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THE EFFECTS OF DISCRIMINATION TRAINING ON THE DEVELOPMENT OF STIMULUS CONTROL BY SINGLE DIMENSIONS OF A COMPOUND STIMULUS

by

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Date ______ Chairman of Examining Committee

Date ______ Executive Officer

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The City University of New York

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The research to be reported is concerned with some of the conditions that govern the establishment of conditional relationships between selected features of the environment (stimuli) and certain other aspects of behavior (responses). It is customary to refer to such conditional relationships as "stimulus control".

A widely accepted concept of stimulus control derived from the analysis of Lashley and Wade (1946) and elaborated by Jenkins and Harrison (1960), Heinemann and Rudolph (1963) and Terrace (1966) is as follows: The degree to which a given stimulus controls behavior is reflected in the generalization gradient, the function relating stimulus value to a measure of response probability. A generalization gradient that is a horizontal line indicates no stimulus control along that continuum, i.e., changes in the value of the stimulus do not change the probability of the response in question. The steeper the gradient the greater the change in response probability for a given change in stimulus value and, hence, the "sharper" the stimulus control.

Discriminative training, the reinforcement of a selected response in the presence of one stimulus but not in the presence of another, appears to be an essential condition for a stimulus to gain control over the response in question. Jenkins and Harrison (1960) found that a 1000 cps tone always present during reinforcement gained control over behavior only if the training session included periods in which no tone was presend during which the pigeon's response (key pecking) was not reinforced. That is, without differential reinforcement, a generalization test in which the frequency of a tone was varied from 300 to 3500 cycles per second revealed virtually no difference in the rate of response. Even in the complete absence of the tone the rate of resp nse remained almost unchanged. On the other hand, discriminative training resulted in well-defined gradients along the dimension of tonal frequency.

However, in many operant conditioning situations, as, for example, in the classical study of Guttman and Kalish (1956), sloping generalization gradients were obtained following what <u>seemed</u> to be simple reinforcement of the selected response in the presence of a given stimulus. Heinemann and Rudolph (1963) pointed out that in studies such as this, in which the stimulus appears on the response key, "so-called nondifferential training methods actually do involve some differential training, at least in the sense of training to discriminate between the presence and absence of the stimulus." (page 654). This assertion was supported by convincing evidence. Generalization gradients along the dimension of luminance were obtained following key-peck training in the presence of a light-grey stimulus. The stimulus for one group was a thin annulus surrounding the response key; for another group a rectangular cardboard of light-grey covered the entire response-panel. A sloping generalization gradient for luminance was obtained in the former case, a flat gradient in the latter. With the small annulus the occurrence of the response was not reinforced in the absence of grey. Hence, differential training occurred. In the case of the large stimulus there was little opportunity for this to occur.

Clearly changes in many dimensions of the stimulus-complex present during training are correlated with differential reinforcement. But do all stimulus dimensions so correlated come to control behavior?

Butter (1963) reinforced pigeons for responding in the presence of a band of light of 550 mu in a vertical position. Generalization tests revealed non-horizontal gradients for both wavelength and angular orientation with the sharpest decrement in responding occurring when the stimulus was varied along the two dimensions simultaneously. Here two stimulus dimensions were shown to control the response. Possibly had tests for other dimensions been given, such as a test for control by luminance of the line, similar gradients would have been obtained.

However, a number of experiments seem to show that the effectiveness of stimuli as bases for the formation of a discrimination vary. That is, when two stimuli are correlated with reinforcement one may acquire control more readily than the other. An example of such selectivity in the development of stimulus control is seen in a frequently cited experiment by Reynolds (1961). Two pigeons were trained on a successive discrimination in which the positive stimulus was a white triangle on a red background, while the negative stimulus was a white circle on a green background. When the components of these stimuli were presented separately--red, green, triangle, circle--one bird responded only in the presence of the red background, the other bird only in the presence of the white triangle. Reynolds entitled this article "Attention in the Pigeon" and indeed something more than the principle of differential reinforcement seems to be required to account for these results.

Reynolds' use of the term "attention" identifies it with the operations which denote stimulus control:

> "In general, an organism attends to an aspect of the environment if independent variation or independent elimination of that aspect bring about variation in the organism's behavior. Thus a gradient of generalization to tones (cps), for example, is a way of showing that the organism was attending to the frequency of the sound in whose presence responding had been reinforced, but a flat generalization function may indicate a lack of attention to the frequency of the sound." (page 203).

The suggestion that such a concept as "attention" is necessary, carries with it the implication that more is meant by the term than simply a synonym for stimulus control. It seems to imply a selectivity in this control. The various dimensions of a compound stimulus may or may not control the behavior in question.

