TACTUAL STIMULUS GENERALIZATION GRADIENTS IN THE RAT

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CHAPTER I

INTRODUCTION AND BACKGROUND

When organisms interact with their environment they are confronted with the fact that its stimulus properties are in a constant state of change. For example, if a dog is trained to come to the call of his master he must learn to respond even though the call is never reproduced in exactly the same manner. The fact that he comes, under widely divergent stimulus conditions, illustrates the fact that the exact reproduction of the stimulus condition is not necessary for an organism to behave in a consistent manner. An organism trained to respond to one stimulus or a set of stimuli will also respond in a similar way to similar stimulus conditions. The technical term for this behavioral phenomenon is stimulus generalization.

When attempting to investigate stimulus generalization one can choose between the various sense modalities and their corresponding stimuli. As will be shown later, many studies have demonstrated that stimulus generalization can be obtained using various sense modalities. The present study is directed to the question of whether stimulus generalization occurs with tactual stimuli in a free-responding operant conditioning situation. As the literature review will indicate, tactual stimulus generalization gradients have been demonstrated in classical conditioning; no information on tactual generalization gradients in operant conditioning has been reported.

Review of the Literature

The phenomenon of stimulus generalization was discovered in Pavlov's laboratory by Krasnogorsky (cf. Pavlov, 1927). The most comprehensive investigation of stimulus generalization was reported by Anrep (1923). Anrep reported stimulus generalization data from three dogs using the conditioning techniques that were developed in Pavlov's laboratory. A permanent fistula had been surgically mounted in the parotid salivary gland of Anrep's subjects (*S*s). From this fistula drops of saliva could be collected and measured. His study was designed to show that generalization of a reflex could be obtained within the same receptor using the techniques of trace conditioning of reflexes. The results showed that a response similar to but smaller in magnitude than the one elicited by the unconditioned stimulus (UCS) could also be elicited by tactual stimulation at various points along the dog's body. These responses elicited by stimuli placed at points along the body gradually diminished in magnitude the farther they were from the point originally conditioned. He also showed that this generalization existed on both sides of the animal.

To clear up criticisms of Anrep's data (e.g., Loucks, 1933), Bass and Hull (1934) conducted a well controlled classical conditioning study using human Ss. A tactual-vibratory stimulus was used as the conditioned stimulus (CS). One spot of the body of S was stimulated and paired with the UCS, electric shock, until conditioning took place, as measured by the conditioned galvanic skin response (GSR). Then three points, in addition to the one used in conditioning, were stimulated and the respective GSR measurements were taken. The result was a demonstration of a stimulus generalization gradient much like that reported by Anrep, viz., the response decreased in strength the more removed the stimuli were from the original CS.

Hovland, in a series of studies with human Ss, used a tone as a CS and a shock as a UCS to investigate some of the parameters of what he referred to as "generalization of conditioned responses." His dependent variable was the GSR measured by the method of Tarchanoff. The first two of his studies (Hovland, 1937a; 1937b) are the most relevant for the discussion at hand. At the time of the first study, no one had investigated the relationship between the magnitude of response and the distance of various test tones from the conditioned tone with respect to frequency. Hovland attempted to work with four tones that were twenty-five just noticeable differences apart in frequency. Using the Method of Limits he established the points above and below his standard tone of 1000 cycles per second. One of the two extreme tonal values was then presented to one-half of the Ss respectively and paired sixteen times with the UCS. Results obtained during the testing portion of the trials reveal a generalization gradient that was concave upward. These results concur in a general way with the Anrep and Bass-Hull gradients. The gradients showed an orderly decrease in response magnitude from the point of original stimulation, although gradients differed in several interesting ways. Both Anrep's and Bass and Hull's gradient were convex-upward, while Hovland's was concave upward. Hovland's gradient also showed a marked drop from the original point to the next one tested, similar to Anrep's, but Bass and Hull obtained only a slight drop at this point. The reason for these differences is almost impossible to determine because of the many differences in procedures. Hovland suggested that in the previous studies the subjects were given a subtle form of discrimination training which was necessary in order to maintain the response in strength. This differential reinforcement of the original response seems to be reflected in the slope of the gradient, a conclusion supported by other data that Hovland reported in the same paper.

The independent variable in Hovland's second study was the frequency of the tone that was used as the CS. To hold the effect of the intensity *per se* constant two groups of subjects were used. One group of subjects was conditioned to the strongest tone and the other to the weakest tone. Results from these two groups were pooled to determine the generalization gradient as independent of the intensity effect. Although the gradient for intensity was not as steep as the one reported for the frequency of tone, it was of the same general shape.

Another of Hovland's studies (1937c) is of direct relevance to the present study. Here he used a vibrotactual stimulus similar to the one used by Bass and Hull. In this study the UCS was shock and the response was the conditioned GSR. Half of Ss were conditioned with a weak vibrator and half with a strong vibrator. When acquisition training was completed non-reinforced testing was started with both intensities of vibration. The results showed generalization for both groups of Ss. In particular, those Ss who were trained with the weak CS gave large responses to the strong CS when first tested. On the other hand, those trained with a strong CS gave small responses when tested with the weak vibrator.

Lashley and Wade (1946) presented a serious challenge to the accepted notions of stimulus generalization as advanced by the neo-Pavlovian school. They maintained that this system was based upon two main assumptions:
(1) association by contiguity, with or without the additional assumption of the Law of Effect, and (2) the irradiation or spread of effects of training. They point out that although the Pavlovian physiological theory of irradiation and concentration of cerebral excitations has

been discarded, his followers have retained the concept of stimulus generalization as an association of the conditioned reaction with a range of stimuli beyond that used in conditioning. They concluded after conducting several studies that stimulus generalization is a failure of association and that there is no irradiation of spread of effects of training during primary conditioning. Stimulus generalization would only exist after an organism had differential training with respect to the stimuli being used. That is, if the organism had experience with only one value of a stimulus, there would be no stimulus generalization.

