THE EFFECT OF THE AMOUNT OF TRAINING ON THE DEVELOPMENT OF GENERALIZATION GRADIENTS AROUND S+ AND S- DURING INTERDIMENSIONAL DISCRIMIINATION

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ABSTRACT

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By

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Four groups of pigeons trained on a free operant avoidance schedule were given interdimensional auditory discrimination training. A probe technique with or without probe shock was employed to obtain daily generalization gradients around S+ for two groups of birds and around S- for two groups of birds. Responding was summated across three days of training for the three birds in each group to show the development of group generalization gradients for three day blocks of discrimination training. Excitatory gradients around S+ emerged in the first three days of training, steepened through the ninth to twelfth day of training, and remained stable with additional training. Inhibitory gradients around S- emerged in the first three days of training, steepened through the ninth day, and remained stable with additional training. This development is similar to that described in the appetitive situation and suggests that the same process of gradient development operates in both the appetitive and avoidance situations. In the present study, results were interpreted in terms of relaxation theory.

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INTRODUCTION

Interdimensional discrimination training superimposed on a free operant avoidance schedule was employed in this study to examine the effect of the amount of discrimination training on the development of generalization gradients around a safety signal and a warning signal.

Numerous studies have been run using the free operant avoidance paradigm developed by Sidman (1953). Free operant avoidance is defined by two temporal parameters: a shock-shock interval (S-S), the period of time between shocks in the absence of a response, and a response-shock interval (R-S), the period of time that a response postpones shock. The first response in a session ends the shock-shock interval and begins a response-shock interval. Each additional response reinitiates the response-shock interal. The animal may postpone shock indefinitely by responding before the shock-shock and response-shock intervals produce a shock. In free operant avoidance as originally designed by Sidman, no exteroceptive stimuli warn the animal that a shock is impending.

The early research on free operant avoidance was conducted primarily with rats and monkeys. The analysis of free operant avoidance behavior using pigeons has been difficult. Most early attempts employed the key peck as the avoidance response. However, Hoffman and Flechler (1959) were unable to condition the key peck in an avoidance situation and abandoned it in favor of a head lifting response. Rachlin and Hineline (1967) were able to condition the key peck in an avoidance situation, but found that the response extinguished too rapidly to be useful. More recently, Ferrari, Todorov and Graeff (1973), using special shaping, fading in shock, and shock adjustment techniques, were able to condition the key peck to shock avoidance. However, the procedure was complicated and, even after extensive training, three of their four subjects avoided less than 90 percent of the scheduled shocks.

Smith and Keller (1970) suggested that the incompatability of a key peck response with the pigeons' unconditioned response to shock, an upward lifting of the head, caused the difficulty in using the key peck in free operant avoidance. Using a treadle press, which is compatable with the pigeons' unconditioned response of jumping and wing flapping, Smith and Keller were able to obtain stable avoidance responding. No special fading in of shock, shaping, or shock adjustment was needed. Moreover, most pigeons trained under this procedure avoided over 90 percent of the scheduled shocks.

Klein and Rilling (1972) used the treadle press response to examine the effect of different shock-shock and response-shock intervals on the free operant avoidance behavior of pigeons. They found a shock-shock interval of five seconds and a response-shock interval of 20 to 25 seconds produced optimal acquisition of avoidance behavior. The Smith and Keller and Klein and Rilling experiments have established the methodology for the study of free operant avoidance behavior with the pigeon.

Exteroceptive stimuli may be superimposed on free operant avoidance behavior by modifying training into components where the Sidman schedule is in effect and components where the Sidman schedule is not in effect. A warning signal is a stimulus associated with an aversive stimulus. A safety signal is a stimulus associated with the absence of the aversive stimulus. Thus, the stimuli presented when the Sidman schedule is not in effect are safety signals. The stimuli presented when the Sidman schedule is in effect are warning signals. From its association with shock, the warning signal acquires aversive properties. According to Rescorla and Lolordo (1965) and Weisman and Litner (1972), the warning signal becomes a Pavlovian elicitor of fear. The safety signal, on the other hand, acquires reinforcing properties and becomes a conditioned positive reinforcer (Weisman and Litner, 1972) from its association with the absence of shock. It can also be called a Pavlovian inhibitor of fear or a signal for relaxation (Denny, 1971). Avoidance responding in the presence of a warning stimulus should increase, while avoidance responding in the presence of a safety signal should decrease. Many studies have demonstrated such differential responding when a safety signal and warning signal are superimposed upon a baseline of free operant avoidance (Badia and Culbertson, 1971; Weisman and Litner, 1972; Roberts, Greenway, and Hurwitz, 1970; Gilbert, 1971).

Stimulus generalization of the stimuli on the dimension of the warning signal is obtained if other stimuli on the warning signal dimension elicit lesser amounts of responding as a function of their distance from the warning signal. Therefore, one should expect that a decremental or excitatory gradient of stimulus generalization would form around the warning stimulus if a generalization test were performed on the warning stimulus dimension.

Stimulus generalization of the stimuli on the dimension of the safety signal is obtained if other stimuli on the safety signal dimension elicit increased responding as a function of their distance from the safety signal. Greater amounts of avoidance responding should result in the presence of each stimulus as a function of the lessened amount of inhibition or relaxation produced by each stimulus. Therefore, one would expect that an incremental or inhibitory generalization gradient would form around the safety signal value if a generalization test were performed on the safety signal dimension.

Interdimensional discrimination training (Jenkins and Harrison, 1962) can be used to test these expectations. Interdimensional training involves the use of a dimension of S- (the safety signal dimension) that is orthogonal to the dimension of S+ (the warning stimulus dimension). All stimuli on the S+ dimension are assumed equally distant from all stimuli on the S- dimension. Using this method it is possible to obtain generalization gradients around S+ and S- without the possibility of the results being confounded by an interaction of excitatory effects from S+ and inhibitory effects from S- (Hearst, Besley, and Farthing, 1967).

One study has been performed using pigeons in interdimensional discrimination training with free operant avoidance to obtain generalization gradients around S+ and S-. In a paper submitted for publication, Klein and Rilling, (1973) used such a procedure and found an excitatory generalization gradient with maximum responding at the warning signal value for a group of birds with a warning signal of a 1000 Hz tone and a safety signal of white noise. An inhibitory gradient with minimum responding at the safety signal value was obtained in generalization testing with a second group of birds with a safety signal of a 1500 Hz tone and a warning signal of white noise.

The use of frequency as the dimension of generalization requires caution. An equal loudness curve at the 85 DB intensity used is not available for the pigeon. Existing data on auditory thresholds show maximum sensitivity at 1000 Hz (20 DB) with decreasing sensitivity to a threshold of 40 DB at 300 and 4000 Hz. (Heise, 1953; Stebbins, 1970; Dalton, 1967; Dalton, Price, and Smith, 1967). If such differential sensitivity exists at the 85 DB level, the gradient obtained in the present experiment may be the result of intensity discrimination. However, the actual dimension used by the subject in forming the discrimination is incidental to the development of the gradients. The present study interprets the data on the frequency dimension.

Although no studies of the effect of the amount of discrimination training on the development of generalization gradients have been run using avoidance procedures, there are numerous appetitive studies on this effect. Most of the studies obtaining appetitive gradients, however, simply employed the presentation of a reinforced stimulus during training without including nonreinforced S- stimulus presentations. Therefore, intentional differential reinforcement (discrimination training) was not employed. However, if discrimination training is necessary to produce generalization gradients (Lashley and Wade, 1946; Sutherland and Mackintosh, 1971), it must be assumed that some type of discrimination training occured. It has been suggested that pecks off the lighted key were unreinforced and created an unintentional differential reinforcement condition in what was labeled nondifferential learning (Heineman and Rudolph, 1963), which allowed the development of the observed generalization gradients.

There is a lack of agreement in many of the studies of the effect of the amount of training on generalization gradients around a stimulus signaling reinforcement in appetitive studies (Hall, 1966; Mednick and Freedman, 1960; Kimble, 1961). Some authors say that the gradient steepens with training, some say that it first steepens and then flattens, and others say it flattens quickly without much initial steepening.

It is possible that the different procedures used by different authors had different amounts of unintentional discrimination training which caused the differences in the shape and development of gradients. Hearst and Koresko (1968), on the other hand, argue that much of the confusion results from the failure of early experimenters to distinguish between absolute generalization gradients, which plot the number of responses to each test stimulus, and relative generalization gradients, which plot the percentage of the total responses made to each test stimulus, or to distinguish between using the slope of the gradient or the amount of generalized responding to test stimuli as measures of generalization.

