CONCURRENT GENERALIZATION GRADIENTS FOR FOOD-CONTROLLED AND SHOCK-CONTROLLED BEHAVIOR

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In the presence of a bright light, monkeys were trained to press a lever to avoid shock and to pull a chain for food reward. After gradients of generalization to other light intensities had been determined for each response, gradients were subsequently secured after training in a brightness discrimination and under several free-shock conditions. The following results were obtained: (1) Generalization gradients prior to discrimination training were much steeper for the food-controlled response than for the shock-controlled response. This finding was confirmed in another study in which rats served as subjects. (2) After discrimination training, both gradients became much steeper, but the avoidance gradient still showed more generalized responding than that of reward. (3) After a period of continuous testing with all the different test intensities, the two gradients became even steeper. In addition, differences between the two gradients virtually disappeared. (4) The intermittent delivery of free shocks during a previously non-shocked light intensity radically affected the shape of the avoidance gradient, just as the addition of an avoidance contingency did during the same, previously non-shocked, light intensity.

Although the phenomenon of stimulus generalization has been demonstrated in many experiments (Mednick & Freedman, 1960), few studies have been concerned with the effects of different behavioral variables on the amount of stimulus generalization. For example, the relative influence on generalization of such factors as degree and type of motivation, reinforcement schedule, and amount and delay of reinforcement has not been well-established.

The present experiments compare the characteristics of stimulus generalization when behavior is controlled by food reinforcement with that developed under conditions of shock avoidance. Preliminary results (Hearst, 1960) indicated that stimulus generalization was greater for behavior under aversive control. The experiments to be discussed here amplify several aspects of the earlier findings and extend the results to stimulus generalization which occurs after discrimination training. In addition, the effects of several other experimental manipulations (amount and type of discrimination training, "free" shocks) on the shape and slope of the separate generalization gradients for appetitive and aversive behavior are studied.

METHOD

Subjects

Five young, male Rhesus monkeys were the original subjects. However, two of these were eliminated from the experiment because they developed illnesses either during or immediately after experimental Phase 1, and only three monkeys (U-556, U-613, and U-760) went through all procedures. This report is therefore based on data derived exclusively from these three animals. Results for the prediscrimination tests of all five subjects have been reported elsewhere (Hearst, 1960).

Animals were fed a daily ration of approximately 70 Foringer Monkey Pellets and one orange. Pellets obtained during experimental sessions counted as part of the daily total of 70 pellets. The feeding periods occurred immediately after experimental sessions when the subject was returned to its home cage; experimental sessions thus began with subjects that were food deprived for 20-24 hr. Water was continuously available in the home cages of the animals.

Apparatus

The experimental test chamber was a commercially produced model (Foringer Primate and Carnivore Chamber), with a cubical ex-

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perimental space 24 in. per side. Two responses were available for the subjects: They could either press a lever mounted on one sidewall of the chamber, or pull a chain mounted in the ceiling. A pellet dispenser released pellets into a hopper mounted in the same sidewall as the lever. Shocks, approximately 5 ma for 0.6 sec, could be delivered through stainless steel bars in the floor of the chamber. A Grid Shock Scrambler was used to distribute shock power over the bars, sidewalls, lever, and chain. A 110-VAC, 60-watt General Electric bulb, which was mounted above a circular milk glass screen (5 in. in diameter) in the ceiling of the chamber, near the chain, acted both as a houselight and as the generalization test stimulus.

During generalization testing, the intensity of this houselight was varied in discrete (though unequal) steps by a group of fixed resistors in series with the light. The 11 available test intensities were included in the prediscrimination generalization tests, but only 8 of these were used in subsequent generalization tests. These various light intensities were measured with a General Electric Multi-Cell light intensity meter (cosine-corrected) several times during the experiment; when these calculations were made, the meter was placed approximately 1 ft below the glass screen, the most usual position for the monkey's head. Intensity values were read to the nearest one-tenth of a foot-candle. Because the houselight bulb had to be replaced a few times during the experiment, intensity readings taken over the entire experiment varied slightly (usually less than 0.5 ft-ca).

The experimental chamber was located in a small, lightproof cubicle. A white noise generator remained on continuously inside the cubicle and served to mask sounds from adjacent rooms. A system of relays, timers, and counters was used to automatically vary stimulus intensities, program reinforcements and shocks, etc., and to tabulate lever presses and chain pulls. Two Gerbrands cumulative recorders provided separate records of lever presses and chain pulls. With few exceptions, animals were run every week day.