Seeking to determine whether stimulus generalization does exist, Razran (1949) reviewed sixty-seven studies as reported from Pavlov's laboratory, five studies coming from Yale laboratory (Hovland) using GSR conditioning on human Ss, and his own data collected on human Ss with salivation as the CR. His conclusion from the Russian literature was that "Non-conditioned generalization stimuli do evoke conditioned responses, and these responses are smaller in magnitude than those evoked by the conditioned stimuli." According to Razran, Hovland's data shows that not one of the Ss had a consistent generalization gradient, but, as previously stated, the grouped data does show the generalization gradient. Razran concluded a failure of association, as postulated by Lashley and Wade, could account for much of the reported generalization data but it did not explain all of it. Apparently for most psychologists involved in conducting research in the area of stimulus generalization, the issue of whether it existed or not appears to have been settled affirmatively by Razran's review.

A problem that has interested many investigators is that of the shape of the stimulus generalization gradient. Both Hull (1943) and Spence (1937) have made extensive deductive use of what they have assumed to be the shape of the gradient. For Spence, the gradient was symmetrical about the CS value and the concave downward. For Hull, the gradient was to be symmetrical about the CS, but the form was concave upward rather than downward, as formulated by Spence. Several of the studies that will be reported later show that the gradient has no invariant shape but that the shape is dependent upon several variables.

Some of the work that has been reported by Guttman and Kalish (1956) bears upon this issue. They were interested in testing the hypothesis that a relationship between the discriminability of spectral colors and stimulus generalization along the wave-length continuum existed. Employing free-operant techniques, four groups of six pigeons were trained to peck at a disc illuminated by monochromatic lights of 530, 550, 580, and 600 Mu. Response rates during extinction were used to plot the bidirectional gradients. As their results indicate, the assumption that there was a direct relationship between the discriminability of spectrum colors and stimulus generalization along the wave-length continuum was open to question. In fact, their data suggests that the generalization gradient and the discriminability of the stimuli might be independent. For example, when the stimulus changes from a green to a yellow the response rate to this change should be abrupt. Their data indicates this is not what occurs, instead, a gradual change in the response strength rate takes place.

Guttman and Kalish also investigated the changes in the generalization gradient accompanying the changes in response strength as measured by rate of response. A close correspondence was found between the changes in the form of the gradient during extinction and changes associated with individual differences in response strength. Their results also indicated that the individual gradients and the averaged gradients were not the same. Some of the individual gradients were bilaterally convex, some concave, and some concave on one side and convex on the other. They concluded that the linearity observed over the central range of the averaged curve may well be the result of a random distribution of concavities and convexities. They also reported that the gradient became flatter as extinction progressed.

As mentioned before, Hull (1943) assumed a symmetrically shaped stimulus generalization gradient. In addition to assuming this, he postulated that if there were overlapping gradients they would summate in an exponential manner to yield a gradient of greater response strength. To test this notion Kalish and Guttman (1957) conducted a study with twenty-two pigeons in a free-operant situation. Using variable interval reinforcement (VI) three groups of subjects were trained to peck at a disc. One group was trained at 540 and 550 Mu, another at 530 and 560 Mu, and the third at 520 and 570 Mu. The generalization testing was conducted during extinction using values of test stimuli from 500 to 590 Mu. Their results indicated that the gradients obtained in this manner were basically consistent with those resulting from training to a single stimulus. In other words, training involving two discriminative stimuli result in gradients that appear similar to those in which only one stimulus is used in training. According to the authors, the results can be explained by either the summation or nonsummation hypothesis. They suggest that in order to test the notion of summation in a more adequate manner another study should be conducted. In this suggested study three training stimuli would be used, spaced approximately ten millimicrons apart in order to provide a sufficient degree of double overlap.

In another study Guttman and Kalish (1958) further investigated the relationship between discriminability and generalization. Again pigeons were used as subjects and were trained on one wave-length value of a visual stimulus but tested on ten or twelve different wave-lengths. Once again the results indicated that generalization and discrimination may not be opposites. If they were, one would expect that as the stimulus changed color over the test values used the birds performance would change abruptly. However, this is not what happened. The curve of responding was quite orderly with the training stimuli giving the highest rates and decreasing at more distant values.

Because the animal data gathered by Guttman and Kalish over several studies conflicted with the general notions about the nature of the discriminability of a stimulus and generalization, Kalish (1958) decided to conduct a study using human subjects to see if the animal data could be replicated. Prior to the study he had other subjects judge stimuli using the Method of Single Stimuli. With this method the judges reported whether or not the stimulus that was currently being presented was different from the one that they had seen and been instructed to use as a standard. This preliminary work gave him four values above and below the standard value which were one just noticeable difference apart. The subjects in the experiment were instructed to release a telegraph key whenever the stimulus presented was different from the standard. Releasing the key turned off the stimulus light. The results conflict with those presented for animals, but were in agreement with the notion that the discriminability is the inverse of generalization. Kalish assumed that the major difference between generalization and discrimination centers around the use of differential reinforcement during training, which, of course, revives the issues raised by Lashley and Wade.

What can be made of these results is not clear. Kalish suggests that the differences in procedure may well account for the discrepancies in the two sets of data; when a discriminability function is generated the procedures are different from those used when a generalization gradient is produced. It is the author's opinion that the procedural differences between the animal and human research could well account for the differences in the data. One gross difference immediately apparent is that Kalish's subjects were not reinforced for one value of the stimulus and then tested during extinction, as in many animal studies. Since humans follow directions, the training procedure is usually omitted and the subjects are simply instructed to respond. In the present case they were told not to respond when the stimulus was different from the original one. Once again, given this type of instruction, humans would be expected to show much narrower generalization gradients, as they did in this experiment.

After Guttman and Kalish demonstrated that the phenomena of stimulus generalization could be studied using the free-operant situation, and, with these techniques, the gradient could be studied in single organisms, research trend was started in a direction away from theory testing to empirical study of the variables that determine the form of the gradient. Pierrel (1958), working with auditory stimulation and using the rat as a subject, investigated the effects of continued discrimination training and changes in the gradient due to extinction. After being trained to lever press on a VI schedule with a 59 second mean, her rats were exposed to variable periods of S^D and S with high and low auditory intensities (separated by 40 db) associated with either stimulus condition. An S^D is a stimulus correlated with reinforcement; an S is a stimulus correlated with nonreinforcement. For half of the animals the high intensity was the S^D and for the other half the low intensity was the S^D. This procedure was continued for six weeks until a stable ratio between responses in S^D and S was obtained. At this point the procedure was changed in such a way that during the S^D periods the conditions were the same as before, but three additional S stimuli were presented. These stimuli were 10, 20, and 30 decibels removed from the S^D. This procedure was continued for 18 days until stable performance was obtained. At the end of this time, 12 days of extinction was started.

