represents the number of test responses to S+ (0°).

responding during cycle A, a slight contrast effect can be discerned for Subject B-315. The gradients of two of the three Group 7B subjects tended to be U-shaped (B-304, B-303), but the minima of B-304's gradient occurs at 580 nm, rather than at 570 nm. While the average gradient of this group tends to be U-shaped, in that maximal responding occurred to test stimuli most remote from S—, there is an intermediate peak at 560 nm.

The slope of the gradient obtained from Group 7B (see Table 3) did not differ significantly from zero. The average gradient for this group is not, however, truly representative of each subject. The gradient of B-303 was significantly different from zero (slope of 490 to 570 nm segment: -0.729 ; $p < 0.05$). The gradients of B-304 and B-315 each had elevations at 580 nm. For this reason, they did not yield slopes that were statistically different from zero.

(c) *Group 8 (massed extinction followed by nonreinforced responding in the presence of S+)*. The rate functions and generalization gradients obtained from this group are shown in Figure 16. If one compares the rate of responding during cycle B with the rate of responding during cycle A, small contrast effects can be observed in the rate functions of all Group 8 subjects. In all three cases, however, the rate of responding to S+ during cycle C (the warm-up period before the generalization test) was too low to be classified as a contrast effect. Peak-shifts are apparent in all three gradients obtained from Group 8.

(d) *Group 9 (massed extinction followed by noncontingent reinforcement in the presence of a blank key)*. Rate functions and generalization gradients of the subjects of this group are shown in Figure 17. Contrast was not observed in the rate functions of any subject of this group. As mentioned earlier, this should come as no surprise because there was no stimulus on the key during cycles B and C, nor was responding required. Peak-shifts, however can be seen in the case of each of the gradients obtained from this group.

DISCUSSION

The present results show that the mere extinction of responding in the presence of a discriminative stimulus is not a sufficient condition for producing either a peak-shift or

inhibitory stimulus control. These results confirm those of Honig *et al.* (1959) and of Weisman and Palmer (1969). The present results also demonstrate that, following massed extinction, a peak-shift and inhibitory stimulus control can be obtained if any of the three experimental procedures intervene, for as little as 3 min, between massed extinction and the generalization test. In this sense, our results confirm an earlier observation of one of the authors (Terrace, 1966a, 1972a) that the peak-shift and inhibitory stimulus control covary as a function of the same training conditions.

At first glance, the effects of our procedures following massed extinction may appear dramatic. Further analysis makes clear, however, that the results pose many more theoretical questions concerning the acquisition of discriminative and inhibitory stimulus control than they can answer. These include (1) the nature of the equivalence between reinforced and nonreinforced responding to S+ and noncontingent food presented in the absence of S+, (2) the function of reinforcement following massed extinction, and (3) whether, following massed extinction, S— functions as an inhibitory stimulus.

The Functional Equivalence of Reinforced and Nonreinforced Responding to S+ and Noncontingent Food Presented in the Absence of S+

In view of the subject's earlier history of reinforcement on a VI schedule, it is not surprising that a 3-min opportunity to engage in nonreinforced or reinforced responding to S+ produced equivalent effects. Given the many reinforcements that occurred in the presence of S+ during baseline training, one would expect S+ to function as a secondary reinforcer. Following massed extinction, it appears as if the secondary reinforcing effect of S+ *per se* is indistinguishable from the effect of primary reinforcement. As plausible as the secondary reinforcing function of S+ might seem, however, it should be remembered that, in a strict sense, that function was not actually demonstrated in this experiment. However, given the numerous demonstrations of secondary reinforcement under similar conditions, there is little reason to doubt that S+ did function in this manner.

What was not anticipated was the equivalence between noncontingent food, presented

GROUP 8 (NONCORRECTION PROCEDURE)
 MASSED EXTINCTION → NONREINFORCED RESPONDING TO S+

Fig. 16. Individual and group average rates of responding to S+ before and after massed extinction (left-hand portion); generalization gradients of Group 8. Consult text for explanation of Points A, B, and C along the abscissa.

in the absence of S+, and the presentation of S+, either with or without the opportunity to obtain reinforcement. This equivalence has

two important theoretical implications. One has to do with a temporal interaction between periods of reinforcement and extinction, and

GROUP 9 (NONCONTINGENT PROCEDURE)
MASSSED EXTINCTION → NONCONTINGENT REINFORCEMENT
IN THE PRESENCE OF A BLANK KEY

Fig. 17. Individual and group average rates of responding to S+ before and after massed extinction (left-hand portion); generalization gradients of Group 9. Consult text for explanation of Points A, B, and C along the abscissa.

the other with the importance of contrast as a precursor of the peak-shift and inhibitory stimulus control.