PROCEDURE AND RESULTS

Phase 1: (Prediscrimination Gradients)

Training. The animals were first trained to depress the lever to avoid shocks (Sidman,

1953). Every lever press postponed shock for 10 sec; by responding at least once every 10 sec, the subjects would avoid shock entirely. In Sidman's terminology, the response-shock and shock-shock intervals were both equal to 10 sec. The chain was absent from the experimental box during training of the avoidance response.

During this training phase, and during all subsequent experimental sessions prior to generalization tests, the houselight remained on continuously at its maximum intensity (28.1 ft-ca). An exception to this rule was made for Monkey U-760, which was left in the experimental box overnight because its daily session began at 5 p.m. At the conclusion of each session for this subject, the houselight went out and the animal remained in complete darkness until the next morning.

All subjects learned the avoidance response fairly rapidly; after six or seven sessions of exposure to the schedule, they rarely received more than one or two shocks per 2-hr session. On the next day, a generalization test was run for the avoidance response. This test was similar in all procedural details to the subsequent generalization tests of Phase 1; because data for the single avoidance gradient obtained at this point in the experiment were virtually the same as those obtained in the later concurrent test, the results of this initial test will not be discussed further here.

During the next experimental session, the chain manipulandum was introduced into the apparatus and the animal was reinforced with a pellet of food each time it pulled the chain (continuous reinforcement). The avoidance schedule was still in effect, so that avoidance lever-pressing continued even while the monkeys were learning the chain-pulling response.

The food-reinforcement schedule was then changed to a variable-interval (VI) schedule with a 2-min mean interval. Thereafter, the subjects were exposed to approximately ten 2-hr sessions, when the schedules of food reward and shock avoidance were simultaneously in effect in the presence of the brightest light intensity.

Testing. The next session was the first concurrent generalization test session. During this session, light of 11 different intensities was presented in a mixed order, 12 times at each intensity. The 11 intensities included the brightest, which was used during condi-

tioning, and 10 others, which were all dimmer than the conditioning stimulus (CS). Each presentation of a given stimulus lasted 30 sec, and then another intensity was immediately presented. The animals could obtain neither food nor shock during the generalization test; the lever response and chain response were subjected to extinction conditions.

Fig. 1. Prediscrimination generalization gradients for each subject. The avoidance gradient is connected by solid lines, and the food-reward gradient by dashed lines. All subjects were trained in the presence of the brightest test intensity (indicated as the "CS").

After this initial generalization test, subjects were replaced on concurrent food-reward—shock-avoidance, as before, for another week. Then, a second generalization test was given, identical to the first except that a 10-min preliminary period on the concurrent schedule immediately preceded the test.

Results. The total number of chain pulls and lever presses during each of the 11 light intensities was tabulated during generaliza-

tion tests. The data of the two generalization tests were combined to plot the individual gradients shown in Fig. 1. Relative generalization (on the ordinates) was scaled by assigning the value of 1.00 to the peak of each gradient, the intensity value at which the animal responded most frequently; all other response frequencies were expressed as decimal fractions of this maximum value.

For all subjects in Fig. 1 [and the two others reported in Hearst (1960)], the reward gradient was much steeper than the avoidance gradient. Subjects pulled the chain (the food-linked response) much more often in high intensities of light (close to the conditioning stimulus) than in the dimmer light intensities. In contrast, the avoidance gradient was almost completely flat; subjects were just as likely to press the lever in the dimmest as in the brightest test light. In other words, the response controlled by shock avoidance showed much more generalization than the response controlled by food reinforcement.

Phase 2: (Postdiscrimination Gradients)

The gradients of Phase 1 reflect training conditions during which the same light intensity continuously illuminated the experimental space. If subjects learn to respond in one light intensity and not in another, will the same differences between food- and shock-controlled gradients still be obtained? The next phase of the experiment was designed to determine the influence of such discrimination training on the shapes and relative slopes of the two gradients.

Training. Two of the three subjects (U-556 and U-760) were placed on a procedure in which the dimmest light intensity (0.3 ft-ca) now signalled the same concurrent schedules of food reward and shock avoidance as before; the former conditioning stimulus, namely, the brightest intensity of light (28.1 ft-ca), signalled a period when the animal could receive neither food nor shock. The third subject (U-613) continued in a situation in which the brightest intensity set the occasion for food and shock (just as throughout training); but when the dimmest intensity was on, neither food nor shock was programmed. During the positive stimulus (S^D), therefore, monkeys could obtain food by pulling the chain and could avoid shock by pressing the lever; in the negative stimulus (S^A), extinction was pro-

grammed for both responses, and animals received neither food nor shock.