Data obtained in the second phase of discrimination training produces gradients that are quite similar to those that have been reported by Hovland. That is, they are concave upward and decrease rapidly from the point of the original S^D to the nearest stimulus, 10 decibels away. The gradients fit a hyperbolic function. Individual animals show the same type of decline as found in the grouped data. Rates during extinction systematically declined over time; The gradient held as long as the response rate remained above zero, although as extinction progressed it became flatter.

Again, being interested in determining the variables that are responsible for the shape of the gradient, Thomas, Ost, and Thomas (1960) sought to investigate the effect of a time interval between the training and testing procedure on the gradient. In addition, the investigators were interested in the retention of a discrimination as reflected in the stimulus generalization gradient. They thought that the peak shift could be reversed as the strength of the discrimination decreased.

Training procedures resulted in the subjects (pigeons) learning the discrimination between a stimulus of 550 millimicrons as the positive stimulus and 570 millimicrons as the negative stimulus, while the rate of response was being maintained on a VI 1 minute schedule. A 10 second time out was used between stimulus presentations. The stimuli were present for 60 second intervals. This training was continued until there were five successive S periods without a response. At this point Ss were divided into three groups. Groups 1, 2, and 3, were tested at one day, seven days, and twenty days respectively. Testing was carried out during extinction with the stimuli being present for 30 seconds with a 10 second time out in between presentations. The 11 test stimuli ranged from 490 Mu to 610 Mu in 10 Mu steps, omitting 500 and 600 Mu. Once the generalization testing was completed Groups 2 and 3 were retrained under conditions similar to the original training. This retraining was conducted to give an indication of the extent of retention of the discrimination.

For all three groups the results show the usual peak shift away from the negative stimulus. Conditioned discrimination appears to be well retained over the period of twenty-one days, since the curve for this group is virtually the same as for the other two groups. The difference in retraining time that was necessary to bring groups 2 and 3 to the original criterion was insignificant. This again shows that the discrimination is not seriously affected by the passage of time. Of course, since the discrimination was not affected by the passage of time, the peak shift was likewise not affected.

This review of the literature has not included many of the investigations that have been conducted in the area of stimulus generalization. What has been attempted here is a general survey of the history related to the demonstration of the phenomena. What can be seen in this review is a trend away from the theoretical issues that prompted the early work, to the collection of data that reveals the relationships between crucial variables and the generalization gradient. There has been a great deal of classical conditioning research using auditory, visual, and tactual stimuli. Both auditory and visual stimuli have been used extensively in free-operant research, but the tactual stimulus dimension has been neglected. In the research that will follow an attempt will be made to show that tactual stimuli can be utilized in the free-operant setting and that stimulus generalization gradients can be produced using the rat as a subject.

CHAPTER II

EXPERIMENTAL PROCEDURE

From previous studies it is evident that tactual stimuli affect the behavior of human and animal Ss in classical conditioning studies in much the same manner as auditory and visual stimuli in an operant conditioning situation. However, the question remains as to whether tactual stimuli can be utilized to demonstrate stimulus generalization using operant techniques with rats.

The problem specifically is this: Can rats be trained in a free-operant settling to respond to tactual stimuli in such a way as to demonstrate the phenomena of stimulus generalization? If so, do these gradients have properties in common with those gradients that have been obtained using other sense modalities?

Subjects

Forty hooded male rats, experimentally naive with respect to a free-operant situation, were obtained from the Psychology Department's colony at Oklahoma State University. Before the training sessions started, it was decided that only 35 animals would be used (5 groups of 7 animals each). Therefore, on the final day of successive approximation training 5 animals were dropped from the study. Of these 5 that were eliminated, 3 never pressed the bar during training and the other 2 were exceptionally slow responders.

Apparatus

The basic component used in this study was a modified operant conditioning apparatus, Scientific Prototype Model A-102. The modifications were as follows: (1) the chamber was placed inside of a large plywood box which was sound attenuated; (2) mounted in the wall of this outside housing was a blower which provided constantly circulating air and also partially masked noises from the programing and recording equipment; (3) illumination was provided by two 40 watt bulbs located outside the chamber, 8 in. from the food cup and 6 in. apart. The signal light in the chamber was on continuously. Located 12 in. above the chamber was a one-way window which permitted observation of the animals during the period of successive approximation training. Two counters were used to record the number of responses per session and the number of reinforcements that were delivered per session. A cumulative recorder was also used. A tape programed timer was used to establish the reinforcement contingencies. The film strips, which moved at the rate of 1 mm/sec., were punched in an arithmetic series as described by Ferster and Skinner (1957). Mean intervals used were 3 sec, 5 sec, 10 sec, and 30 sec.

Procedure

The Ss were housed initially in wooden boxes. These home cages were painted a flat gray and had hardware cloth floors. Each box was divided into two equal sections and 4 Ss were housed in each section. One week prior to the experiment the Ss were transferred to cage banks where they remained for the duration of the study. They were also randomly divided into pairs at this time.

All Ss were given one hour of box adaptation while being maintained on a free feeding schedule, during which time 10 45 mg Noyes pellets were dispensed at random intervals. The Ss were then deprived of food for 24 hours and placed in the chamber for 30 min. During this time 15 pellets were available in the food cup. When S was placed in the chamber, the magazine was sounded after 5 min. had passed and 5 min. before the end of the half hour. On the following day each S's response was shaped by E using successive approximation procedures. The duration of all sessions was one-half hour. As Ss learned to bar-press they were allowed to remain in the box under conditions of continuous reinforcement for the remainder of the half hour. This procedure was continued for 3 additional days.

The training phase being completed, all Ss were placed on two weeks of free feeding before the initiation of the experiment. At the end of two weeks all Ss were deprived of food for 24 hours. They were then run in the following sessions respectively: two sessions of continuous reinforcement, one of VI 3 sec, one of VI 5 sec, four of VI 10 sec, one of VI 20 sec, and five of VI 30 sec. Each session was followed by one hour of free feeding with Purina dog food. On the second day of VI 30 sec the 100 grade sandpaper was attached to the lever and remained in effect through the extinction trials.

After four days exposure to the 100 grade sandpaper extinction was begun. When extinction trials were initiated, the Ss were divided into groups. Membership in these groups was determined by S's performance during the four preceding days of training with sandpaper. Each group was extinguished with one of the sandpaper grades; extinction sessions were run for 8 days.