It should be noted, however, that this usage of the term "attention" is purely descriptive. It in no way explains the observed selectively in stimulus control. It has the advantage of clarity since the existence or non-existence of "attention" in a given situation need not be inferred. It may be observed directly in the sloping generalization gradient.

More commonly the term "attention" is used to refer to a selective or "filtering" process which ultimately makes itself felt in what is learned. Used in this manner it is meant to be an explanation of observed events. In a recent review of the work in this area Mackintosh (1965) presents evidence for the view that discrimination learning involves two stages. He suggests that an animal must first learn to "attend" to the relevant stimulus dimension and then to make the correct choice among stimuli on this dimension. Attempts to understand the nature of the variables affecting the development of such "selective attention" and the major theoretical accounts of it are also reviewed by Mackintosh.

The use of the term "attention" as both descriptive of certain events and as an explanation of these events is unfortunate. To avoid confusion in the analysis of the research to be presented, the expression "selective stimulus control" is used when description is intended. However, since the present research is concerned with the development of selective stimulus control, and attempts to provide an explanation of this phenomenon, the relation between this research and that concerning the conditions affecting "selective attention" should be noted. The expression "selective attention" will be used where necessary to denote "attention" in its explanatory usage.

The situation chosen for study is one frequently cited as evidence for the effect of "selective attention" on the development of stimulus control. Lashley (1942) suggests that "If animals are given a set to react to one aspect of a stimulus situation, large amounts of training do not establish association with other aspects, so long as the original set remains effective for reaching the food." (page 259). Results showing that training on a single dimension prevents to some extent the acquisition of stimulus control by other dimensions of a stimulus compound are not uncommon in the literature (e.g., Lashley, 1938, 1942; Lawrence, 1950; McCaslin, Wodinsky, and Bitterman, 1952). A recent experiment by Mackintosh (1965) also demonstrated this so-called "attentional effect". Rats were given training on either orientation or brightness followed by training on a single compound stimulus (a white rectangle) and were then tested by means of the "reversal, non-reversal" technique for "generalization" between this rectangle and another differing from it either in brightness or orientation. Subjects showed steeper gradients along the dimension on which they had been pretrained.

Selectivity in the development of stimulus control following discrimination training was demonstrated by Newman and Baron (1965) in a quite different situation. These experimenters reinforced pigeons for responding in the presence of a white vertical line on a green key. One group did not receive explicit differential training. Three groups received training with a negative stimulus as well as the positive stimulus described above.

For one group the negative stimulus was a green key--positive and negative periods could be distinguished by this group only on the basis of presence or absence of the line. A second group had a red key as the negative stimulus--positive and negative periods could be distinguished by this group either on the basis of presence or absence of the vertical line or on the basis of key color. A third group had as its negative stimulus a red key with a white vertical line--positive and negative periods could be distinguished only on the basis of key color. Following this training, generalization gradients for line tilt were obtained. They were essentially flat except for pigeons "required" to form the discrimination on the basis of presence or absence of the line. It should be noted that the group for whom both key color and absence of the line were perfectly correlated with reinforcement failed to show evidence of control by the orientation of the line.

Baron (1965) suggests that these results may be accounted for in terms of a "modification of the attending hierarchy with differential training". The existence of such a hierarchy is inferred from data, such as those of Warren (1953, 1954), which suggest that discriminations are formed more readily along some dimensions than along others. Baron suggests that prior to differential training color was higher in the pigeon's "attending hierarchy" than was the angular orientation of the white line. Under these conditions color would acquire control more readily than would angular orientation. However,

> "Raising the relative position of the element low in the hierarchy might hasten control acquisition or increase the amount of control obtained. One way to accomplish this might be through differential training in which 'paying attention' to changes in an element low in the hierarchy is reinforced while 'paying attention' to changes in elements high in the hierarchy is non-reinforced...subjects for whom presence-absence of the line was differentially reinforced while color was not, were expected to pay less 'attention' to color of the surrounding and 'attend' the white line and its angular orientation." (page 66).

The experiments to be reported deal with the effects of pretraining a discrimination on the basis of one dimension of a compound stimulus upon later control of behavior by another dimension subsequently correlated with reinforcement. The effects of differences in the readiness with which a discrimination can be formed on the basis of one dimension upon the development of stimulus control by another dimension will also be considered.

METHOD

Subjects

The subjects were twenty white Carneau pigeons who had not been used in any previous experiments. Twelve of these pigeons were five years old at the start of the experiment; the remaining eight were approximately two years old. Although no effect due to age was expected, an effort was made to assign an equal number of pigeons from these two age groups to the various experimental conditions.

Throughout the experiment the pigeons were maintained at approximately 85% of their free-feeding weight. After they arrived at the laboratory the birds were allowed free-access to food for 11 days. Free feeding weight is the mean weight for the last eight of these days.

