GENERALIZATION OF CONDITIONED SUPPRESSION AFTER DIFFERENTIAL TRAINING¹

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In a modified conditioned suppression procedure, clicks at one frequency (danger signal) preceded shocks, while no shocks followed clicks at a different frequency (safe signal). During generalization tests, the maximal response rate was frequently shifted from the safe signal in the direction away from the danger signal, and the minimal response rate was frequently shifted in the opposite direction, away from the safe signal. There was considerable variability in the results from one animal to another. The generalization tests also suggested different generalization functions according to whether the danger signal was a lower or a higher frequency than the safe signal. The results also showed the development of systematic differences in response rate during and after the safe and danger signals, notably a relatively high rate at the beginning of the safe signal and after the danger signal.

When responses are positively reinforced during one stimulus and not reinforced during another stimulus on the same dimension, the highest rate of responding may occur to test stimuli displaced from the positive stimulus in a direction away from the location of the negative stimulus (Hanson, 1959). This is known as peak-shift.

The question as to whether there is a corresponding (negative) peak-shift in the other direction is difficult to answer with discriminations based on positive reinforcement, since the response rate during the negative stimulus itself is usually close to zero. Guttman (1965) surmounted this difficulty by establishing a high rate of responding to the whole range of test stimuli before discriminative training was started. He was able to demonstrate the existence of a positive and a negative peak-shift.

The present study used differential conditioned suppression (*cf.* Estes and Skinner, 1941) in a design that could reveal the existence of peak-shifts in both directions. Ray and Stein (1959) studied generalization of conditioned suppression following differential training. In

training, performance was suppressed during a stimulus that was always followed by shock, and was not suppressed during another stimulus that was never followed by shock. Although generalization tests were conducted, Ray and Stein did not test with stimuli more extreme than the training stimuli. By using a procedure similar to that of Ray and Stein but with test stimuli more extreme than the training stimuli, the present study allowed for the existence and detection of peak-shifts.

METHOD

Apparatus

The experimental chamber consisted of a standard Grason-Stadler operant conditioning box isolated in a sound-proof room from associated scheduling and recording apparatus. The light in the center of the front panel of the box was on throughout each experimental session. Stimuli used in training and generalization testing were supplied by a Foringer Model 1293 click generator. Electric shock was provided by a Grason-Stadler Model 1064GS shock generator and grid scrambler.

Subjects

Eight experimentally naive hooded rats, derived from the Long-Evans strain, were about five months old at the beginning of the experiment. Each was housed in an individual cage where water was always available. Purina Lab Chow pellets averaging 12 g were given after

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each daily session, to maintain the rats at 75 to 80% of free-feeding weight.

Procedure

The rats were trained in two groups of four each. Four rats were trained to bar-press on a variable-interval schedule of reinforcement with a mean interval of 2 min (VI 2-min). The reinforcer was a 45-mg food pellet. After eighteen 1-hr sessions, conditioned suppression training was superimposed on the VI 2-min schedule. Experimental sessions now consisted of ten 6-min cycles. Each cycle began with a 4-min control period (no clicks) and ended with a 2-min stimulus (clicks). The click rate was either 4.7 or 25 clicks/sec. One frequency was always terminated with a 1.0-ma, 0.5-sec shock to the grid floor. The other frequency was never terminated with shock. The stimulus that was always terminated with shock is designated the "danger signal" (D), and the stimulus never followed by shock is designated the "safe signal" (S). For two rats, D was the higher frequency; for the other two, D was the lower frequency. The order of stimulus presentations in each session was SDSSDDSDS.

On two separate occasions generalization tests were given on two successive sessions. As far as possible, generalization tests were given when there had been some responding during the danger signal in the previous few sessions. Consequently, the generalization tests were given after different numbers of training sessions for each rat. Table 1 presents the number of sessions of conditioned suppression training preceding each generalization test.

During the generalization tests, the VI 2-min schedule of reinforcement was maintained but shocks were omitted. Each of 11 click frequencies was presented for 2 min, separated by 4-min control periods. The frequencies used were 0.7, 1.7, 3.1, 4.7, 6.6, 10.8, 16.0, 25.0, 39.8, 49.3, and 64.0 clicks/sec. For two rats, the stimuli were given in the order 25.0, 4.7, 10.8, 1.7, 49.3, 16.0, 39.8, 3.1, 6.6, 64.0, 0.7 in the first test session of each pair. For the other two rats this order was reversed. In the second test session of each pair, the stimulus sequence was reversed for each rat.

The procedure for a second group of four rats was the same as for the first group, except that: (a) shock intensity was lower (0.5 ma); (b) the schedule of reinforcement was VI 1-min; (c) one session of regular conditioned sup-

pression training was given after the first and third generalization tests. Changes a, b (and c) were made in an attempt to produce (and sustain) relatively weak response suppression.