The Ss were placed into the five groups such that the average response rate for each group was about the same. The range of the groups average rate of response was from 617 to 629 responses per half-hour. Once the five groups were formed, the groups were randomly assigned to their treatment level.

CHAPTER III

RESULTS AND DISCUSSION

The extinction data are presented in Figure 1. All groups show the same general decline in response rate over the eight days of extinction. Some of the discrepancies from this orderly decline will be discussed. For example, it will be noted that the 150 group started with a greater mean number of responses on the first day of extinction and, in general, maintained this position throughout the next seven days. Two exceptions to this can bee seen on Days 5 and 7, although it is clear that the reversals are not the result of a decrease in rate of the 150 group.

The mean rate of response for the eight days of extinction for the five groups is shown in Figure 2. This figure is almost the inverse of what might be expected for a bidirectional gradient with the training stimulus value at 100. Two exceptions to the inversion are seen in the 60 and 120 groups. What would normally be expected is that that 100 group would be the most resistant to extinction and consequently have the largest mean response rate. In addition, the gradient should decline as the stimuli become more removed from this value. Of the four data points only the 120 group shows this type of relationship to the 100

FIGURE I

DAYS BY TREATMENTS

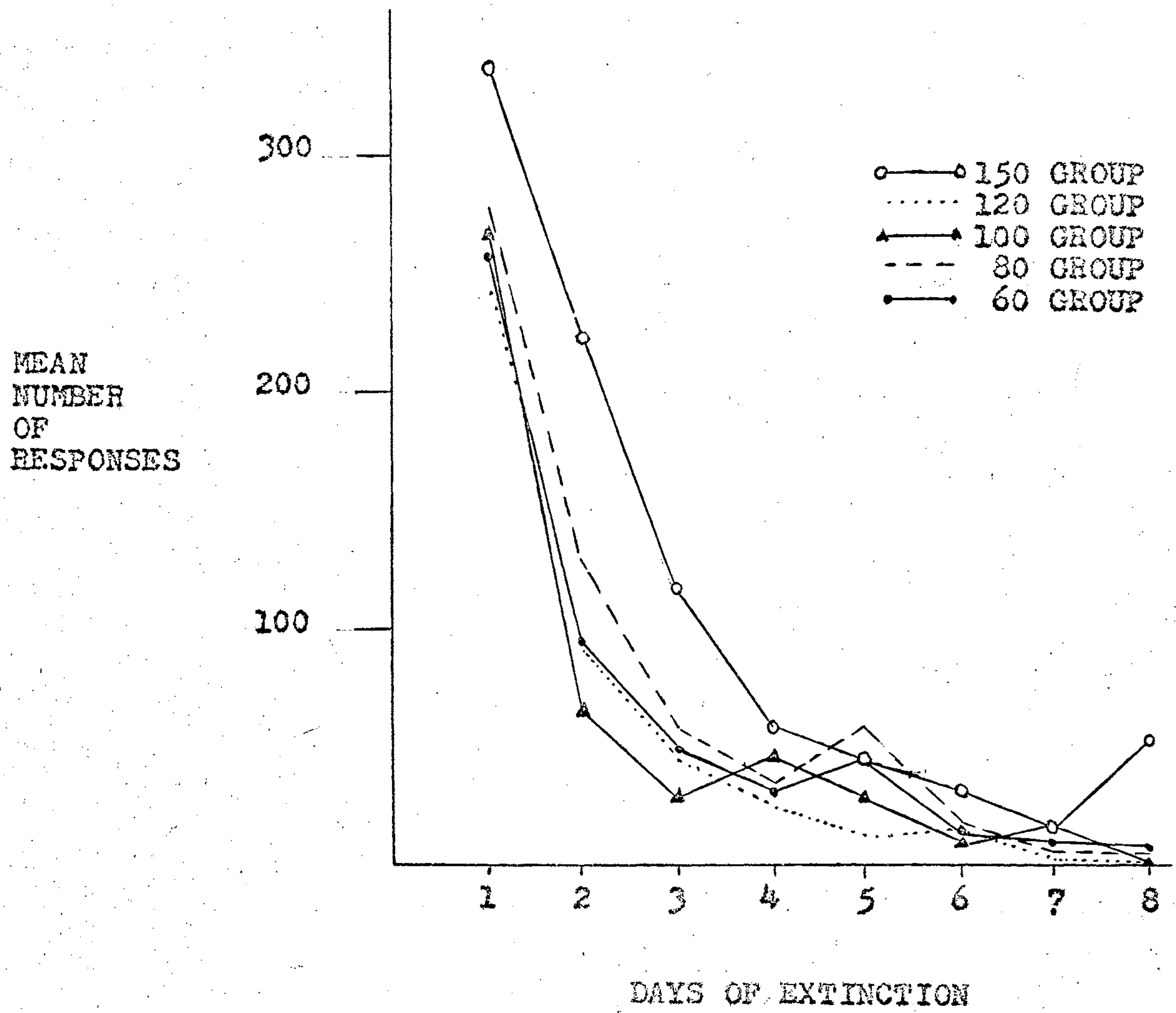
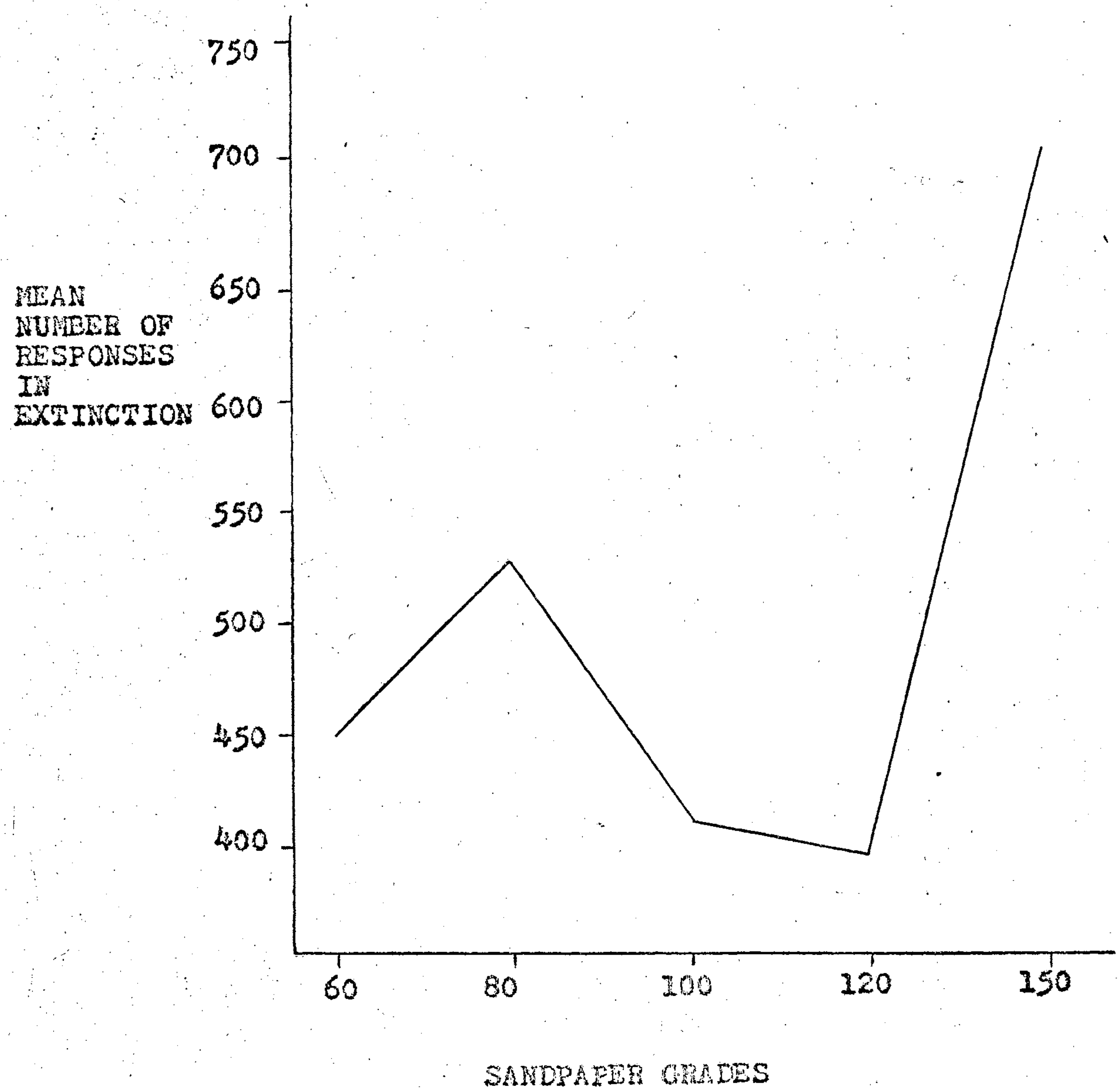