Using an independent groups design with pigeons on a VI schedule of reinforcement, Hearst and Koresko found that the amount of absolute generalization was a direct function of the number of days of training. A shallow excitatory absolute gradient formed around the training stimulus after only two days of training and progressively steepened up to fourteen days of training. Hearst (1971) repeated the study and found that gradients after sixty-four days of training differed little from the gradients obtained after eight and sixteen days of training. Thus, in the appetitive situation without discrimination training, excitatory gradients formed early in training around a reinforced stimulus, sharpened through the first fourteen days of training, and then remained relatively unaffected by additional training.

Farthing and Hearst (1968) ran an appetitive study using interdimensional discrimination training to examine the effect of the amount of training on the development of generalization gradients around S-. After only two days of discrimination training, a shallow absolute gradient of inhibition had formed around the S- value for three of the six subjects. Absolute gradients for the group were significantly different from the horizontal after four days of training and steepened through the first eight days of training. Additional training after eight days had little effect on the gradients. Hearst (1968) ran a similar study and obtained similar results. In the appetitive situation, inhibitory gradients around S- form early in training, steepen through the first eight days of training, and then remain relatively unaffected by additional training.

The present study is designed to examine the development of generalization gradients around a safety signal and a warning signal in an avoidance situation. The use of the probe technique allows the examination of generalization gradients throughout the acquisition of discrimination. It was necessary to increase responding to all generalization stimuli by the addition of unavoidable shock in probe components, thereby eliminating flat, low response rate gradients which formed around the S- probe stimulus.

Unlike most appetitive studies, the present study employs interdimensional discrimination training. Therefore, the comparison of the gradients obtained in this study with the excitatory gradients obtained by Hearst and Koresko in an appetitive situation must be cautious. On the other hand, a more direct comparison is possible with the inhibitory gradients obtained by Farthing and Hearst, as interdimensional discrimination training was used in that study.

It must be stressed that the explanatory mechanism is incidental to the results of the present study. All major theories of avoidance learning predict the same results, the progressive development with training of an excitatory gradient around the warning signal and an inhibitory gradient around the safety signal. Although relaxation theory is used to interpret the results of this study, its use does not imply exclusive support for that theory.

METHOD

Subjects

Twelve experimentally naive White Carneaux pigeons served as subjects. The pigeons had stainless steel electrodes implanted through the pubic arch (Azrin, 1959). The electrodes were attached to an electrical connector mounted on a leather harness worn on the pigeon's back.

Apparatus

A small experimental chamber was employed to maximize the probability of a treadle press response. The chamber was a plexiglas box 11.75 in. (29.8 cm.) high by 8.5 in. (21.6 cm.) wide by 8 in. (20.5 cm.) deep. The sides of the chamber were covered by .25 in. (.64 cm.) thick rubber pads. A foot treadle 2.5 in. (6.1 cm.) long by 3.5 in. (8.9 cm.) wide and extending 2.5 in. (6.1 cm.) into the chamber was centered on the front wall of the chamber. The treadle was mounted at a 30° angle to the floor with a front edge 1 in. (2.4 cm.) above the floor. A force of 60g (0.6 N) with a downward displacement of .5 in. (1.2 cm.) was required to operate a microswitch connected to the treadle. The chamber was lighted by a G.E. 7.5 W. bulb mounted on the top of the chamber.

The experimental chamber was mounted in a sound attenuating enclosure, serviced by a remote ventilating fan, which also provided a masking noise of 55DB. Conventional electro-mechanical equipment housed in an adjacent room was used to control stimulus presentations and session length. Treadle responses were monitored by a cumulative recorder and electro-mechanical counters.

The shock source was a 7.8v ac transformer, adjustable from 0 to 7.8 volts via a Variac. The shock source was connected to the pigeons via a cable attached to a mercury swivel. Internal resistance was measured for each pigeon before each session by a Wheatstone bridge to insure a resistance under 10 ohms. Implanted electrodes were cleaned when necessary to reduce resistance by rotating the implanted portion of the stainless steel loops into an exposed position and scraping the deposits with a knife blade.

Auditory stimuli were generated by a Model LG-18 Heathkit audio generator and a Marietta white noise generator. A Realistic Model AA-18 solid state amplifier was used to amplify all stimuli to 85 DB as measured in the chamber with the A scale of a B & K Model 2204 sound pressure meter. The speaker was a Realistic Model 40 1303 8 in., 8 ohm speaker mounted in the sound attenuating enclosure next to the experimental chamber.

Procedure

Each experimental session consisted of a series of two minute avoidance components, with a 5 second time out, as signaled by a darkening of the house light, between components.

Preliminary training for all subjects began with two 30 minute (14 two minute avoidance components) sessions of free operant (Sidman) avoidance training with a shock-shock interval of 5 seconds, a response-shock interval of 25 seconds, and a 4 ma. shock of .25 second duration. In the third and fourth sessions, shock intensity was increased to 7.8 ma. In the fifth through the fourteenth session, session length was increased to 62.5 minutes (30 two minute avoidance components). In the fifteenth through the twenty-second session, session length was increased to 91.5 minutes (44 two minute avoidance components). No auditory stimuli were presented in the preliminary training. A base line measure of response rate was obtained during the last five sessions of preliminary training (sessions 18-22). Responses in the 5 second time out between components were not included.

Discrimination training was introduced in the twenty-third session. A discriminative stimulus was presented for the entire two minute component. The positive stimulus (S+) was associated with the avoidance schedule, and the negative stimulus (S-) was associated with the extinction of the avoidance schedule. During extinction the avoidance procedure was not in effect and no shocks occured. A total of 22 S+ and 22 S- presentations arranged in pseudo-random order were made in each discrimination session. The only restriction was that no more than three consecutive presentations of the S+ stimulus or the S- stimulus occurred. In the 5 second time out between components, no stimuli were presented and the house light was off.

Four groups with three subjects in each group were used. For Groups 1 and 2, S+ was a 1000 Hz tone and S- was a white noise. For Groups 3 and 4, S+ was a white noise and S- was a 1000 Hz tone.

Generalization tests were run daily starting with the first discrimination session (session 23). Generalization test stimuli were two minute component probes of tones at 300, 450, 1000, 1500, 2250, and 3400 Hz (Hoffman and Fleshler, 1961). These stimuli were presented in randomly chosen S+ or S- components, designated as probe components, during the last 60 minutes of each discrimination session. Each test stimulus was presented once in each discrimination session. The order of assignment of stimuli to the probe components was governed by a 7X7 latin square. The first 30 minutes of each session was used to allow for warm-up and contained no test probes. For Groups 1 and 2, the test stimuli were presented in S+ components; for Groups 3 and 4, the test stimuli were presented in S- components.

No shock was delivered for groups one and three during any probe component in the first 15 discrimination sessions (sessions 23-37). To increase the response rate to the generalization stimuli for the final 6 discrimination sessions (sessions 38-43), one unavoidable shock occured 5 seconds after the beginning of the stimulus presentation in each probe component. This produced a total of seven unavoidable shocks in each of the final six discrimination sessions.

For Groups 2 and 4, one unavoidable shock occured 5 seconds after the beginning of the stimulus presentation in each probe component for all discrimination sessions (sessions 23-42). See Table 1.

Treadle press responses to each probe stimulus were counted and generalization gradients based on the number of responses to each stimulus value were formed. For Groups 1 and 2, the gradients were on the warning stimulus (S+) dimension, and for Groups 3 and 4, the gradients were on the safety signal (S-) dimension. A seperate gradient was generated by each bird for each day of training. The responses were also added across days to examine group gradients at three day intervals. In addition, a count of responses in all S+ and S- components not serving as probe components was taken and used to determine the maintenance of discrimination.

Discrimination training continued for 21 sessions (sessions 23-43). Criterion for discrimination was reached when the rate of response to S- was less than 10 percent of that to S+ in two consecutive sessions. Responses in the probe components were not included in calculating this percentage.

RESULTS

Table 1, column V shows that ten of the twelve subjects were avoiding 95 percent or more of the scheduled shocks during the last five sessions of prediscrimination training (sessions 18-22). Only Bird 388 (85%) and Bird 2193 (93%) were avoiding less than 95 percent of the scheduled shocks.