Temporal Interaction Between Reinforcement and Extinction

Both the peak-shift and inhibitory stimulus control have been shown to result from nonreinforced responding in the presence of an S— that is alternated with S+ (cf. Terrace, 1964, 1966*b*, 1972*a*). Various investigators have also noted that long periods of nonreinforcement result in emotional behavior, a state of affairs that has often been referred to as frustration (cf. Amsel, 1958, 1962; Skinner, 1938, p. 138; Terrace, 1969). These emotional responses appear to occur during both simple extinction and during discrimination learning.

However one wishes to characterize the consequences of nonreinforced responding to S— that are responsible for the peak-shift and inhibitory stimulus control, these consequences do not appear to have a lasting effect unless extinction is followed by some form of reinforcement. One compelling interpretation of these results is that reinforcement interacts with the effects of frustration in a way that allows the organism to compare a favorable state of affairs with one that is less favorable. How soon such a comparison needs to be made cannot be specified by the present results. In order to do so, one would obviously have to vary the time between the end of massed extinction and the administration of reinforcement. If, however, the occurrence of the peak-shift and inhibitory stimulus control results from an interaction between the frustrative state of the organism at the end of extinction and the subsequent occurrence of a reinforcing state of affairs, one would predict that a delay in presenting a reinforcer after extinction would reduce the effect of that reinforcer. In this connection, it is interesting to note that when S+ and S— were alternated on successive days, neither inhibitory stimulus control (Yarczower and Switalski, 1969) nor behavioral contrast (Wilton and Clements, 1972) was observed to occur (but also see Premack, 1969).

The various results discussed indicate the importance of a temporal dimension in characterizing the manner in which periods of reinforcement and extinction interact. There seems little doubt that nonreinforced responding changes the state of the organism and that,

other things being equal, the strength of this state decreases with the passage of time. Whether or not one would want to refer to this state as "frustration" seems to be a question of semantics, rather than one of scientific rigor.

Is Contrast a Necessary Precursor of the Peak-Shift and Inhibitory Stimulus Control?

In both Experiments II (Groups 5A, 5B) and III (Group 9), responding in the presence of the blank key occurred at a near-zero rate. Accordingly, one can conclude that the occurrence of contrast, *per se*, is not a necessary condition for the occurrence of either the peak-shift or of inhibitory stimulus control. This conclusion may require qualification on two grounds. It might be argued that free food "contrasts" with a reduced rate of responding in extinction in the same manner as does responding to an S+ at a higher rate. One might also want to verify that a contrast effect, based on a comparison of the rates of responding to S+ before and after massed extinction, might not have occurred during presentations of S+ in the generalization test.

At present, there is no theoretical framework available for relating free food and an increased rate of responding to S+. While, in a broad sense, both phenomena would appear to be examples of "excitation", the use of such a term has no analytic force, in that it cannot specify, *a priori*, why either an increase in the rate of responding to S+ or free food should produce excitation. In the absence of a specific theory of excitation, it would seem unwise to characterize the presentation of food as an example of a contrast effect or to take explanatory comfort in equating contrast and free food as excitatory effects. It is of interest to identify other stimulus situations that might produce the same effects as the three situations we employed following massed extinction. For example, would a "neutral" stimulus, such as a geometric form, (a) evoke responding following massed extinction, and (b) either a peak-shift or inhibitory stimulus control occur under such circumstances? Likewise, would an opportunity to attack another pigeon suffice to establish a peak-shift or inhibitory stimulus control following massed extinction?