Initially, the two extremes of light intensity were presented in a mixed order throughout 3.5- or 4-hr experimental sessions. Presentations of each stimulus intensity lasted 2, 4, or 6 min. The sequence of S^D and S^A was so arranged that the animal spent an equal amount of time in each stimulus over an entire session. However, after three daily sessions on this procedure, the avoidance discrimination showed very little improvement; subjects continued to press the lever at the same rate in the presence of both S^D and S^A . In contrast, the animals soon learned the food-reward discrimination and, after these three sessions, chain-pulling rates in S^A were less than 40% of their S^D rates for all three subjects.

A decision had been made beforehand to test for postdiscrimination generalization gradients only after discrimination learning had reached more or less equal levels for both responses, *i.e.*, when the S^A rates were less than 10% of S^D rates for both lever pressing and chain pulling. Generalization data taken before such equivalence had been attained might be difficult to interpret, since any gradient differences could be attributable to differences in level of acquisition of the discrimination for the two responses. In order to improve the avoidance discrimination, the following procedures were successively instituted for all subjects:

- (1) The response-shock and shock-shock intervals were decreased to 5 sec to increase the likelihood of shocks in S^D . Such shocks could provide additional "feedback" regarding the appropriateness of avoidance responding.
- (2) S^D and S^A were alternated every 2 min.
- (3) S^D and S^A were alternated every 15 min.
- (4) S^D 's of 10 min and S^A 's of 50 or 30 min were alternated through 7.5- to 10-hr sessions.

The avoidance discrimination gradually improved, probably both as a result of continued training and as a result of the above procedures (particularly No. 4). Eventually, response rates in S^A were consistently less than 10% of the S^D rates for both responses in all animals.

Testing. On the day of the postdiscrimination generalization test, the monkeys were first exposed to an 80-min period when the usual concurrent schedule of food reward and shock avoidance was in effect in S^D ; S^D 's of 10 min

alternated with S^A 's of 30 min during this period. Such a preliminary to the generalization test was included to make sure that the animals' discriminative performances were up to normal on this particular day and to minimize any possible warm-up effects.

Fig. 2. Postdiscrimination generalization gradients for avoidance (solid) and food-rewarded (dashed) behavior. Two subjects had the dimmest test intensity as the S^D (indicated as the "CS"), whereas the third subject (U-613) had the brightest test intensity as the S^D . In all cases, the S^A training intensity was at the opposite end of the intensity continuum.

Immediately after this preliminary phase, the generalization test began. During this test, six other intensities were presented in addition to S^D and S^A . The test was quite similar to that of experimental Phase 1, except that only eight intensities were tested and each presentation lasted 2 min rather than 30 sec. The eight intensities were presented six times each in a predetermined mixed order. The animals received neither food nor shock during the generalization test.

Results. Figure 2 shows generalization gradients derived from this test. The steepness of both the food reward and the shock-avoidance gradient has markedly increased over prediscrimination levels. Nevertheless, the same qualitative difference still exists between the two gradients; the avoidance-response gradient lies above the reward gradient for all animals. The greater generalization of the avoidance response is particularly noticeable for Monkeys U-556 and U-760 in the intensity region relatively close to S^D , where the distance between the two gradients was largest.

Phase 3: (Continuous Testing)

In experimental Phase 1 the subjects had been exposed to only one light intensity, and in Phase 2, to only two light intensities (S^D and S^A) during all sessions other than generalization test sessions. Phase 3 was, in essence, a period of combined discrimination training and generalization testing, since subjects were presented with the eight test stimuli, ranging in intensity from S^D to S^A , during every experimental session. This procedure permitted generalization gradients to be plotted on each experimental day. Continued exposure to such a procedure was expected to sharpen the reward and avoidance gradients and to bring them closer together, since experience with all intensities ought to make discriminations among them most efficient.

Training-Testing. The specific S^D intensity was the same for each subject as during Phase 2, and, as before, signalled the concurrent programs of shock avoidance (now 5-sec shock-shock and response-shock intervals) and food reward (1-min variable interval, two pellets per reinforcement). Chain pulling and lever pressing were reinforced only in S^D ; responding in all other test intensities was extinguished.

During this continuous testing phase, which was maintained with some modification for the rest of the experiment (see ahead), each of the eight test intensities appeared 12 times per 3-hr daily session in a mixed order. Each presentation lasted 2 min; and after one intensity terminated, another was immediately presented.