Figure 1 presents the S+ and S- response rates for the last five days of prediscrimination training (sessions 18-22) and demonstrates the acquisition of discrimination (sessions 23-43). As can be seen from Figure 1, the use of the probe technique allowed the measurement of generalization gradients without affecting the acquisition of discrimination. For all birds the response rate during S- dropped almost immediately to low levels (3-5 responses per minute) upon presentation of the discriminative stimuli. The response rate during S- for all birds in Group 1 (1143, 962, 1566) and Group 2 (359, 388, 1996) continued to drop smoothly with additional discrimination training, stabilizing below one response per minute for five of the six birds by the eighth discrimination session. The S- response rate for the birds in Group 3 (2007, 1532, 66) and Group 4 (3717, 665, 2011) dropped more gradually and erratically than the rates for the birds in Groups 1 and 2, causing the subjects in Groups 1 and 2 to take significantly fewer days of training to attain the discrimination criterion than the subjects in Groups 3 and 4 (t=2.24, df=10).

Group 1 attained the discrimination criterion in an average of six discrimination sessions. Group 2 attained the discrimination criterion in an average of eight discrimination sessions (Table 1, column VII). This difference is not significant (t=.69, df=4). Group 3 attained the discrimination criterion in an average of 12.33 discrimination sessions. Group 4 attained the discrimination criterion in an average of 11.33 discrimination sessions. This difference is not significant (t=.20, df=4), indicating that the addition of probe shock early in training does not affect the acquisition of discrimination.

The introduction of the discriminative stimuli caused increased responding to S+ in some birds and decreased responding in others on a random basis. Birds 359, 2007, and 3717 were the only subjects to show behavioral contrast, an increase in S+ responding along with a decrease in S- responding. Birds 1143, 962, 1566, 388, 66, 1532, 2001, and 665 showed behavioral induction, a decrease in S+ responding as well as in S- responding in the first several days of discrimination training. Except for Bird 338, a baseline level of S+ responding was regained by the sixth discrimination session in all birds showing induction.

Eleven of the twelve subjects showed a decrease in avoidance percentages during S+ presentations in the first session in which the novel discriminative stimuli were presented. Only Bird 2011 showed an increase in avoidance percentages from 95 percent to 96 percent. This subject did show a decrease to 90 percent shock avoidance in the third discrimination session (Table 1, Columns V and VI). Note that a decrease in avoidance percentages is not synonomous with a decrease in avoidance response rate and is, therefore, not shown in Figure 1.

Figure 2 shows the development of absolute group generalization gradients as a function of the number of days of discrimination training. Each gradient represents summated responding across three days of training for the three birds in each group.

For Group 1, a shallow excitatory gradient with maximum responding at the S+ probe value emerged early in training (days 1-3). This gradient steepened with additional discrimination training through days 7-9 of training.
The number of responses to the S+ probe value increased over the first nine days of training, while the number of responses to the other generalization probe stimuli decreased over the same period. Less of a decrease in responding was shown to those stimuli nearest in value to the S+ stimulus. Additional

training after the first nine days had little effect on the shape of the gradients or on the number of responses to each probe stimulus.

The addition of one unavoidable shock in each probe component for the final six discrimination sessions (sessions 38-43) raised the entire generalization gradient. The increase in responding was least for the S+ probe value, which resulted in a slight flattening of the excitatory gradient in the final six sessions.

The development of daily gradients produced by individual birds (Figure 3) paralleled the development of group gradients for the first fifteen discrimination sessions. The addition of unavoidable probe shock produced more erratic responding to the test stimuli in the last six generalization tests, causing the gradients to be less well formed than those obtained without probe shock. In the majority of cases, however, an excitatory gradient around the S+ probe value emerged.

The use of unavoidable probe shock in all discrimination sessions in Group 2 resulted in increased responding to all probe values for days 1-3. In days 1-3 of training, an excitatory gradient around the 670 Hz probe tone emerged. Over the first nine days of discrimination training, responding to the S+ probe value remained stable, while responding to the other probe stimuli decreased. The result was the formation of an excitatory gradient around the S+ probe value. Responding to the S+ probe value increased slightly in days 10-12. This increase, coupled with stable responding to the other probe stimuli, resulted in the slight steepening of the gradient. Additional training after days 10-12 had no effect on the shape of the gradient or on the number of responses to each probe value.

The development of individual gradients show erratic responding over the first three days of discrimination training, (Figure 4). However, by day 4 an excitatory gradient was present around the S+ probe value for Birds 359 and 388. Bird 1996's responding was more erratic and a clear excitatory gradient around the S+ probe value was not present for this bird until the tenth day of discrimination training.

For Group 3, a shallow excitatory gradient emerged early in training (days 1-3) with maximum responding to the S- probe value. Responding to all probe stimuli decreased over the first nine days of training, resulting in a flat, low response rate gradient by days 10-12. Additional training after the ninth day had little effect on the shape of the gradient or the number of responses to each probe stimulus.

The addition of unavoidable probe shock increased responding to all probe stimuli (Days 16-21). The increase in responding was smallest to the S- probe value and greater for the other probe values as a function of their distance from S-. Therefore, in Group 3, an inhibitory gradient around the S- probe value emerged in sessions with unavoidable probe shock. The gradient remained stable over the six days the probe shock procedure was employed.

The development of individual gradients for the birds in Group 3 paralleled the development of group gradients, (Figure 5). All birds produced a flat, low response rate gradient by the eleventh discrimination session. The addition of probe shock produced an inhibitory gradient around the S- probe value in most sessions of the final six days of training.

These results indicate only that an inhibitory gradient was present by the sixteenth discrimination session. They do not show the development of the gradient. Such development is shown by Group 4.

The addition of unavoidable probe shock in all discrimination sessions in Group 4 did not increase the overall response rate to the probe stimuli over the rate for Group 3 in days 1-3. However, unlike Group 3, a shallow inhibitory gradient emerged in days 1-3 of training for Group 4. The response rate to all probe stimuli decreased during days 4-6 of training. In days 7-9, the response rate to only the S- probe tone continued to decrease, resulting in a steepening of the inhibitory gradient around the S- probe value. The shape of the gradient and the number of responses to each probe stimulus remained stable with additional training after days 10-12.

The individual gradients for Group 4 show erratic responding early in training, (Figure 6). After the eighth day, however, all birds produced an inhibitory gradient around the S- probe in the majority of sessions.

Figure 7 shows the percentage of responses to the S+ probe value during generalization testing as a function of the number of days of discrimination training in Group 1. The percentage of responses to the S+ probe value increased in a regular manner over the first ten days of training and then remained stable with additional training. The addition of probe shock produced higher responding to all probe stimuli and resulted in the drop in the percentage of responses to the S+ probe value shown in days 16-21.

TABLE 1. Column 1 gives the values of the discriminative stimuli for each group. Column 11 gives the sessions employing probe shock for each group. Column 111 gives the sessions not employing probe shock for each group. Column V shows the mean percentage of shocks avoided over the last five sessions of prediscrimination training. Column V1 shows the mean percentage of shocks avoided during the first session of discrimination training. Column V11 shows the number of sessions of discrimination training before the discrimination criterion were met.

TABLE 1.

Group	I Discrimination Training	II Ses. with Probe Shock	III Ses. No Probe Shock	IV Subjects	V Mean% Avoidance Ses. 18-22 (Predisc.)	VI % Avoid. 1st. Disc. Session	VII Ses. to Disc. Criterion
Group 1	S+=1000 Hz			962	95	89	4
Late Probe	S-=White Noise	38-43	23-37	1566	97	92	8
Shock, S+				1143	96	95	6
Group 2	S+=1000 Hz			388	86	85	9
Early Probe	S-=White Noise	23-43	None	1996	99	97	12
Shock, S+				359	93	92	3
Group 3	S+=White Noise			66	99	97	15
Late Probe	S-=1000 Hz	38-43	23-37	1532	99	98	10
Shock, S-				2007	97	96	12
Group 4	S+=White Noise			2011	95	96	4
Early Probe	S-=1000 Hz	23-43	None	3717	99	97	10
Shock, S-				665	95	92	20

DISCUSSION

It has been proposed that the presentation of a novel stimulus in free operant avoidance is likely to have a facilitating effect on the avoidance behavior (Stone and MacLean, 1963). Klein and Rilling's data (1973), on the other hand, show that the presentation of novel stimuli has a depressing effect on avoidance behavior, resulting in a decrease in avoidance percentages caused by the decrease in response rates. The decrease in avoidance percentages allowes the animal to encounter the extinction contingency during S- and, thus, facilitates discrimination learning. This argument predicts the rapid acquisition of discrimination.