Table 1

Sessions of conditioned suppression training preceding each generalization test.

Subjects	Shock Intensity (ma)	Test			
		I	II	III	IV
1	0.5	14	15	34	35
2	0.5	12	13	34	35
3	0.5	17	18	35	36
4	0.5	15	16	38	39
5	1.0	52	52	76	76
6	1.0	71	71	93	93
7	1.0	67	67	82	82
8	1.0	101	101	114	114

RESULTS

Different response rates during S and D were established after the first few sessions. All rats had a low response rate during D and a higher response rate during S. A clear difference between response rates during D and S was maintained throughout the experiment.

Generalization test results of individual rats are shown in Table 2. An analysis of variance of these data revealed no difference in mean rate between the two groups, no differences as a function of click rate *per se*, independent of its correlation with shock/no-shock, and no effect of whether the danger signal was a high or a low click frequency. There was an effect of test number; it can be seen from Table 2 that (except for Rats 5 and 6) response rate generally declined from Test 1 to Test 4. These results are of minor interest. Of more interest are the differences in response rate in the presence of the test stimuli. In the statistical analyses, this effect appeared as a significant interaction between click rate and direction of correlation between click rate and danger signal. Thus, the procedure resulted in a non-uniform rate of responding to the various test stimuli.

The mean response rate as a function of click rate in all tests is shown in Fig. 1. The value ($\times 8$) of each point can be obtained by adding the four rates in each row for each rat in Table 2. The rates of every rat except one

Table 2

Results of Four Generalization Tests: Numbers of Responses during 2-Min Periods of Each Test Stimulus

Test Stim (Clicks/Sec)	Rat 1				Rat 2				Rat 3				Rat 4				Rat 5				Rat 6				Rat 7				Rat 8			
	Test				Test				Test				Test				Test				Test				Test				Test			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
0*	37	14	4	1	15	12	6	2	8	8	2	3	25	24	4	5	12	18	15	12	17	20	21	24	36	32	18	7	5	6	5	0
0.7	24	15	3	0	0	5	0	1	10	8	4	1	15	27	0	10	7	14	11	4	26	4	19	11	59	8	13	11	9	13	4	0
1.7	17	22	1	1	0	0	3	0	8	8	4	5	10	42	6	5	9	10	13	3	0	31	33	7	11	21	23	10	5	6	1	0
3.1	26	0	8	2	0	0	0	0	11	10	8	6	17	50	5	12	10	21	20	14	14	18	11	4	42	19	19	8	6	8	7	0
4.7 ^b	27	14	2	2	1	0	4	0	13	11	6	8	6	19	10	9	13	10	14	1	0	4	0	35	14	48	23	5	5	2	0	0
6.6	39	16	3	3	0	0	0	0	5	9	5	6	14	16	3	7	10	36	18	17	19	15	19	15	64	15	37	7	4	7	3	1
10.8	77	20	0	0	16	0	7	3	5	9	2	8	6	21	2	9	17	11	14	8	23	21	1	47	15	61	20	4	0	9	5	1
16.0	27	15	6	1	18	6	12	1	6	6	5	2	8	17	0	8	17	30	26	6	26	16	12	19	2	22	22	5	1	0	6	0
25.0*	33	27	11	0	16	21	7	7	4	3	1	0	2	21	0	5	13	8	8	8	6	37	12	31	2	18	6	2	0	0	5	0
39.8	33	25	6	0	30	9	9	2	8	2	0	3	0	3	2	2	23	25	14	14	15	29	35	49	0	0	4	1	0	0	0	0
49.3	41	18	9	1	21	18	20	6	6	14	1	1	9	38	1	4	22	39	20	11	31	21	2	50	0	0	2	9	0	0	0	0
64.0	9	9	3	2	20	11	2	4	11	12	8	3	20	23	9	6	20	34	13	10	28	4	22	41	0	2	19	15	0	0	0	0

* This row gives the response rates during the ten 4-min control periods that separated the presentations of the 11 test stimuli. The total number of responses in the 10 periods of a session have been divided by 20 to give numbers comparable to others in the table.

^b In these rows, boldface indicates that the stimulus was the danger signal in training sessions, and italics indicates that the stimulus was the safe signal.

Fig. 1. Absolute response rates during generalization tests (average of four test sessions) after differential training in which shock always followed the presentation of one click frequency (D, arrowed) and never followed the presentation of another (S, arrowed). The dotted line represents the response rate in the (no clicks) control periods. The data are from Table 2: each point represents the total ($\times \frac{1}{6}$) of the four numbers in a given row for each rat; each dotted line represents the total ($\times \frac{1}{6}$) of the four numbers for each rat in the top row. The abscissae are logarithmic.