FIGURE II

GENERALIZATION GRADIENT



group. Before discussing the possible causes for this finding the data will be examined statistically.

A summary of the statistical analysis of the extinction data is found in Table I. As can be seen, the mean square for day is significant (P .01) with 7 and 210 d. f. This reflects the extinction trend over days.

TABLE I

ANALYSIS OF VARIANCE

Source	d.f	Sum of Squares	Mean Square	F
Treatments	4	74,588.0	18,647.0	1.18
Error (a)	30	471,474.0	15,715.0	
Days	7	1,917,360.0	273,909.0	88.0**
Days X Trials	28	52,467.0	1,873.0	1.0
Error (b)	210	653,179.0	3,110.0	
Total	279	3,169,068.0		

**Significant beyond the .01 level.

The treatment effect, grades of sandpaper, does not reach significance, nor is there is a significant interaction of treatments and days. Because the mean square for treatments is not significant, one is led to the conclusion that the treatments did not have a differential effect. As can be seen in Figure 2, the gradient that was obtained was essentially uninterpretable in terms of the stimulus dimension used. The present data cannot be attributed to the effects of intermittent reinforcement because, as was shown in Chapter I, many studies have been conducted using this procedure and have obtained generalization gradients for groups of subjects as well as individual subjects.

Much of the slight irregularity that is to be found in the extinction curves for the different groups was caused by the chewing responses of the animals. Although chewing is not an unusual response during extinction, in this case the animals would chew on the abrasive until part of it came loose from the lever. Several of the animals were observed to bite down on this loose piece and pull vigorously for a few seconds. During these brief pulling and chewing periods the rate would be high.

The major defect in the study is the delayed introduction of the sandpaper into the operant training. There is no assurance that the 100 grade sandpaper introduced this late in training ever functioned as a discriminative stimulus and exerted any control of the bar pressing behavior. Had a no sandpaper control group been employed the extent to which the sandpaper actually controlled response rate would have been known. One may speculate that the apparently superior performance of the rats extinguished with the 150 grade sandpaper, a very smooth grade, is due to decremental performance factors associated with the coarser grades of sandpaper. A more remote possibility is that their higher rate reflects greater generalization from the training conditions which obtained prior to the introduction of sandpaper to the generalization test conditions. Certainly the subjects performing with this very smooth grade of sandpaper were not in a situation much different from that they had been in before their four days of exposure to the 100 grade.

Considering these and other difficulties, no argument will be offered to support the notion that the data in Figure 2 represent a true stimulus generalization gradient. What is needed is a second study in which these problems are overcome or controlled. In the second study this has been attempted.

CHAPTER IV

EXPERIMENT II

The data of Experiment I did not demonstrate clearly that stimulus generalization gradients could be obtained using tactual stimuli. In view of the generality of the generalization phenomena, a further study was conducted, using a somewhat different methodological approach. In this study animals were given discrimination training with tactual stimuli before generalization tests were made and the generalization tests, were conducted under continued intermittent reinforcement rather than extinction. The procedure is described in detail below.

Subjects

Two female albino Sprague-Dawley rats were used as *Ss*. Both of these animals had previous laboratory experience in which the nose lever response was shaped and maintained with food reinforcement. A detailed description of the training experiences of these animals can be found in Michael's (1963) laboratory manual. The *Ss* were maintained at approximately 85% of their free-feeding weight for the entire study.