Results. Subjects were exposed to this procedure for at least fifteen sessions, two or three of which were devoted to an examination of the effects of various drugs. (These

results will not be discussed here.) The last three sessions on this procedure, during which no drugs were administered, were pooled together to obtain the individual gradients shown in Fig. 3.

Fig. 3. Postdiscrimination gradients for avoidance (solid) and food-rewarded (dashed) behavior after continuous testing with all eight test intensities.

For Subjects U-556 and U-760 the continuous testing procedure resulted in reward and avoidance gradients which are virtually superimposable (Fig. 3). However, Monkey U-613 still displayed relatively more generalization of the avoidance response.

Phase 4: (Continuous Testing; Free Shocks in S^D)

Because very stable and reproducible gradients that were not likely to be affected very much by additional experience in the situation were now obtainable from session to session, the influence of several other independent

variables on the shape and form of the generalization functions was next investigated. The first of these subexperiments involved a study of the effects of unavoidable or "free" shocks (Sidman, Herrnstein, & Conrad, 1957).

Sidman (1958a) has suggested that shocks may produce a broadening of generalization gradients. This conjecture can be tested in several ways. One method might involve the scheduling of unavoidable shocks in S^D alone; another method would study free shocks given in the S^A intensity furthest removed from S^D , whereas other methods might explore the effects of free shocks given unpredictably during an experimental session, without regard to the light intensity in effect at the time the shock was scheduled. Only the first two of these methods were examined here (Phases 4 and 6).

Training-Testing. During Phase 4, free shocks were programmed to occur on the average once every 2 min (VI 2 min) in S^D . Because each S^D presentation lasted 2 min, as did presentations of all other light intensities, this variable-interval schedule of shock delivery meant that some S^D periods would pass without any shock, while other S^D periods might include as many as two or three free shocks. Free shocks were of the same intensity and duration as shocks which might occur because the animal failed to press the lever in time during S^D . Just as in previous phases of the experiment, no shocks or food rewards were possible during all other light intensities.

Results. Figure 4 displays the generalization gradients obtained during this free-shock procedure; the data are combined for the last 3 days on this schedule after performances were stable. The new procedure had very little effect on the gradients for reward and avoidance. In fact, the gradients show slightly better discrimination along the intensity continuum than do the gradients of Fig. 3 (no free shock). This minimal improvement may be attributable to the continued exposure of the subjects to the experimental situation, or perhaps to the possible "feedback" function of free shocks in S^D .

Phase 5: (Continuous Testing; Free Shocks Discontinued)

Training-Testing. Before an investigation of the effects of free shocks given at the other end of the intensity range (S^A) was initiated

Fig. 4. Postdiscrimination gradients for avoidance (solid) and food-rewarded (dashed) behavior under continuous testing procedures. "Free" shocks were intermittently delivered during S^D ("CS").

in Phase 6, subjects were returned to the procedure of Phase 3 (no free shocks) to see if the removal of the free shocks and continued experience in the situation might itself have effects on the gradients. Such testing without free shocks was continued for at least five sessions for each of the three animals; the data of Fig. 5 include results from the last three sessions on this procedure.

Results. Figure 5 indicates that removal of free shocks had no appreciable effect on the gradients for reward and avoidance. Both remained very much the same as they had been in Phases 3 and 4.

Phase 6: (Continuous Testing; Free Shocks During Extreme S^A)

Training-Testing. In the next phase of the experiment, the free-shock schedule, which had been in effect during S^D in Phase 4, was reestablished; however, the free shocks were now delivered during the S^A light intensity farthest removed from the S^D stimulus. Just

Fig. 5. Postdiscrimination gradients for avoidance (solid) and food-rewarded (dashed) behavior under continuous testing procedures. "Free" shocks were no longer given during S^D .

as during Phase 4, the free shocks were presented on a variable-interval schedule of 2 min, so that some free-shocked S^A periods passed without shock and others included two or three shocks.

Every other aspect of the experimental procedure remained exactly the same as during Phases 3 and 5: Lever pressing was required for shock avoidance and chain pulling was rewarded during S^D , whereas lever presses and chain pulls were subjected to extinction conditions in the seven other light intensities. Lever presses during the free-shocked S^A period thus had no programmed consequence for the animal.

It will be noted that Phase 4 provides a control for the effects of "number of shocks" on the avoidance and reward gradients. During Phase 4, the subjects received approximately the same number of shocks (free and otherwise) per session as during Phase 6; any changes which occurred in the shapes of the

gradients in Phase 6 must therefore be related to where (*i.e.*, in what stimulus intensity) the shocks were given and not just to their occurrence. An equal number of shocks had no effect in itself on the two gradients under study (Phase 4).