(#3) show evidence of at least one kind of peak-shift. Only in the case of #3 are the highest and lowest response rates at the S and D click rates; in all other cases, higher or lower response rates occurred at click rates more extreme than S or D. Six of the eight animals responded on the average (four tests) at a higher rate to a stimulus more extreme than S than they responded to S (Rats 2, 6, 5, 4, 8, and, by a small margin, 7). Also, six of the eight animals responded at a lower rate to a stimulus more extreme than D than they responded to D (Rats 2, 1, 5, 4, 7, and 8).

It is possible that the highest rates were given to stimuli adjacent to S, rather than to S itself, because these adjacent stimuli were more different from D than was S. That is, the peak-shift away from S might have been a manifestation of generalization decrement of conditioned suppression. One observation that goes against this interpretation is that the peak response rates are higher than the control response rates obtained in the absence of any clicks (see Fig. 1). If stimulus generalization decrement of conditioned suppression were

the only reason for differential response rates during tests (*i.e.*, conditioning trials with the safe stimulus had no effect), these rates would all be between the rate during D and the control rate. The interpretation that a peak-shift on the side of S is due solely to stimulus generalization decrement of conditioned suppression can also be rejected on statistical grounds. The interpretation implies that the highest response rates should occur to the stimulus most remote from D on the stimulus generalization dimension (*i.e.*, 0.7 or 64.0 clicks/sec). However, the rate during the stimulus most remote from D was on the average about two responses/min *lower* than the rate during the "peak" stimulus (3.1 or 39.8 clicks/sec). The difference is reliable ($t = 2.39$; $df, 7$; $p < 0.05$). This shows that absolute response rate, after reaching a peak in the vicinity of S, declined in the stimuli more remote from D.

Relative response rate was calculated for each of the test frequencies in each of the four tests for each of the rats. These ratios were averaged for each frequency and are shown in Fig. 2, plotted separately according to whether the danger signal was 4.7 or 25.0 clicks/sec. According to Fig. 2, peak-shifts occurred on both the side of S and the side of D when D was the higher click frequency, but only on the side of S when D was the lower frequency.

Response rate was not uniform throughout stimulus presentations. Figure 3 shows variations in response rate at various stages (Sessions 18, and 31). Figure 3 shows that the initial effect of shock was a depression of response rate immediately following D. This effect gave way in later sessions to an elevation of response rate in the first minute after shock. After about 10 sessions, the highest response rates were generally in the first minute after shock. This was the case for every rat in Sessions 18 and 31, shown in Fig. 3. The high rate following shock was noted in the original report of Estes and Skinner (1941), who described it as a "compensatory" rate increase.

Figure 3 shows that a higher response rate occurred during S (especially during the first minute) than during the first minute of the following control periods in Session 31. This effect may be identified as an instance of behavioral contrast (*cf.* Reynolds, 1961), since it is a rate change in the presence of one stimulus which is in the opposite direction from a

Fig. 2. Relative response rates during generalization tests (average of four test sessions) after differential training in which shock always followed the presentation of one click frequency (D) and never followed the presentation of another (S). The relative response rate is calculated as A/B , where A is the response rate during the test stimulus and B is the control rate in the absence of any test stimulus. These data are given in Table 2. Test #4 of Rat 8 was omitted, since the control rate was zero. The results are differentiated according to whether D was the lower (circles) or the higher (squares) click frequency. The numbers beside each point are their standard deviations. The abscissa is logarithmic.

Fig. 3. Response rates during the first and second minute of S, the first and fourth min after S, the first and second minute of D, and the first and fourth minute after D. These rates are given (from left to right) for three sessions (1, 18, and 31), showing progressive changes in performance. D did not always follow the control period after S; this is indicated in the middle of the figure by the omission of the lines between data points. The number of each animal (1, 2, 3, or 4) is indicated for Session 1.

controlled rate change during a different stimulus. (It should be noted, however, that response rates during S are not higher in Session 31 than they were in Session 1.)

DISCUSSION

The present results agree with those of previous studies in revealing orderly stimulus gen-

eralization of conditioned suppression (*e.g.*, Ray and Stein, 1959; Winograd, 1965). Further, the results are similar to those of Guttman (1965) in showing that discriminative training (differential conditioning), in some circumstances at least, produces a peak-shift of the most effective S^+ away from S^- , and of the most effective S^- away from S^+ . Some generality of this effect is indicated by the fact that Guttman's results were obtained with pigeons, positive reinforcement, and wavelength of light as the stimulus dimension, while the present results were obtained with rats, electric shock, and click-rate as the stimulus dimension.