Apparatus

Initially, Ss were trained in a cylindrical, clear plastic chamber of the type (Davis Scientific Instruments) used in the introductory laboratory course at Arizona State University. A feeder cup and nose lever (Crossman, 1963) were mounted on the inside of the chamber, and a 15 watt bulb was located over the top of the chamber. Immediately below the lever there was a 3 in. x 3 in. rectangular hole in the metal floor under which a sheet of sandpaper was placed in such a way that the animal had to stand on the sandpaper while operating the lever. Later a metal ice chest chamber was used to obtain better control of extraneous sounds. In this chamber there was a feeder cup, a nose lever, and a false floor of fiber-board with a rectangular hole 2 in. x 6 in. Under this false floor sandpaper was placed in such a way that S had to stand on the surface of the paper in order to operate the lever. The placement of the sandpaper under the floor in such a way that no paper edges were exposed effectively prevented the animals from chewing the paper, one of the problems encountered in Experiment I.

Four grades of sandpaper were used as tactual stimuli during the testing portion of this experiment: they were 36, 50, 100, and 220. The sandpaper was manufactured and graded by the Minnesota Mining and Manufacturing Company, St. Paul, Minnesota. Grade 36 was quite rough and the

220 grade was a smooth finishing paper. Both the 36 and the 220 grades were used in the discrimination training. A masking noise was used to signal the start of a trial and its termination. The ice chest chamber 10 in. x 10 in. x 12 in. was placed inside of a freezer chest in order to assure better sound attenuation. No lights were available for S in either the chamber or the freezer. The recording and controlling equipment were located beside the freezer.

Procedure

Because Ss had previous laboratory experience the nose lever response did not have to be shaped. Therefore, they were placed on their respective VI schedules, and exposed to the corresponding grade of sandpaper without any preliminary training. For Animal #62, the roughest grade of paper (36) was always paired with the VI 30 sec schedule, and the finest grade (220) with the VI 3 min schedule. This condition was reversed for Animal #47. These conditions were in effect until the time of testing when all grades were paired with the VI 3 min schedule. During testing the VI 3 min schedule was used rather than an extinction schedule in order to maintain the response rate for a longer period of time.

The training procedure was carried out for 18 sessions in the cylindrical, plastic chamber, but after that time the animals were run in the freezer. This change of procedure was necessary because the noises produced by the equipment were disrupting the behavior and also providing cues with respect to the availability of a reinforcer. Both of these problems were overcome when the ice chest chamber was used in the freezer chest.

During each session the Ss were given 4 trials with one stimulus present and its corresponding schedule, and 4 under the other condition. These trials, each 5 min. in length, were randomly presented with the restriction that no more than two trials in a row could be the same. There was a 1 min intertrial interval during which time S was placed in a retaining cage and E changed the sandpaper. The paper was changed on each trial even if the same grade was being used again. This procedure was followed in an effort to eliminate any cues that might be available on the sandpaper from trial to trial. Both of the Ss adapted to the handling very early in the study and would begin responding immediately when returned to the chamber.

When the Ss had learned the schedule-sandpaper discrimination, stimulus generalization testing was begun. The criterion for discrimination was the S's performance was consistent with the current schedule and sandpaper and that the performance remained relatively consistent during the trial. Once this criterion had been obtained, two additional grades of paper were introduced. For both of Ss all grades were now being paired with the VI 3 min schedule. An exception to this condition will be noted in Figure 4 on the first trial. On this trial both Ss were exposed to VI 30 sec with their appropriate grade of sandpaper. This procedure was used to over come the slow warm-up that usually took place in the first period. After the first day of testing all trials were run with the VI 3 min schedule in effect. This last procedure was continued for 6 days.

Results and Discussion

The cumulative records in Figure 3 show the typical performance before the test periods. As can be seen, the rate of response is under the control of the tactual stimulus. For example, at A no reinforcements have been presented for a relatively long period of time but the rate is still much higher than if S were on the VI 3 min schedule. The rates during the VI 3 min show the reverse, as at point B, where the reinforcement occurred early, and yet, the response rate still remains below that of the VI 30 sec performance.

The first day of testing can be seen in Figure 4. These cumulative response curves show that response rate is still being controlled by the tactual stimuli, even though the schedule had been changed to VI 3 min for all grades of sandpaper. In this same figure it can be seen that as the grade of paper is changed the rate changes in a direction that would indicate stimulus generalization. For example, if the rate is high on the 220 grade, the 100 grade still maintains a high rate of response, but not as high as the 220 grade. The 50 grade controls a response rate that is not as low as the 36 grade, but not as high as the 100 grade. The animal that had 36 as the discriminative stimulus for high rates shows just the reverse of this rate and grade relationship. In Figure 5 the average performance of each animal over six days is plotted. This figure shows that the tactual stimulus generalization gradient is present, even though it has become flattened due to the extended amount of time the animals had been exposed to the VI 3 min schedule. For both Ss a gradient of stimulus generalization was reproduced on successive days indicating that data from the tactual stimulus dimension coincides with the data that have been collected on other sense modalities.

A gradient that declines as the graded distance increases away from the stimulus that was associated with the more frequent reinforcement was displayed by both animals. The fact that #47, while trained with the smoothest sandpaper on the VI 30 sec schedule, had a higher response rate than #62 on the same schedule, but rough sandpaper, is suggestive of an intensity effect, but may only be a reflection of individual differences. This intensity effect is summarized by Mednick and Freedman (1960) in their review article. They concluded that when trained with a high intensity the slope of the generalization gradient will be greater than the low intensity trained S. One might conclude that the grade used with the VI 30 sec schedule constituted the training stimulus and,

FIGURE III.