Fig. 6. Postdiscrimination gradients for avoidance (solid) and food-rewarded (dashed) behavior under continuous testing procedures. "Free" shocks were intermittently delivered during the S^A intensity at the opposite end of the intensity continuum.

Results. The animals were exposed to this new procedure for at least nine sessions, by which time their behavior had stabilized. Gradients were calculated from pooled data obtained on the last 3 days of the procedure. Figure 6 shows these gradients.

The free-shock procedure had a radical effect on the two gradients. Even though lever pressing served no programmed function during the free-shocked light intensity, lever-pressing rates were extremely high during this intensity. This change in avoidance behavior resulted in a bowl-shaped, nonmonotonic

gradient for all three subjects (Fig. 6). Avoidance responding at the middle-intensity values (*i.e.*, neither the S^D nor the free-shocked intensity) was relatively greater than on the prior procedures (Phases 3-5), and indicates greater generalization than previously.

No strong conclusions can be drawn about the shape of the food-reward gradient under this free-shock procedure. Although the gradients of reward may appear fairly similar to the avoidance gradients, a good deal of chain pulling during the free-shock intensity came immediately after or during the delivery of shocks; in what seemed as almost an unconditioned escape response to the shock, subjects leaped at the chain or grabbed it as they raced around the cage. These chain pulls were so topographically dissimilar to normal chain-pulls for food reward that their occurrence may be considered as at least partially an artifact and a reason for viewing the reward gradients of Fig. 6 as contaminated. In contrast, the subjects maintained their avoidance responding at a fast rate even when free shocks had not occurred for some time; lever pressing thus cannot easily be accounted for in the same way as chain pulling, *viz.*, as part of the mass of escape movements elicited by shocks. The fact that avoidance responding shows more generalization than before in the middle (nonshocked) ranges of intensity (Fig. 6), whereas chain pulling does only to a much lesser degree (and solely in Monkey U-760), also indicates that the new peak in the appetitive gradient might, at least partially, be due to escape responding of this sort.

"Superstitious chaining" of lever pressing and chain pulling (Sidman, 1958b) possibly may have contributed to the development of the second peak in the appetitive gradients of Fig. 6; chain pulling may have been maintained to some extent by spurious correlations with shock avoidance. Phases 1 and 2 of the present experiment gave little evidence of such chaining, since the appetitive and avoidance gradients were very dissimilar and the two types of behavior displayed differential acquisition rates for the intensity discrimination. By the end of Phase 3, however, the two gradients of Monkeys U-556 and U-760 were virtually superimposable; the possibility exists that by this time a spurious correlation between the two responses had been established in these two subjects. The fact that

chain-pulling rates were consistently much lower than lever-pressing rates in all subjects argues against such a simple "chaining" interpretation, however. At any rate, complications induced by the shock-elicited chain pulling mentioned above and by possible superstitious chaining make extensive interpretation of the bimodal appetitive gradient of Fig. 6 rather unprofitable.

*Phase 7: (Continuous Testing;
Free Shocks Discontinued)*

Training-testing. Animals were next returned to the continuous testing procedure of Phases 3 and 5 to check on the recoverability of prior levels of performance and to provide a base line on which to study the effects of a new procedure in Phase 8.

Fig. 7. Postdiscrimination gradients for avoidance (solid) and food-rewarded (dashed) behavior under continuous testing procedures. "Free" shocks were no longer given during the extreme S^A .

Results. This return to the old procedure was continued for at least six sessions, or until behavior had stabilized (at most 15 sessions,

Monkey U-613). The last three sessions were combined to calculate the data of Fig. 7.

Within a few sessions after the free-shock procedure was eliminated, Monkeys U-556 and 760 showed complete recovery of their former gradients (Fig. 7). Monkey U-613 continued to show much more generalization of the avoidance response than it had during comparable Phases 3 and 5; when its performance finally stabilized, it retained a second peak at the intensity previously free-shocked in Phase 6. Monkey U-613's reward gradient, however, displayed congruence with its counterparts of Phases 3 and 5.

Phase 8: (Continuous Testing; Extreme Intensities Both S^D)

Training-testing. During the final phase of the experiment, the light intensities at either end of the intensity continuum were both made S^D's for avoidance lever-pressing and food-rewarded chain-pulling. Lever presses and chain pulls in the presence of the six other test intensities were extinguished as before.