Apparatus

Training and testing were carried out in two identical animal chambers purchased from Grason-Stadler Company. The bird's compartment was 11 x 11 x 13½ inches in size. The floor, ceiling and two walls of this compartment were covered with acoustic tile. A metal panel separated the subject's compartment from the compartment housing the stimulus and food presenting devices. The response key, a circular disk one inch in diameter, was located in the center of the panel about eight inches from the floor. Four inches beneath the key was a 1 3/4 x 2 inch opening through which a tray filled with grain could be made available. Availability of food was signaled by the sound of a solenoid as the food tray moved into place and by a light which illuminated the grain hopper. Reinforcement was a three second period of access to the food. The entire box was enclosed in a sound-proff chamber.

The visual stimulus, a black line 1/8 inch in width and one inch in length on the white circular key, was produced by a projector mounted behind the key. This device could transilluminate the key with white light and a black line in any of 12 different orientations. During training only two orientations of the line were presented. These were the vertical line (90°) and the horizontal line (0°). During generalization testing these stimuli plus six other line orientations were presented. The additional test stimuli were the black line at angular orientations of 30°, 60°, 75°, 105°, 120°, and 150°.

The auditory stimuli were produced by a five inch speaker located in the subject's chamber. Sinusoidal signals were delivered to this speaker by two audio-oscillators. During training one was set at a frequency of 1000 cycles per second (cps); the other was set at 320 cps. During testing six additional tones were presented. These additional test stimuli were frequencies of 450, 600, 800, 1350, 1800 and 2400 cps. The sound pressure level of the eight stimuli was approximately 65 decibels re 0.0002 dyne/cm^2 as measured with a sound level meter.

The chamber was illuminated by a 10-watt bulb during working periods. The duration of the working period was 37 seconds. These periods were separated by a seven-second blackout during which the houselight and stimuli were turned off.

Programming and recording were accomplished by a series of relays, timers, counters and a 52-point, three-bank stepping switch.

<u>Experimental Design and Procedure</u>

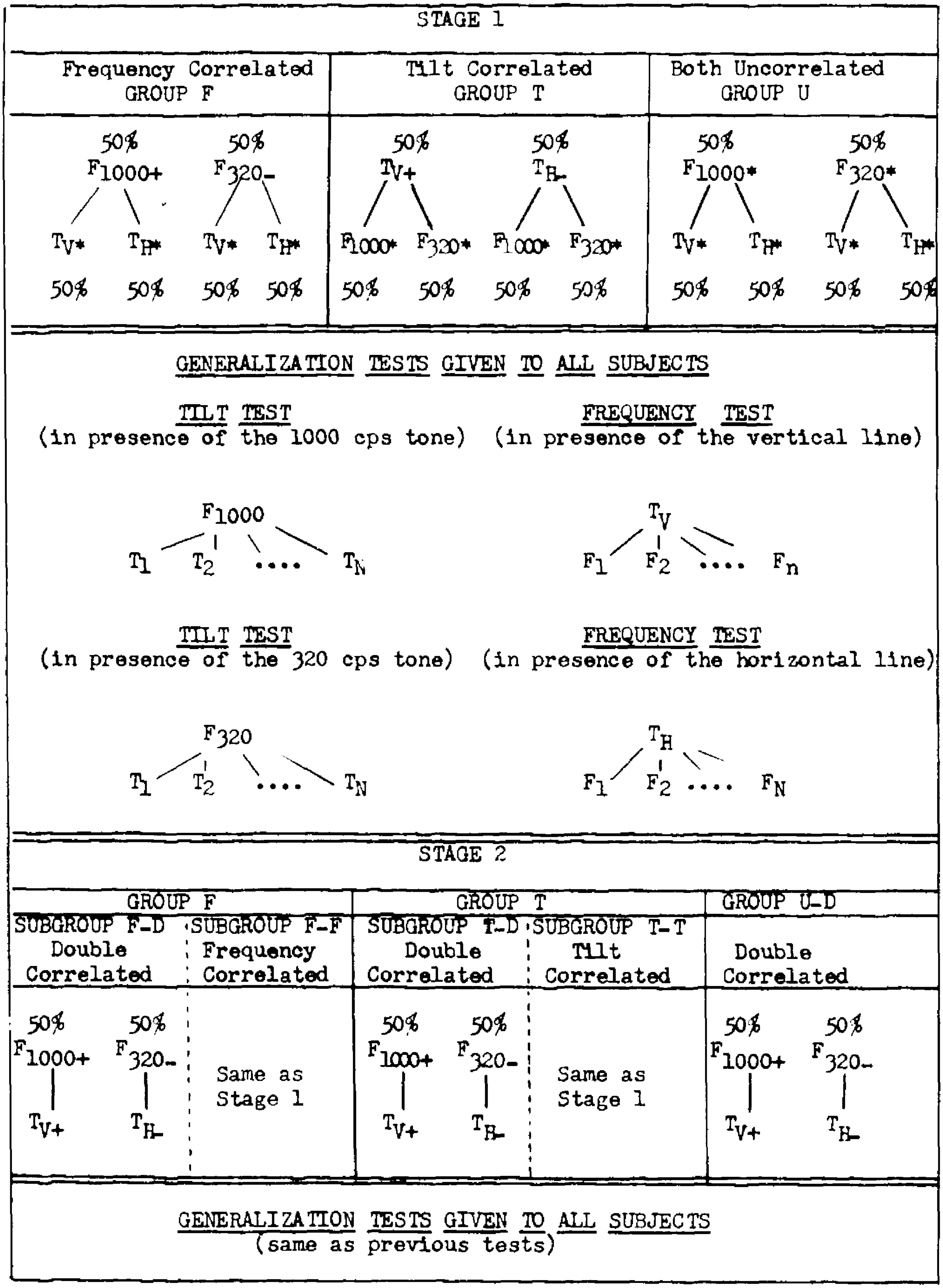
The basic design of the present experiment is outlined in Figure 1. The auditory stimuli are referred to as F, the visual stimuli as T.