It is clear from the data obtained in the present study that in an avoidance situation with interdimensional discrimination training, the animal readily learns that the avoidance response is unnecessary during the S- component of the schedule. For all birds, the S- rate of responding fell quickly and was clearly lower than the S+ rate as early as the first day of training (Figure 1). If avoidance behavior was facilitated by novel stimuli, increased rather than decreased avoidance percentages should occur and the subjects should take longer to encounter extinction during S-.

The drop in avoidance percentages with the presentation of the novel discriminative stimuli in the present study supports Klein and Rilling's hypothesis that a reduction in avoidance percentages is necessary for discrimination learning in an avoidance situation. This decrease in avoidance percentages, however, may not be the result of a decrease in response rate. Of the eleven birds in this study showing a decrease in avoidance percentages in the first discrimination session, only five showed a corresponding decrease in S+ response rate in that session, while two birds showed no change and four birds showed an increase in S+ responding. It is clear from these data that a response decrease is not necessary to produce an avoidance percentage decrease. The presentation of novel stimuli may affect the temporal patterning of responding, which could lead to an increase in S+ responding and still result in a decrease in avoidance percentages. The cumulative records obtained in this experiment were too gross to permit the analysis necessary to examine this hypothesis.

Data from Group 1 clearly illustrates the development of group generalization gradients around S+ (Figure 2). Birds 1143 and 1566 produced individual excitatory gradients around S+ as early as the second day of discrimination training (Figure 3). This differential responding occured after the birds had experienced only one previous two minute presentation of each probe stimulus, indicating keen discrimination on the tone dimension. This keen discrimination is again evidenced in the day 1-3 gradient for Group 1, (Figure 2).

The group generalization gradients around S+ for Group 1 in this study formed early in training, initially steepened with additional training, and were fully formed by the ninth day of training. Relaxation theory can be used to describe the development. In pretraining, fear became conditioned to the stimuli of the experimental setting. In discrimination training, fear became conditioned to the 1000 Hz tone (S+) and relaxation became conditioned to the white noise (S-). Responding to each generalization stimulus was a function of the amount of fear associated with the experimental situation, the amount of generalized fear from S+, and any competing relaxation response. Incremental learning is assumed by relaxation theory. The relaxation response to S- was weak early in training and increased as training progressed. This increase in relaxation is indicated by the decrease in S- response rate for Group 1 over the first seven days of training (Figure 1). The increased relaxation response would carry over to the probe components following S-, resulting in the lower response rates to the probe stimuli shown by sessions 7-9. In addition, a weak relaxation response to each probe stimulus would form over this time and lead to a further reduction in response rate to the probe stimuli. The incremental learning of fear to the S+ stimulus caused an increase in responding to the S+ probe at the same time.

The result of the above process is the shallow appetitive gradient around the S+ probe value in days 1-3, and a sharpening of that gradient through days 7-9. Additional training after day 9 had no effect on the shape of the gradient or the number of responses to the probe stimuli. This indicates that the fear response associated with S+ and the relaxation response associated with S- had reached asymptotic levels by about the ninth day of training. The fact that all birds in group one had developed stable S- response rates and two of the three birds had developed stable S+ response rates by this time supports this idea.

The percentage of responses to the S+ probe increased over the first eleven days of training in Group 1, (Figure 7). This increase was caused by an increase in responding to the S+ probe coupled with a decrease in responding to the other probe stimuli. The leveling of the percentage of responses to S+ shortly after the ninth day of training again indicates that the fear and relaxation responses had reached asymptotic levels at that point.

The use of probe shock in days 16-21 for Group 1 increased responding to all probe stimuli. In terms of relaxation theory, the shock increased fear level in the probe components. However, the fear level was already at a high level in the S+ probe component by this time as indicated by the already high response rate to the S+ probe. Therefore, the added shock could increase the already high fear level in the S+ probe by only a small amount, resulting in a small increase in responding to that probe. On the other hand, the other probe stimuli had lower fear levels as a result of less generalized fear from the S+ stimulus. The addition of shock increased the lower fear levels more causing a greater increase in responding to these stimuli than to the S+ probe. Note, however, that even with shock in probes, excitatory gradients around the S+ probe value emerged.

The development and steepening of the excitatory gradients with training is consistent with the findings of Hearst and Koresko in the appetitive situation. However, in the present study, the amount of absolute generalization to each stimulus value, as measured by the number of responses emitted to each generalization stimulus, decreased over the first nine days of training. Only responding to the S+ probe stimulus increased. Hearst and Koresko found an increase in absolute generalization with training, resulting in an increase in responding to each stimulus.

The use of interdimensional discrimination training in the present study could cause this discrepancy. The response rate to each generalization stimulus in the present study was a function of the generalized fear from S+ and any competing relaxation response. Many of the probe trials used to obtain the generalization gradients were preceeded by an S- component. The response tendency of relaxation associated with the S- stimulus carried over into the probe trial and competed with the generalized avoidance response, resulting in a lowering of the response rate in that probe component. In addition, each probe stimulus, since it had never been assoicated directly with shock, came to elicit a relaxation response of its own which also competed with the avoidance response.

In the Hearst and Koresko study there was no comperable S- component. Therefore, responding to each stimulus was a function of the amount of generalization from the training stimulus. No competing relaxation response was involved. Therefore, as the training stimulus elicited increased responding, responding to the generalization stimuli also increased. Because of the differences in stimuli and training procedures used in the present study and that of Hearst and Koresko, it is impossible to directly compare the development of the excitatory gradients in the avoidance situation with those in the appetitive situation.

Group 2 shows the development of gradients for birds with one unavoidable shock in all probe components (Figure 2). Unlike Group 1, which shows a doubling in response rate to the S+ probe over the first nine days of training, Group 2 shows stable responding to the S+ probe over the first nine days of training. Responding to the other generalization probes decreased through the first six sessions and then stabilized. The result was a fully formed excitatory gradient around the S+ probe. A slight increase in responding to the S+ probe in days 10-12 of discrimination training caused a steepening of the gradient.

In discrimination training, the S+ stimulus signaled the avoidance situation and produced fear and a high response rate. The response level to the probe stimuli was a function of the amount of generalized fear from S+, the fear elicited by the shock, and any competing relaxation response. In the S+ probe, the unavoidable shock produced fear and, in addition, indicated to the bird that the shock procedure was still in effect. Thus, the shock produced a high response rate to the S+ probe from early in training. No buildup in fear level or response rate to the S+ probe was necessary as it was in Group 1. As in Group 1, the relaxation response associated with S- was weak early in training and increased in strength with training. This increase resulted in a gradual lowering of the response rate to the other probe stimuli caused by the carry over of the relaxation response to the probe components. The development of S- responding in Group 2 again supports this interpretation (Figure 1).

Note that the number of responses to the S+ probe in Group 1 for sessions after days 7-9 and in all sessions in Group 2 is similar. This indicates that the fear level to the S+ probe was in full strength by day nine in Group 1 and that the fear could not be greatly increased by the addition of shock.

The addition of probe shock in early discrimination training had no effect on the acquisition of discrimination. Only a small nonsignificant difference in the time to discrimination criterion existed between Groups 1 and 2. In addition, the use of early probe shock had little effect on the rate of development of the generalization gradients. The effect was basically one of elevating the entire gradient. This result agrees with the findings of Sidman (1961) and Klein and Rilling (1973) that the general form of the generalization gradient is independent of variables that alter the subject's rate of response. In Group 1, however, the gradients were formed by an increase in responding to the S+ probe and a decrease in responding to the other probe stimuli, while in Group 2 they were formed by a decrease in responding to all but the S+ probe stimulus, but no increase in S+ probe responding.

Group 3 was designed to show the development of inhibitory gradients around S-. Instead, a flat gradient as shown in Figure 2 emerged. With the flat gradient it is impossible to determine if the birds were not responding because all of the stimuli were neutral or if they were inhibiting responding to each stimulus. The addition of shock in the probe components for the final six sessions showed which of these two possibilities was happening. If all of the stimuli were neutral, the response rate to each stimulus would have been raised equally and produced a flat gradient of a higher response rate. If the birds were inhibiting responding, an inhibitory gradient would emerge around the S- probe value. Such a procedure is the avoidance situation counterpart of the resistance to reinforcement procedure in appetitive studies (Hearst, Besley, and Farthing, 1970).

The result of the addition of probe shock in Group 3 was the formation of an inhibitory gradient around the S- probe value. In terms of relaxation theory, the shock produced a fear response which competed with the relaxation response. The relaxation response was strongest to the S- probe value and less to the other probe values as a function of their distance from S-. Therefore, responding was lower to the S- probe and increased to the other values as they became further in value from S-.