Results. Subjects remained under these conditions for approximately 10 sessions, when behavior had fairly well stabilized. The last three sessions were combined to plot the data of Fig. 8.

Avoidance gradients for all three subjects were almost perfectly symmetrical and showed peaks of equal magnitude at either end of the intensity continuum. Subjects quickly learned to press the lever and avoid shock in the presence of two light intensities; after the first session on the new procedure, a subject rarely received more than one or two shocks per 3-hr session.

The food-reward gradients showed great differences, depending on the individual subject. The reward gradient for Monkey U-760 was virtually equivalent to its avoidance gradient, since both gradients were bowl-shaped and symmetrical. Monkey U-613's chain-pulling rate in the dimmest intensity had been at a zero value ever since discrimination training started in Phase 2; and this subject never learned that chain pulls in the low-intensity S^D would be rewarded in Phase 8. Even a few "free reinforcements," given by the experimenter in the presence of the dimmest intensity, failed to initiate chain pulling during this light intensity. Monkey U-613's re-

Fig. 8. Postdiscrimination gradients for avoidance (solid) and food-rewarded (dashed) behavior under continuous testing procedures. The two extreme intensities (brightest and dimmest) were S^D's (CS's) for both avoidance and food reward; the six intermediate intensities served as S^A's for both responses.

ward gradient thus remained very steep and monotonic, typical of its previous performance.

Like Monkey U-760, Subject U-556 displayed a bowl-shaped, nonmonotonic reward gradient; but the peak at the "new" S^D was of a greater magnitude than the second peak at the "old" S^D. Incidentally, the procedures of Phase 8 were continued beyond the achievement of stability (*i.e.*, beyond the approximately 10 sessions noted above) in order to study the effects of some pharmacological agents. During this period (seven additional sessions), the two peaks of U-556's reward gradient came closer together in magnitude than was the case in Fig. 8. Even at the end of this continued exposure to the Phase 8 procedure, however, chain-pulling rate in the dim stimulus was still less than 70% of the rate in the bright stimulus.

ADDITIONAL EXPERIMENTS²

The finding (Phase 1) that avoidance responses generalize more than appetitive responses was subjected to additional verification in an experiment with rats. In the monkey experiments, all subjects had been conditioned in the presence of the brightest light intensity and tested only on dimmer intensity values; in addition, avoidance-response rates had been much higher than the rates for the food-reinforced response. In the rat studies, some subjects were conditioned in the presence of the brightest light and others in the dimmest light. Also, a combination of food-reinforcement and avoidance schedules was selected which produced much higher rates for food reinforcement than for shock avoidance. Confirmation of the monkey results with these rat subjects would thus lend more weight to a conclusion that avoidance gradients are characteristically flatter than appetitive gradients.

Training. Ten male, Osborne-Mendel albino rats, 90-100 days old at the start of training, were used in this experiment. Four of these subjects, designated "reward" animals, were trained to depress a lever to obtain condensed milk rewards (0.1 ml for 3 sec) on a 1-min, variable-interval schedule; these animals were maintained at 75% body weight throughout experimentation, and were tested after approximately 24-hr food deprivation. The other six animals were trained to press a lever on a Sidman-type avoidance schedule in which the response-shock interval was 30-sec and the shock-shock interval was 5 sec. Shock intensity was set at approximately 1.5 ma and shock duration at 0.4 sec. These latter animals, designated "avoidance" subjects, had food and water constantly available in their home cages. Experimental sessions were 2 hr for the four reward subjects and for four of the six avoidance subjects; the remaining two avoidance subjects were tested during the night in 6-hr sessions.

In contrast to the monkey experiment (Phase 1), each rat learned only one response, reinforced (depending on the individual subject) by either food reward or shock avoidance. The schedules were not concurrent, as they had been with the monkeys.

²The help of Alice Torovsky in the conduct of the rat studies is gratefully acknowledged.

The generalization test stimulus was a 120 VAC, 6-watt houselight fitted into the glass top of the experimental cage directly above the area near the lever. Half of the animals in each group were trained in the presence of the brightest light intensity (32.0 ft-ca, as measured with the meter placed 0.25 in. below the bulb), and half in the dimmest intensity (0.25 ft-ca). For the four reward subjects and four of the six avoidance subjects, this training stimulus (CS) was always on when the animal was in the experimental box. For the two "night" animals (avoidance), the light remained on during the scheduled 6-hr test sessions; however, a blackout was in effect thereafter, from the session's termination until the subject was removed the next morning. After approximately 10 sessions on these procedures, the behavior of all subjects had stabilized, and generalization tests were run during the next experimental session.