It might be argued that presentations of S+ during the generalization test provide an opportunity for contrast to occur. Our data indi-

cate, however, that the rate of responding to S+ during the generalization test was not a good predictor of the occurrence of a peak-shift or of inhibitory stimulus control. The rates of responding to S+ during *some* presentations were higher than the rate of responding that occurred during baseline training. There was, however, no general correlation between the occurrence of contrast, during responding to S+ during the generalization test, and the occurrence of a peak-shift or inhibitory stimulus control. One should also keep in mind the absence of inhibitory stimulus control in the gradients obtained from both Groups 2C and 6B. S+ was omitted from the test stimuli presented to Group 2C, but was included in the test stimuli presented to Group 6B.

As a final point, it should be kept in mind that the occurrence of contrast during a generalization test may not be a good predictor of an overall contrast effect. To date, there do not appear to be any systematic data that bear on the validity of rate of responding to S+ during a generalization test (conducted in extinction) and the rate of responding to S+ during a discrimination session.

Numerous experiments on successive discrimination learning employing a VI → VI EXT paradigm, (particularly paradigms that employ a correction procedure), indicate that one would expect to see a contrast effect during the first session of discrimination training (e.g., Terrace, 1963). It may be that the factor(s) responsible for the occurrence of contrast are also operative in the occurrence of inhibitory stimulus control and the peak-shift. The occurrence of contrast may, however, require more alternations between S+ and S- than does the occurrence of the peak-shift or of inhibitory stimulus control.

Even though massed extinction with a correction procedure produced a generally greater degree of inhibitory stimulus control than did massed extinction without a correction procedure, it is not clear whether this difference is attributable to (a) the greater amount of time of the correction subjects in S- (cf. Tables 4 and 6), (b) the longer opportunities of the correction subjects to respond to S-, (c) the lower terminal rate of responding to S- of the correction subjects at the end of massed extinction, or to some combination of these factors. Just the same, it is desirable to replicate the procedures of the present experi-

ment with the combined-cue and resistance-to-reinforcement tests for the inhibitory function of a stimulus, as suggested by Hearst *et al.* (1970) and by Rescorla (1969).

The definition and measurement of inhibition in successive discrimination learning is too complex a subject to pursue in the discussion of an experimental paper (cf. summary by Hearst, 1972). It may prove helpful, however, to evaluate the inhibitory status of S- by asking to what extent did responding antagonistically to the reinforced response develop at the end of massed extinction? Terrace (1972b, 1974), for example, has shown that following discrimination learning with errors, S- occasions responding "antagonistic" to the response reinforced in S+. In this experiment, human subjects were required to hold onto a joystick continuously and to pull the joystick towards them in order to obtain a reinforcer. An antagonistic response was defined as a response that occurred in a direction opposite to that required during S+. While antagonistic responses developed early during discrimination training and occurred exclusively during S-, they did not occur during the first few presentations of S-.

The presumed relationship between S-'s functions as an inhibitory stimulus following massed extinction, and the occurrence of antagonistic responding is based upon the following premise. Inhibition implies the occurrence of a stimulus-occasioned response that is specifically incompatible with the response whose frequency is reduced. While responding antagonistic to the key-peck (e.g., Terrace, 1966a, pp. 316-317) may have developed at the end of massed extinction, particularly in those subjects for which the correction procedure was in effect, it is doubtful that stimulus control of such antagonistic responses (with respect to S-) could develop until S- and S+ alternated with one another within a relatively short period of time. Accordingly, one would expect to find antagonistic responding under the control of S- during inter- and intra-dimensional generalization tests in which one can discern a peak-shift or inhibitory stimulus control. Conversely, one would expect to find little or no antagonistic responding under the control of S- following training that does not result in the peak-shift or in inhibitory stimulus control. What has yet to be resolved is whether antagonistic responding exists in the

presence of S— following massed extinction (either with or without stimulus control by S—). Given the availability of techniques for measuring antagonistic responses (cf. Terrace, 1974), both of these predictions can be subjected to experimental test.

Whatever the outcome of these and related experiments suggested by the speculative analysis of the present results, it should be noted that the failure to obtain a peak-shift or inhibitory stimulus control following massed extinction provides an excellent preparation for studying the minimal conditions necessary for the occurrence of these phenomena. Of greater fundamental interest, however, are the insights that this type of research can provide concerning the interaction of stimuli associated with reinforcement and with extinction.

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