TYPICAL PERFORMANCE BEFORE
TEST PERIODS

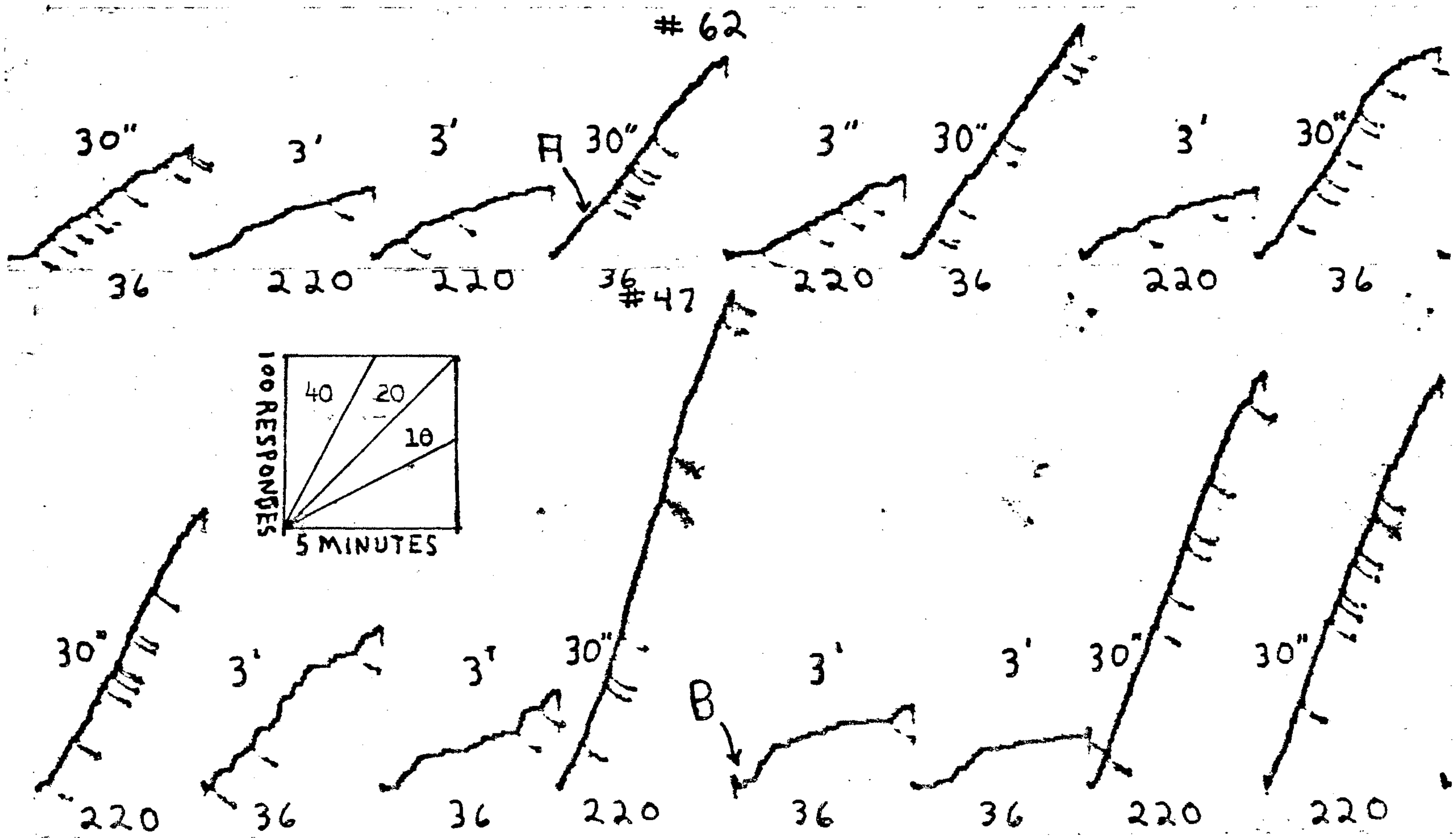


FIGURE IV.