Testing. Light of eight different intensities was presented during generalization test periods. These test intensities were equally spaced along a logarithmic scale; the exact values used were 32.0, 16.0, 8.0, 4.0, 2.0, 1.0, 0.5, and 0.25 ft-ca. During generalization testing, each presentation of a given intensity lasted 30 sec and was immediately followed by the next scheduled intensity. The order of presentation of the eight different intensities was mixed, and each intensity was presented 15 times during the entire test for a total of 120 presentations (60 min).

Before the generalization test, food-reinforced subjects were given a 10-min warm up, under the same conditions as during prior training; and a 30- to 45-min warm up was arranged for the avoidance subjects. During training sessions, approximately this amount of time was necessary before the subjects' responding stabilized at normal values. Once the generalization tests began, extinction was programmed; no shocks or rewards were obtainable during the test.

Results. Table 1 shows the results of this experiment. The median number of responses in each test intensity was calculated for each subject over the first 10 presentations of each intensity, and the mean of these medians was used as the group measure from which "relative generalization" was derived in the same way as in Fig. 1-8 above. The data of those subjects for which the dim light was the CS

Table 1
Relative Amount of Generalized Responding to Each Test Intensity During
First 10 Trials of Generalization Test
(Peak of Curve = 1.00)
Distance from CS (Log Units)

	0 (CS)	1	2	3	4	5	6	7
Reward (N = 4)	1.00	0.74	0.59	0.56	0.60	0.49	0.46	0.41
Avoidance (N = 6)	0.82	0.93	0.66	0.93	0.90	0.71	0.90	1.00

were combined in this analysis with the data of those animals for which the bright light was the CS. The slopes of the avoidance and appetitive gradients showed the same qualitative differences, regardless of which stimulus intensity was present during training.

The reward animals clearly showed a relatively sharp, graded decrease in responding as light intensity was varied more and more from the original training stimulus; avoidance gradients, in contrast, showed no systematic change in response probability as a function of stimulus intensity. A statistical analysis of these group data revealed that the slope of the avoidance gradient did not deviate significantly from horizontal, whereas the linear trend of the appetitive gradient was statistically significant ($F_{1,3} = 10.58$, $p < .05$). Further analysis showed that the linear component of the "group $\times$ stimulus intensity" interaction was statistically significant ($F_{1,8} = 12.03$, $p < .01$). This result indicates that as the stimulus intensity varied more and more from the CS intensity, the difference between the two gradients increased in a linear fashion. These statistical findings thus support the conclusion that the appetitive gradient is steeper than the avoidance gradient.

Although the individual records of the four reward animals were considerably more irregular than those of the monkeys, they showed the highest response rates in the vicinity of the original CS and the lowest rates at intensity values far from the CS. Only one of the six avoidance animals (the worst avoidance performer) showed any such tendency.

These data thus support the conclusion of the earlier experiments that generalization gradients obtained after reward training are sharper than those obtained after avoidance training. In the rat experiments, this finding was obtained even when the absolute value of the CS was varied and even though food-

reinforced lever-pressing rates were more than twice as great as avoidance-response rates; in the monkey work, avoidance rates had been the higher of the two. The rat study also suggests that the appetitive-aversive differences obtained with the monkeys in Phase 1 were not simply a function either of concurrent scheduling or of the physical characteristics and spatial position of the different responses (lever press vs. chain pull) used.

DISCUSSION: CONCLUSIONS

Under the conditions of the present experiments, it has been shown that stimulus generalization prior to any discrimination training is much greater for a shock-controlled response than for a food-controlled response. This is true for both rats and monkeys even though training procedures differ considerably for the two species. After discrimination training, both generalization gradients become much steeper, although the avoidance gradient still exhibits greater generalized responding than that of food reward. The two gradients can be rendered even steeper and made virtually equivalent by continued experience with all the different light intensities. Unavoidable shocks (at a new intensity, different from SP) can change the slope of the avoidance gradient in the same way as would the addition of an avoidance contingency in the new intensity.

The specific values of the "drive level" parameters (*i.e.*, shock level, hours of food deprivation) used in this experiment were typical of numerous investigations which have compared appetitive and aversive performance. Since other studies have indicated that the slope of generalization gradients is an inverse function of drive level (Thomas & King, 1959; Rosenbaum, 1953; Jenkins, Pascal, & Walker, 1958; Bersh, Notterman, & Schoenfeld, 1956), it would be worthwhile in the

present situation to examine food-deprivation times and shock levels parametrically. Sidman (1961) has recently shown, however, that changes in shock level which affect avoidance-response rate have no effect on the amount of relative generalization; gradients for the type of avoidance behavior studied here may thus be relatively unaffected by variations in shock parameters. If this proves to be true, few, if any, appetitive gradients are likely to match the flatness of a relatively large variety of Sidman-type avoidance gradients.