Hoffman (1967) used procedures similar to ours but obtained rather different results. Hoffman shocked pigeons at the end of a 1000-Hz tone (danger signal), but not after a 900-Hz tone (safe signal). After this differential training, stimulus generalization tests showed most suppression at 1000 Hz, and least at 900 Hz, repeating a result previously obtained (Hoffman and Fleshler, 1964), *i.e.*, no peak-shifts. However, a modification in his procedure did produce a peak-shift. In the new procedure, the danger signal was present from the beginning of training, but the safe signal was gradually introduced, or faded in from white noise, after which the white noise was faded out. In this case, generalization tests showed a peak-shift for the danger signal, but not for the safe signal. In contrast, our results most clearly showed a peak-shift for the safe signal. At present, we only draw attention to the differences between these results, without being able to explain them.

Figure 2 shows a sharper gradient around D for those rats for which D was the higher frequency. This result differs from that obtained by Winograd (1965), who used a different procedure for determining generalization of rats' conditioned suppression over the stimulus dimension of click frequency. In every session of Winograd's experiment, the test stimuli were presented in turn, without intervening control periods. He found a steeper generalization gradient when the test frequencies were higher than the frequency of the pre-shock stimulus. Winograd speculated that his result was due to a CS-intensity-like effect of click frequency on lever pressing, with higher click frequencies producing faster lever pressing. In the present experiment, it is more likely that

suppression, rather than lever pressing, was related to the absolute click frequency, with higher frequencies producing more suppression and lower frequencies producing less suppression. The peak-shift and the sharper gradient near D for No. 3, 4, 7, and 8 (squares in Fig. 2) is consistent with a tendency for higher click frequencies to produce more suppression. A CS-intensity-like effect on suppression rather than on responding is also consistent with results of Kamin and Brimer (1963). They found that a more intense pre-shock stimulus produced more conditioned suppression, not more responding.

Contrast in the context of aversive control appears under a fairly wide variety of conditions. With a differential punishment procedure (multiple schedule) an increased rate of unpunished responding is obtained (Brethower and Reynolds, 1962). With a differential conditioned suppression procedure, facilitation, as opposed to suppression, is produced by the signal which is never followed by shock (Hammond, 1966; Hendry, 1967). In most sessions of the present experiment, the response rate during safe signals was approximately equal to the response rate during control periods, but response rate in the first minute of the safe signal was substantially higher than the response rate in either the last minute before the safe signal or the first minute after the safe signal (Fig. 3). The weak contrast (*i.e.*, a relatively high rate during the safe signal) reported by Ray and Stein (1959) was probably also due to a relatively high response rate maintained for a short period after the onset of the safe signal. Instances of such transitory increases appear in their results (see their Fig. 1, 2, and 3).

The rate changes shown in Fig. 3 may be understood to include two distinct contrast effects. One kind of contrast is seen in the relatively high rate during the first minute of the safe signal. Contrast, of perhaps a different kind, is also produced by the termination of the danger signal or the delivery of shock. A similar brief enhancement of response rate on termination of punishment may be seen in the results of Brethower and Reynolds (1962). The second kind of contrast effect, by enhancing the control response rate, will affect the apparent magnitude of the first kind of contrast effect, which depends upon a comparison with control rates. The complexity of rate

changes shown in Fig. 3 clearly calls for more detailed quantitative study of momentary rate changes if these effects are to be adequately described.

Finally, the present generalization data bear some resemblance to data obtained by Terrace (1968) and by Grusec (1968). Terrace exposed pigeons to a multiple schedule of reinforcement in which positive reinforcers were contingent on key pecks in two components. Response-contingent shocks were scheduled to occur in the presence of one stimulus (the danger signal) but not in the presence of the other (the safe signal). Generalization tests revealed a shift in maximal responding from the safe signal in a direction away from the danger signal. Inspection of Terrace's data (Fig. 3) does not reveal the existence of a shift in the stimulus associated with minimal responding. However, the absence of this "negative" shift may have been due to the fact that during generalization tests, response-contingent shocks were still administered when the bird responded. After pigeons had been given discriminative training, Grusec (1968) delivered shocks which were not contingent on key pecks in the presence of an S⁻. Birds that had emitted few key-pecks in the presence of S⁻ during discriminative training and which had not shown a peak-shift, did show a peak-shift (away from the "safe" stimulus in a direction away from the stimulus associated with shock) after the administration of non-contingent shocks in the presence of S⁻. Unfortunately no test stimuli were presented that were further away from S⁺ than S⁻. Also, the rate of responding was near zero and thus the existence of a "negative" shift could not be determined.

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