In Group 4 one shock was scheduled in each probe component starting with the first day of discrimination training. This increased the amount of responding to each stimulus, eliminating the development of the flat gradient found in Group 3.

In days 1-3 of training, responding was high to all probe stimuli. A shallow inhibitory gradient was formed on these days as the result of a weak relaxation response to S- and the generalization of that response to the probe stimuli. In days 4-6, responding to all probe stimuli decreased as the result of an increase in the relaxation response with training. Responding to the S- probe continued to decrease in days 7-9, while responding to the other probe values remained stable. This indicates a small increase in relaxation which generalized only to the stimuli most like S- but was too weak to generalize to the other probes. Additional training after the 10-12 days had no effect on the shape of the gradient or on the number of responses to each probe stimulus.

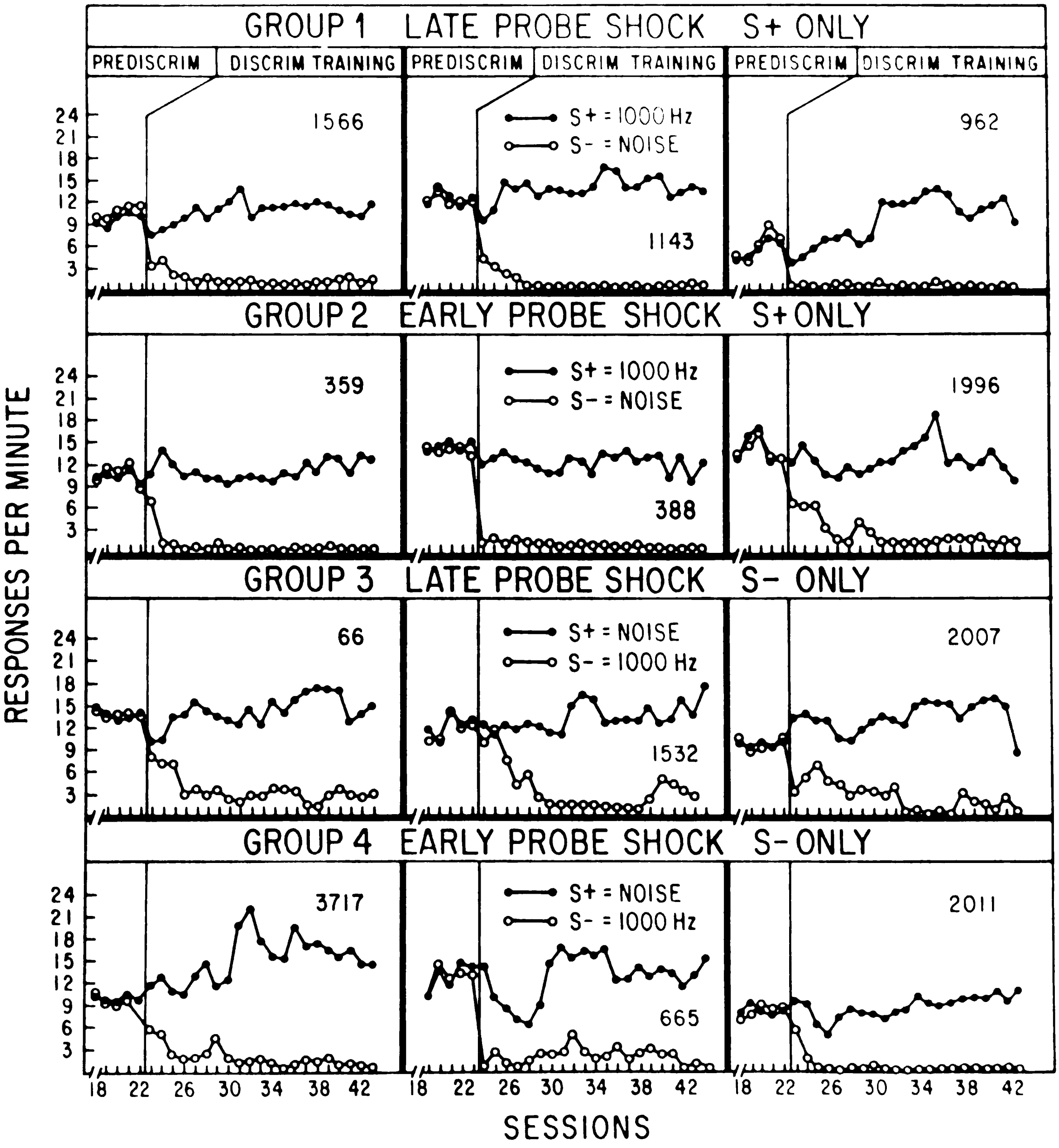
Again, the addition of probe shock early in training had no effect on the acquisition of discrimination. Only a small, non significant difference in the mean time to reach discrimination criterion existed between Groups 3 and 4. However, Groups 3 and 4 took significantly more days of training to reach discrimination than did Groups 1 and 2. This difference is explained by the amount of exposure to the S- stimulus for the different groups. In Groups 3 and 4, each subject had 30 minutes per session of S- exposure as compared to 44 minutes of S- exposure per session for Groups 1 and 2. This difference in exposure time was the result of using seven S- components as probe components for Groups 3 and 4. It took the birds in Groups 1 and 2 about seven to nine sessions to develop a stable S- response rate below one response per minute. The birds in Groups 3 and 4 needed eleven days of training to gain equal exposure to S-. This difference in exposure time caused the difference in days to discrimination criterion.

The development of inhibitory gradients shown by Group 4 is in agreement with that shown by Farthing and Hearst in the appetitive situation. Their data show the beginning of an inhibitory gradient by day 2, and a fully developed gradient by day 8 of training. Additional training had no effect on the shape of their gradient or on the number of responses to each stimulus. In addition, absolute generalization to the test stimuli was not observed in the Farthing and Hearst study. After several days of training, they found that the number of responses to all but the S- test value remained unchanged by additional training and the development of the gradient was caused by a decrease in responding to the S- test value. This is exactly what was found in the present study.

It appears, then, that the development of inhibitory gradients around the S- value in the avoidance situation parallels that in the appetitive situation. The gradients in the two situations form at the same rate and in the same manner. It is reasonable to assume that the same process is operating in both situations.

The development of the gradients in the present experiment have been interpreted in the framework of relaxation theory. Note, however, that although the present findings are consistent with relaxation theory, they do not provide strong exclusive support for that theory.

Figure 1. The last five sessions of prediscrimination training (sessions 18-22) and the formation of discrimination for Group 1 (Late probe shock S+ only), Group 2 (Early probe shock S+ only), Group 3 (Late probe shock S- only), and Group 4 (Early probe shock S- only). The solid circles show response rates during S+ and the open circles show response rates during S-.



GROUP 1 LATE PROBE SHOCK S+ ONLY
PREDISCRIM
DISCRIM TRAINING
1566
S+ = 1000 Hz
S- = NOISE
1143
962
GROUP 2 EARLY PROBE SHOCK S+ ONLY
359
S+ = 1000 Hz
S- = NOISE
388
1996
GROUP 3 LATE PROBE SHOCK S- ONLY
66
S+ = NOISE
S- = 1000 Hz
1532
2007
GROUP 4 EARLY PROBE SHOCK S- ONLY
3717
S+ = NOISE
S- = 1000 Hz
665
2011
24
21
18
15
12
9
6
3
RESPONSES PER MINUTE
18
22
26
30
34
38
42
SESSIONS

Figure 2. Group 1 (first panel), Group 2 (second panel), Group 3 (third panel), and Group 4 (fourth panel) absolute generalization gradients. Each gradient is formed by summating the responding to each tone stimulus across three days of training for the three birds in each group. The closed circles for Groups 1 and 3 indicate gradients obtained without probe shock. The open circles indicate gradients obtained with probe shock. Note that the ordinate scales for Groups 1 and 2 differ from the ordinate scales for Groups 3 and 4. The arrow indicates the S+ probe tone for Groups 1 and 2 and the S- probe tone for Groups 3 and 4.