In a Pavlovian experiment mentioned briefly in Bykov (1958, p. 642), it was found that when "one tone was the signal for a strong conditioned defensive reflex and another tone was the signal for an alimentary reflex, the entire nonreinforced scale of tones provoked the conditioned defensive reflex; the 'food' tone, however, invariably produced only an alimentary conditioned reflex." In this latter experiment also, generalization was greater for the aversively controlled response. Bykov does not state whether different results were obtained with different relative values of shock level and food deprivation, so that the relation between relative drive strengths and relative generalization in this respondent situation remains an open question.

In a classic study, Miller (1944) compared approach and avoidance gradients for rats in a runway conflict situation and concluded that the gradient of avoidance is steeper than the gradient of approach. Miller considered this conclusion to apply to stimulus generalization gradients over a variety of dimensions and not just to spatial discriminations in the runway (Murray & Miller, 1952; Miller, 1959; Miller, 1961). Although the results of the present study clearly contradict such a general conclusion, many procedural differences could possibly account for the divergent results. In addition, Miller (1959) suggests that under certain conditions, the avoidance gradient would be expected to be flatter than the approach gradient, *i.e.*, when mainly internal cues elicit the drive motivating avoidance. Because the avoidance schedule used here is not based on any obvious external cues, Miller's latter conjecture may be applicable to the present findings. An examination of the shape of generalization gradients after training on a reward schedule dependent primarily on internal cues (*e.g.*, a DRL schedule)

might prove illuminating as a further test of Miller's hypothesis.

At any rate, the contrasting results of these studies indicate that the specific parametric schedule values selected for study, as well as the type of reward and avoidance schedules used, are likely to be critical factors in any comparison of appetitive and aversive generalization gradients. Because of the inevitable procedural differences between any single reward schedule and any single avoidance schedule, eventual behavioral differences (*e.g.*, in gradient shape) are difficult to ascribe to motivational variables alone. Therefore, studies which examine gradient shape as a function of specific positive and negative reinforcement-schedule parameters ought to enable a better evaluation of the generality of some of the present findings regarding appetitive-aversive differences.

The effects of discrimination training and the continuous testing procedures of Phases 2 and 3 illustrate, as do many other experiments (*e.g.*, Pierrel & Sherman, 1960; Miller, 1959; Sidman, 1961; Hanson, 1959), that the steepness of generalization gradients is subject to modification and depends on the specific conditions of learning under which the gradients are obtained. The slow acquisition of the avoidance discrimination in Phases 2 and 3, in contrast to the rapid acquisition of the appetitive discrimination, may be a rather general finding, too, since subsequent work in our laboratories with two monkeys in an auditory (click-frequency) discrimination also has revealed quick learning of the discrimination for a variable-interval, food-rewarded lever-response and very slow acquisition (and never a near-perfect performance) of the same discrimination for a concurrent avoidance lever-response. Brady (1959), Verhave (1959), Appel (1960a), and Hearst *et al.* (1960) all have published records of subjects which eventually mastered an avoidance discrimination of this type; but in these four reports, the discrimination involved presence or absence of a stimulus rather than graded values of a continuously present stimulus. The greater stimulus generalization to be expected in the latter case may make an avoidance discrimination of this type very difficult to acquire. Under a mixed schedule of reinforcement, in which the extreme case of stimulus generalization is exemplified (the "stimuli" are either

indiscriminable or the same), one would expect that such an avoidance discrimination would be virtually impossible. Appel (1960b) has in fact shown that monkeys tested on a mixed avoidance-extinction schedule show no evidence of differential rates in the two components, even after prolonged training; it was necessary to punish responses in the extinction component of the mixed schedule before any differential performance in the two components developed.

The radical effects of free shocks given in S^A (Phase 6) support results obtained by Appel (1960a, 1960b), who found that free shocks delivered in S^A could greatly weaken or even destroy a well-formed avoidance discrimination, as well as prevent the original acquisition of such a discrimination. Moreover, in the present experiment the free shocks increased generalized responding to stimulus-intensity values between the two extremes of light intensity so that responding along an entire stimulus dimension was modified. The present data therefore support Sidman's (1958) suggestion that shocks are likely to broaden generalization gradients.

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