FIRST DAY OF TESTING

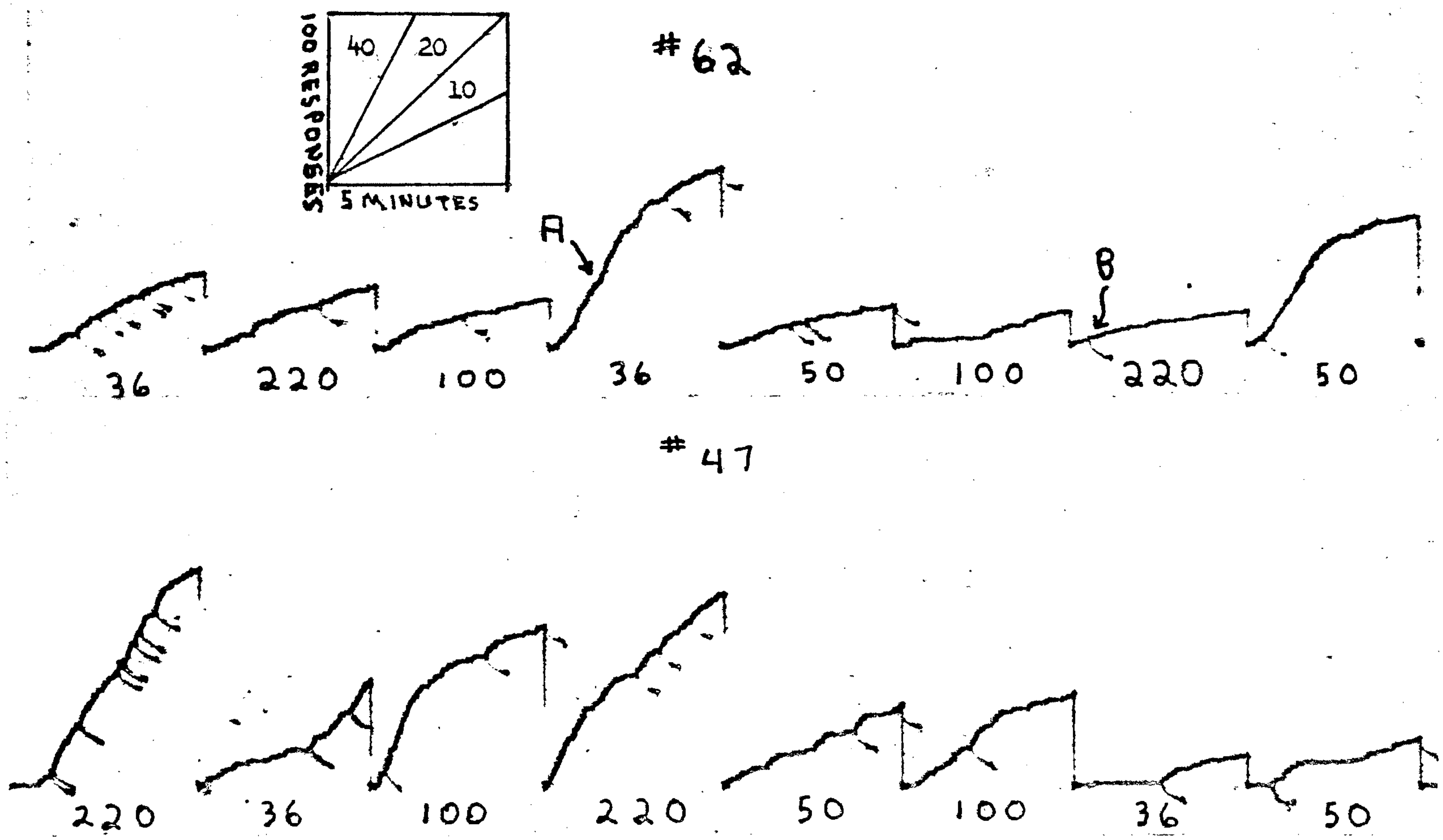
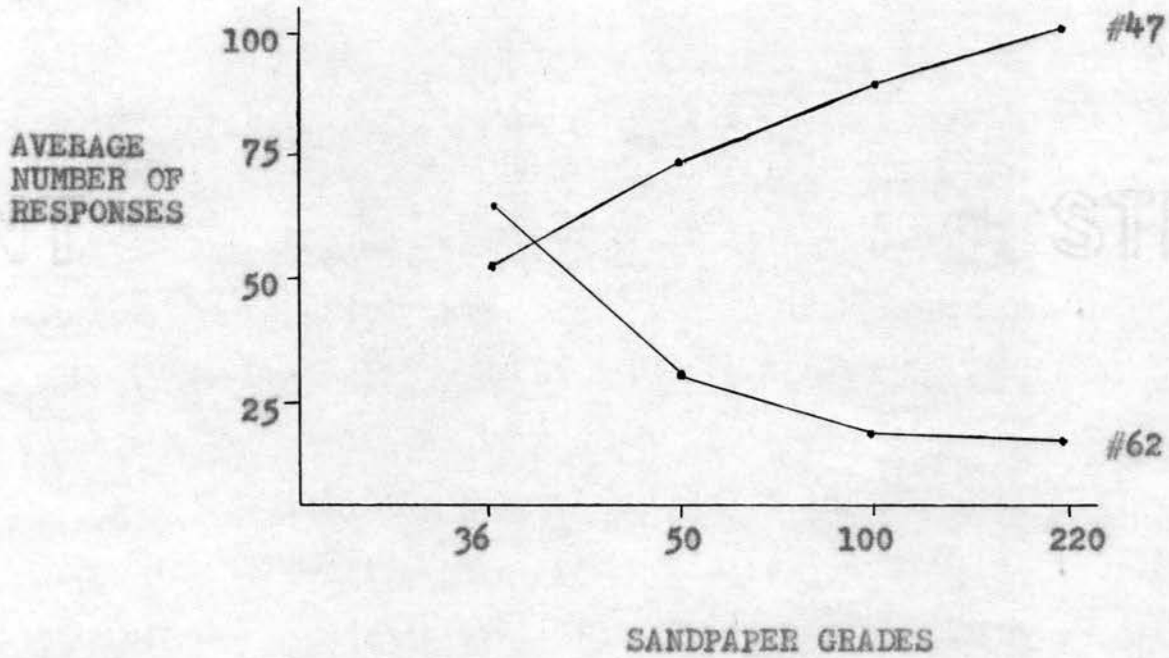


FIGURE V



therefore, these results are in accord with the general findings. But to draw a parallel between grades of sand-paper and the physical dimensions of a stimulus (intensity) would be unwarranted at this time. Intensities of stimuli are frequently expressed as a ratio; that is, so much of a quantity per unit of time or area. Tactual intensity in the present situation would be impossible to specify without further research. At least, two parameters are involved here, and they are the gradient of indentation of the surface of the paw and the number of places being stimulated. When the animal is standing still on the sandpaper, it seems reasonable to assume that the rough paper stimulates fewer points that the smooth, but produces a steeper gradient at those points being stimulated. These effects work in opposite directions rendering an intensity comparison of the rough and smooth papers quite difficult. When the effects of moving the skin over the paper are added, as they must be, the complexity is further increased. The use of stimulus generalization gradients, as in the present study, provides a possible empirical approach to this problem.

CHAPTER V

SUMMARY AND CONCLUSIONS

Two studies were conducted in an attempt to demonstrate that tactual stimulus generalization gradients could be obtained using an operant conditioning situation with rats as subjects. In Experiment I 35 animals were trained to lever press with food reward being presented on an intermittent basis. During the training period the lever was covered with sandpaper and all 35 subjects were exposed to the same grade of sandpaper. Testing for generalization occurred during extinction, and at this time the animals were divided into five groups of seven. One group was extinguished with the original grade of sandpaper on the bar. Each of the other groups was exposed to a new grade of sandpaper during extinction, with two of the new grades being finer and two coarser than the original grade. No well-defined generalization gradient was obtained.

Experiment II involved two animals trained on a multiple VI schedule of reinforcement with food being presented contingent upon a nose-lever press. The multiple schedule consisted of 5 min of VI followed by one min in the retaining cage which was again followed by another VI schedule. This was continued until the animal had been given eight exposures to the VI schedules, four of VI 3 min and four of VI 30 sec presented randomly. The sandpaper which was located under the floor, was changed at the end of each VI component. For one subject of VI 3 min was paired with the roughest grade of paper and the VI 30 sec with the smoothest grade; this was reversed for the other subject. When both subjects had learned to discriminate between these conditions two additional grades were introduced which were intermediate between the training values. At this time all four grades were paired with the VI 3 min in an effort to observe the generalized responding without the rapid change brought about by extinction. This procedure yielded gradients for the two subjects that could be reproduced over successive days of testing. These gradients agree with those that have been obtained using other techniques, other subjects, and other sense modalities. They show an orderly decline from the training stimulus most frequently reinforced. In addition to obtaining orderly and interpretable gradients the data supplies some information on the sensitivity of rats to tactual stimuli in that the values of sandpaper which were used proved to be readily discriminable for the two subjects.

It was suggested that the methodology of this second study might prove useful for further investigation of the intensity dimension in touch. Although the present method of presentation of the tactual stimuli is not as convenient as the usual methods of presenting auditory and visual stimuli, it is a dimension that has been previously lacking in operant conditioning studies. With the development of a simpler method of presentation the tactual stimuli could be used to extend the stimulus dimensions that are currently available for studies of multiple stimulus control.

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