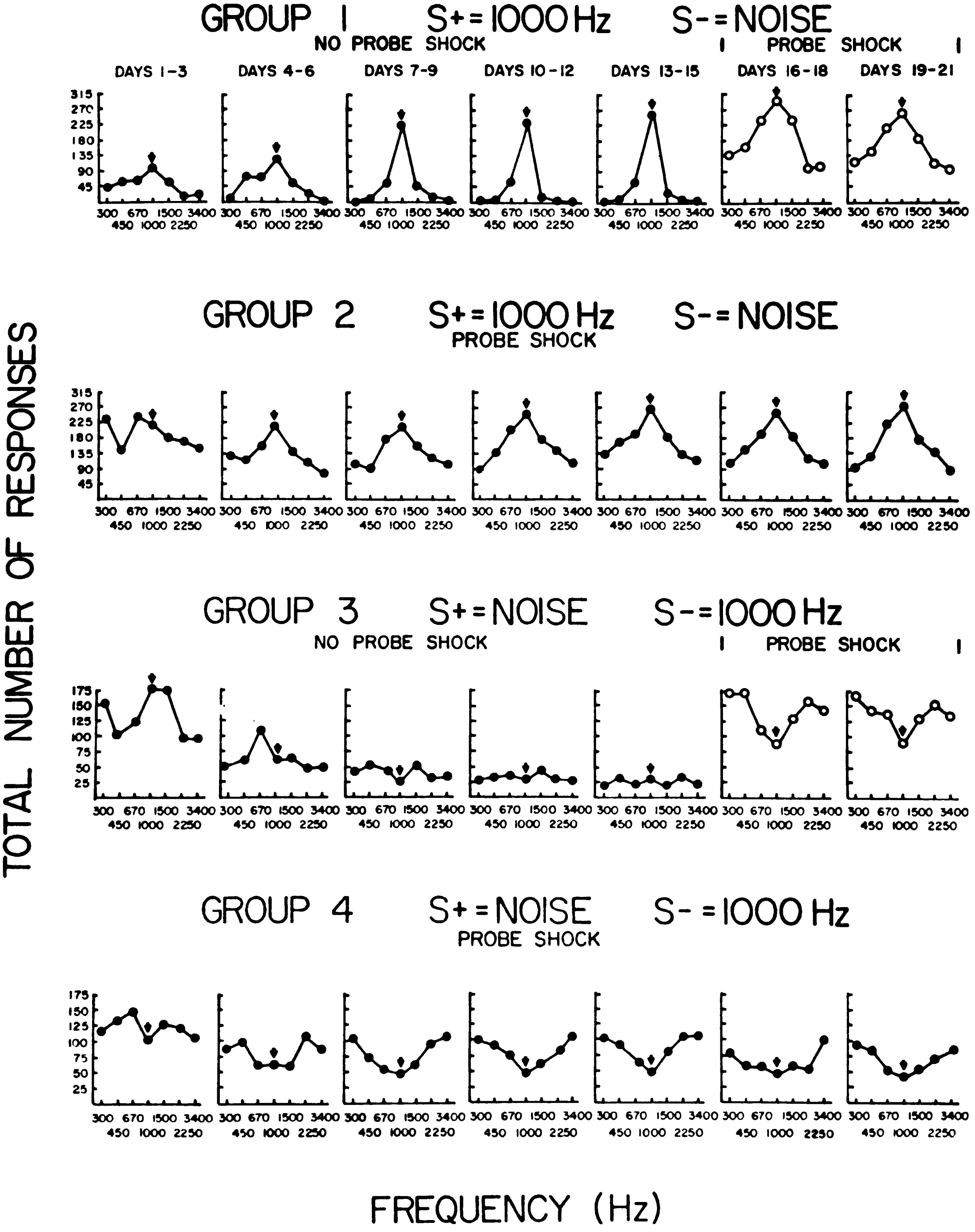

GROUP 1 S+=1000 Hz S-=NOISE
NO PROBE SHOCK
PROBE SHOCK
DAYS 1-3
DAYS 4-6
DAYS 7-9
DAYS 10-12
DAYS 13-15
DAYS 16-18
DAYS 19-21
315
270
225
180
135
90
45
300 670 1500 3400
450 1000 2250
GROUP 2 S+=1000 Hz S-=NOISE
PROBE SHOCK
GROUP 3 S+=NOISE S-=1000 Hz
NO PROBE SHOCK
PROBE SHOCK
175
150
125
100
75
50
25
GROUP 4 S+=NOISE S-=1000 Hz
PROBE SHOCK
TOTAL NUMBER OF RESPONSES
FREQUENCY (Hz)

Figure 3. Group 1 (Late probe shock S+) individual absolute gradients. The number above each gradient indicates the day of discrimination training in which that gradient was formed. The closed circles indicate gradients obtained without probe shock. The open circles indicate gradients obtained with probe shock. The arrows indicate the S+ probe tone.

Group I Late Probe Shock, S+ Only

S+ = 1000 Hz S- = NOISE

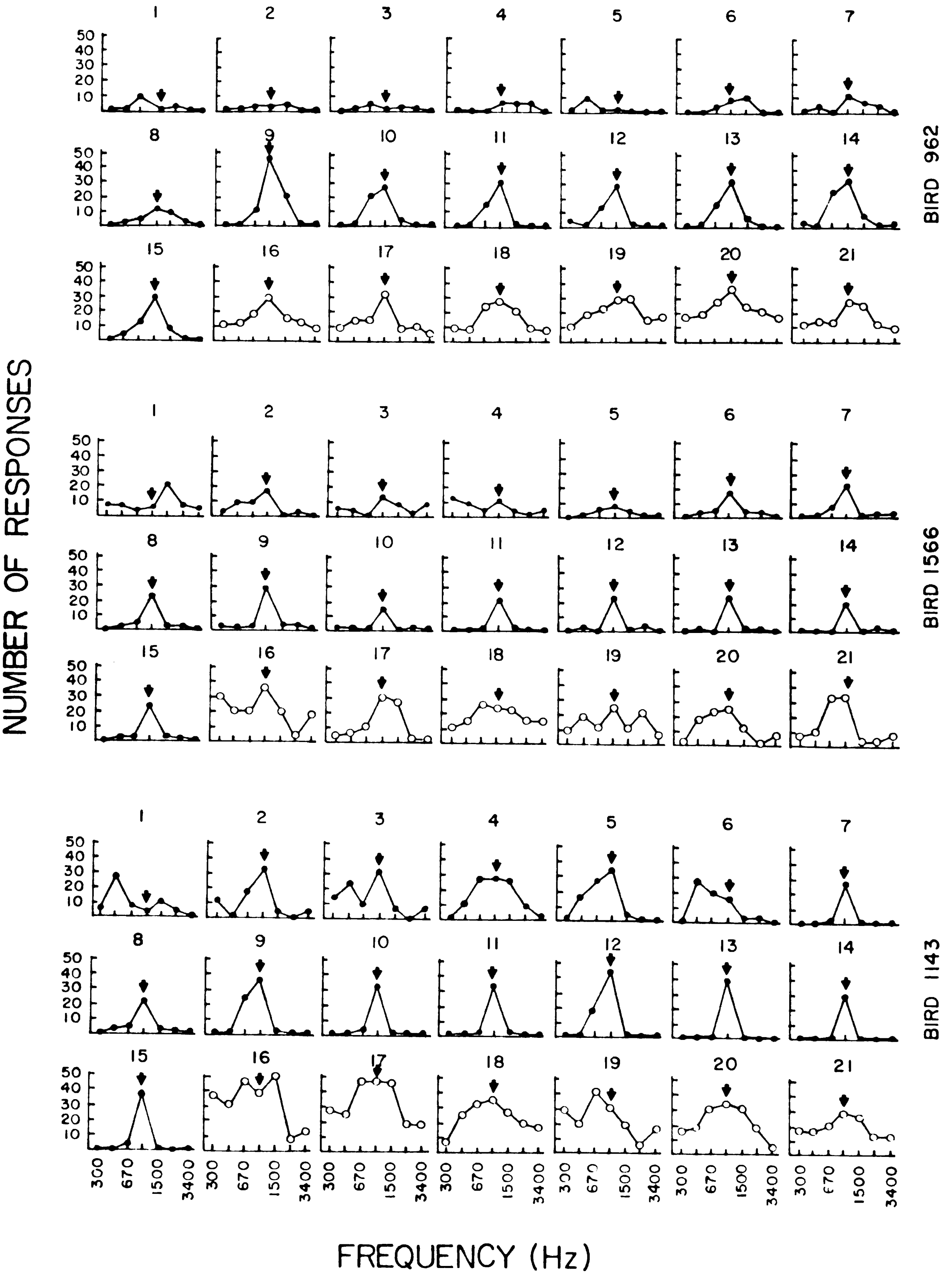


Figure 4. Group 2 (Early probe shock S+) individual absolute gradients. The number above each gradient indicates the day of discrimination training in which that gradient was formed. Probe shock was used in obtaining all gradients. The arrows indicate the S+ probe values.

Group 2 Early Probe Shock, S+ Only

S+=1000 H S- =NOISE

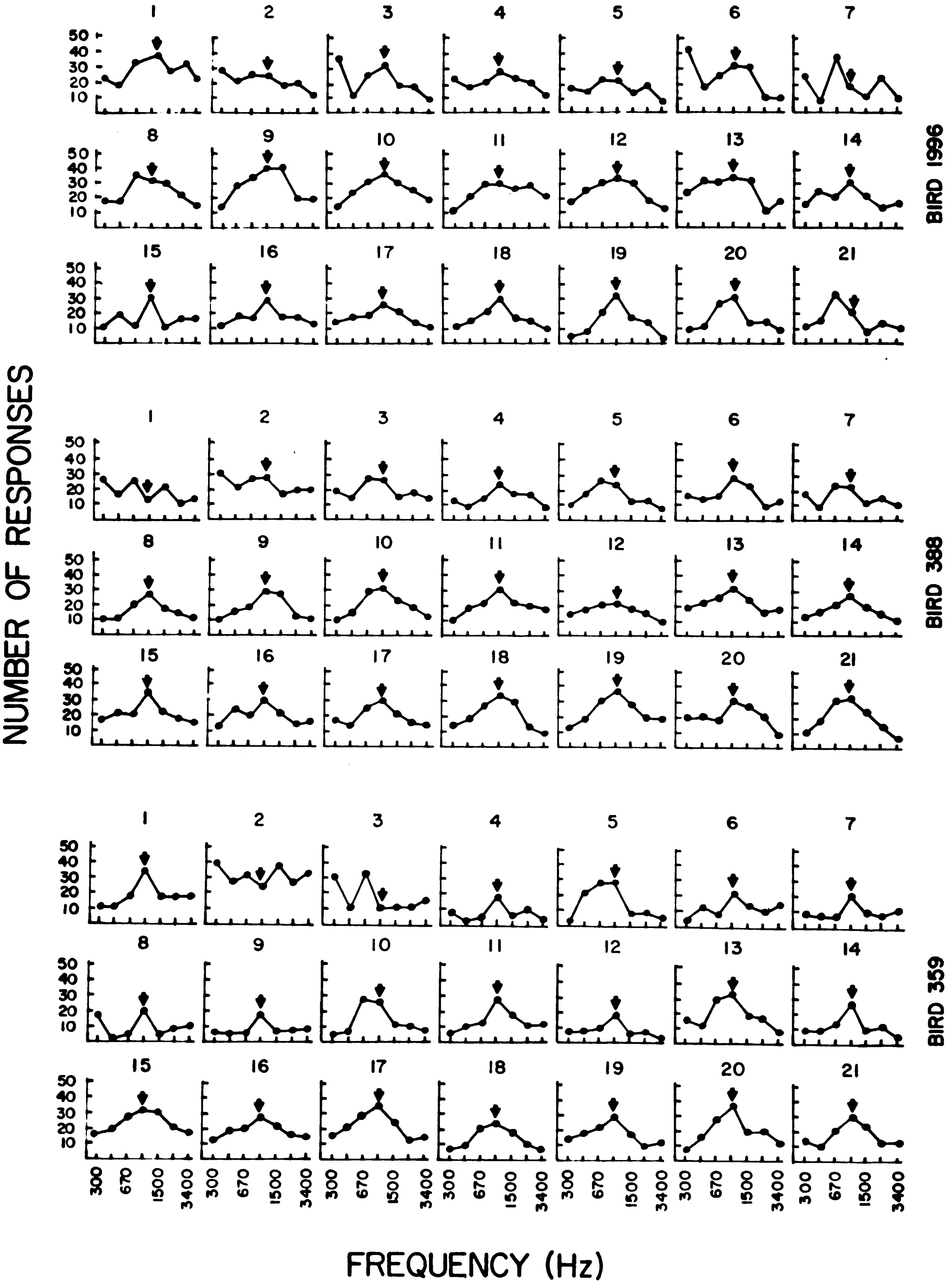


Figure 5. Group 3 (Late probe shock S-) individual absolute gradients. The number above each gradient indicates the day of discrimination training in which that gradient was formed. The closed circles indicate gradients obtained without probe shock. The open circles indicate gradients obtained with probe shock. The arrows indicate the S- probe value.

Group 3 Late Probe Shock S- Only

S+ = NOISE S- = 1000 Hz

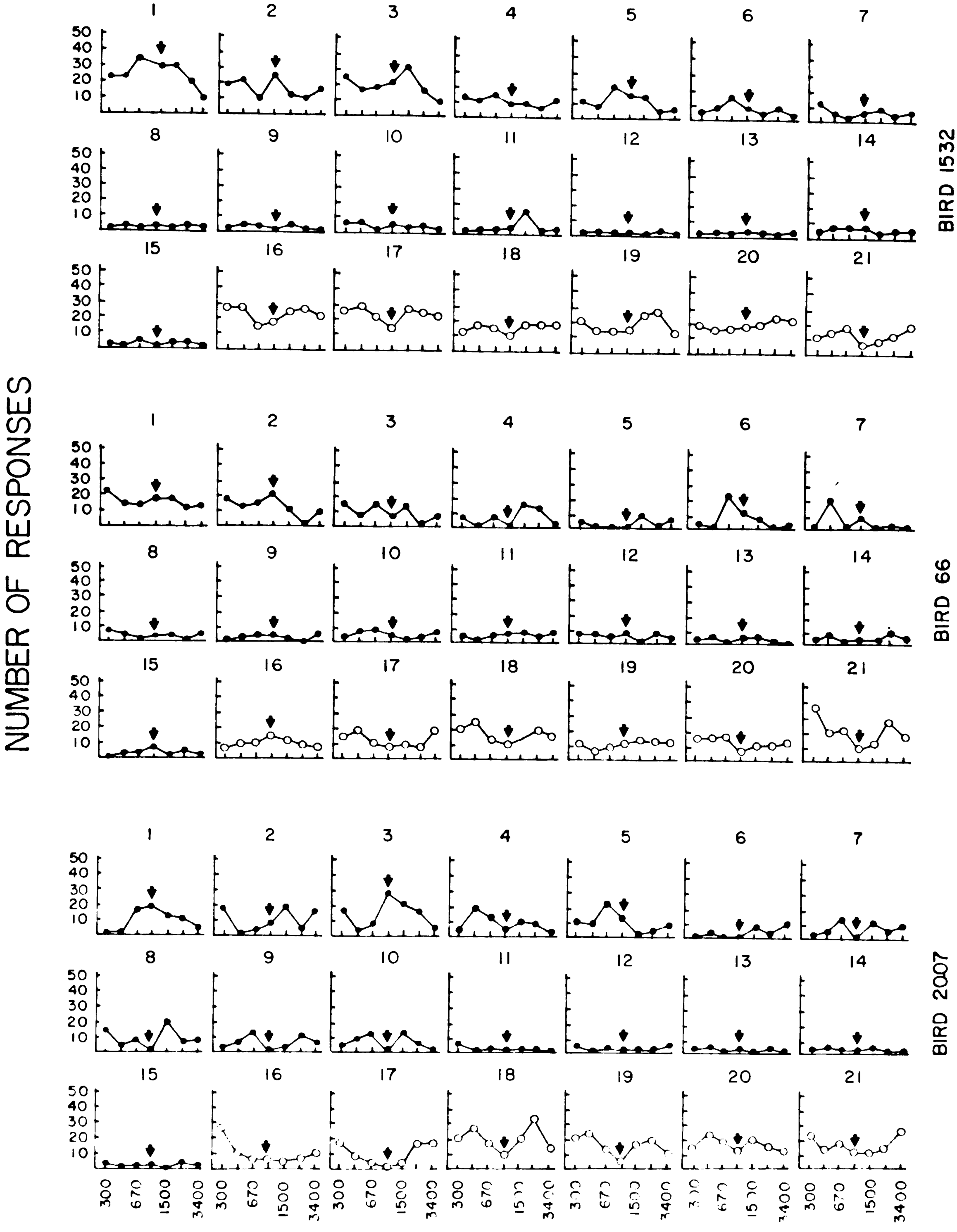


Figure 6. Group 4 (Early probe shock S-) individual absolute gradients. The number above each gradient indicates the day of discrimination training in which that gradient was formed. Probe shock was used in obtaining all gradients. The arrows indicate the S- probe value.

Group 4 Early Probe Shock S - Only

S+ = NOISE   S- = 1000 Hz

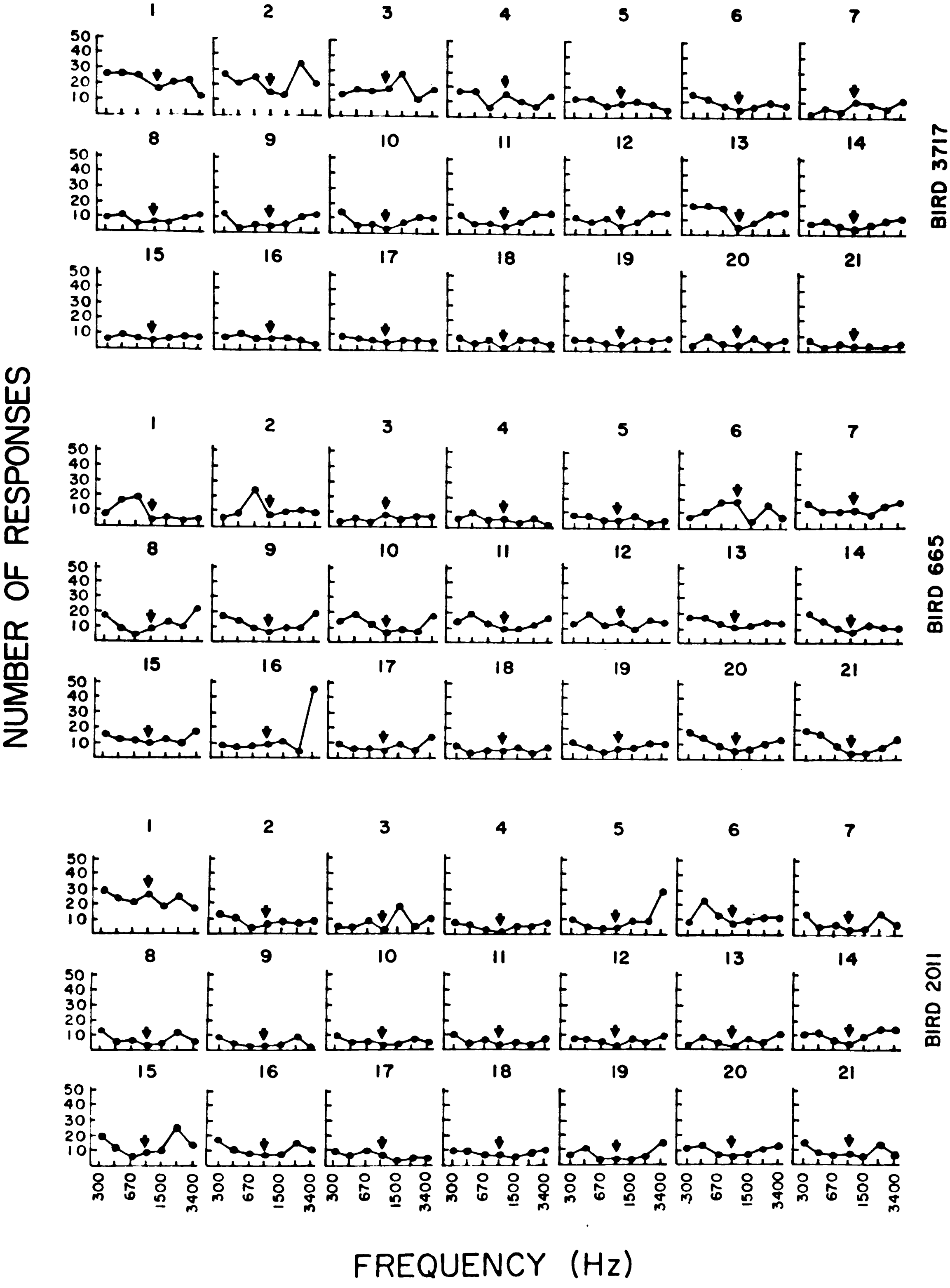
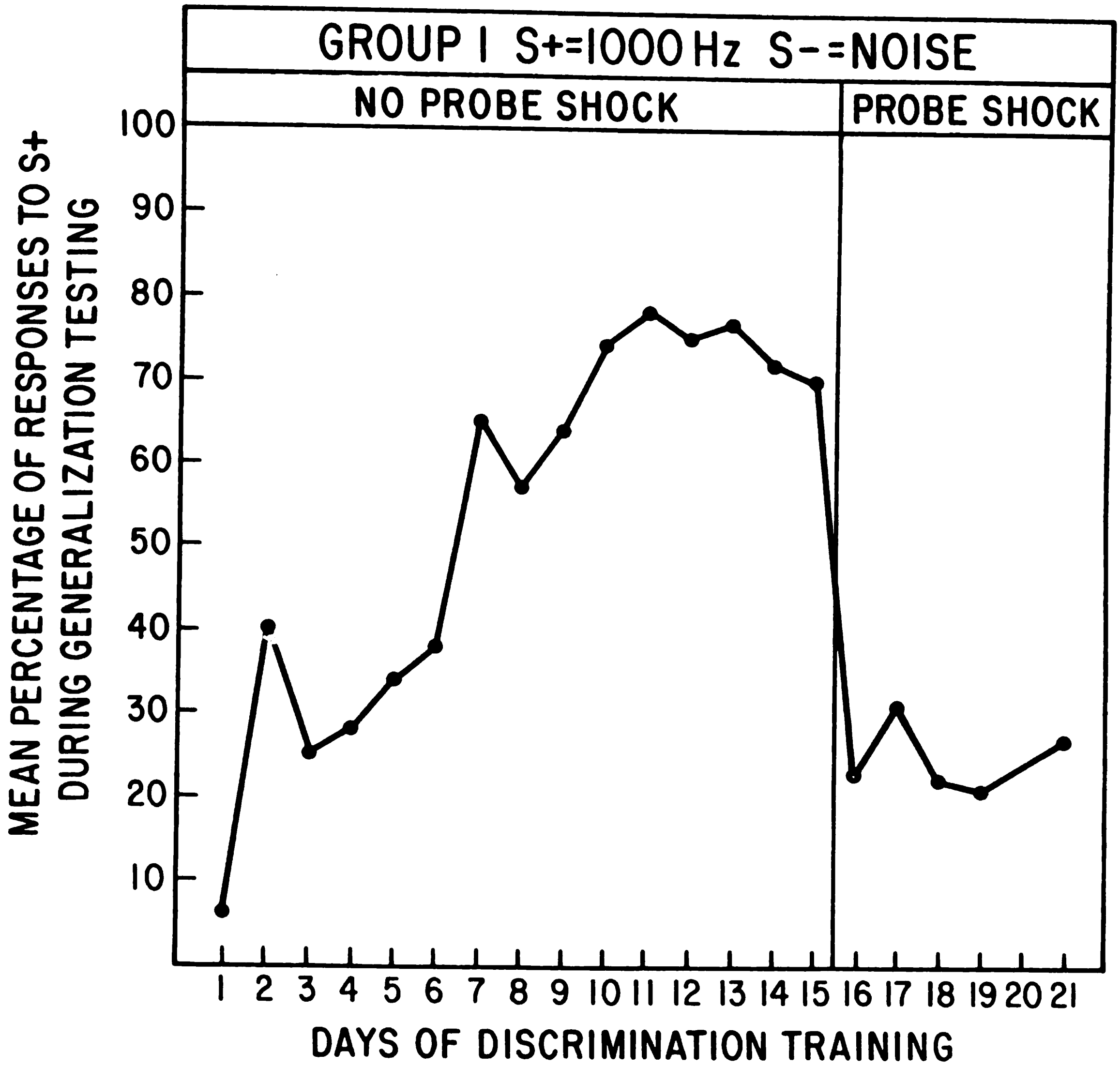


Figure 7. Mean percentage of responses to S+ during generalization testing for Group 1. The points represent the mean percentage of responses emitted by the three birds in Group 1 to the S+ probe for each day of discrimination training.


GROUP I S+=1000 Hz S-=NOISE
NO PROBE SHOCK
PROBE SHOCK
MEAN PERCENTAGE OF RESPONSES TO S+ DURING GENERALIZATION TESTING
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
DAYS OF DISCRIMINATION TRAINING

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