The particular stimulus presented is shown as a subscript. For example, the presentation of the 1000 cycle tone is designated F_{1000}. Vertical (V) and horizontal (H) appear as abbreviations. The terms "correlated" and "uncorrelated" are used to refer to the relationship between the reinforcement schedule in effect and the stimulus events. In the correlated situation one member of the pair of stimuli is only and always present during periods when the response (key pecking) is reinforced and the other stimulus is always and only present during negative periods. The positive stimuli are indicated by the symbols T+ and F+. The negative stimuli are indicated by the symbols T- and F-. On the tilt dimension the positive stimulus is the vertical line, T_V +; the negative stimulus is the horizontal line, T_H -. On the frequency dimension the positive stimulus is the 1000 cycle tone, F_{1000} +; the negative stimulus is the 320 cycle tone, F_{320} -. The condition referred to as uncorrelated describes a situation in which each member of the pair of stimuli on the dimension was presented randomly during 50% of the reinforced periods and during 50% of the non-reinforced periods. Uncorrelated presentations of the various stimuli are indicated by the symbols T_V*, T_H*, F_{1000}*, and F_{320}*.

Reinforcement contingencies in effect during the experiment were as follows:

Uncorrelated presentation on both stimulus dimensions.-- Under this training condition the two stimuli on the tilt dimension and the two stimuli on the frequency dimension were present during all working periods but neither was consistently correlated with reinforcement. This situation is diagrammatically illustrated in Figure 1 as the training condition for the uncorrelated group, Group U, during Stage 1 of the experiment.

Figure 1 - Outline of Experimental Design



One stimulus dimension correlated with reinforcement, the other dimension uncorrelated.-- Two groups were trained under this condition during Stage 1. These were the frequency correlated group, Group F, and the tilt correlated group, Group T. The training conditions for these groups are shown in Figure 1.

"Double correlation"-both stimulus dimensions correlated with reinforcement.-- Three groups were trained under this condition during Stage 2. For these subjects reinforcement always occurred during periods in which the 1000 cycle tone and the vertical line were present; reinforcement never occurred in the presence of the 320 cycle tone and the horizontal line. The groups given this training during Stage 2 are shown in Figure 1 as Subgroups F-D, T-D, and U-D.

Following is a description of the various training and testing conditions involved in the present experiment. They are presented in the order in which they occurred:

Shaping.-- Shaping required a single session for most of the birds. The procedure was as follows: The bird was placed in the lighted box. Neither the visual nor the auditory stimuli to be used in later training were present. A few grains were placed near the magazine. When the bird began eating, the food magazine was operated and remained available until the bird ate from it. The sound thus produced in some instances caused the bird to "freeze". In such an event, the food magazine was not presented again until eating had begun. Magazine training continued until the bird readily ate from the food tray when available. Shaping was begun immediately afterwards. Only movements in the vicinity of the key were reinforced by presentation of the food tray until by the "method of successive approximation" the pigeon was trained to peck the key. He was then given approximately 30 reinforcements. Each reinforcement was three seconds of access to the food tray. At this point reinforcement was continuous--a single peck was sufficient to produce the food tray.

<u>Introduction to the variable interval schedule</u>.-- During the experiment a variable interval schedule of reinforcement having a mean interval of 20 seconds (VI-20") was in effect during positive periods. The shift from continuous to variable interval reinforcement occurred during the session following shaping for most of the birds. At first the food magazine was withheld until two or three pecks were emitted. The interval was lengthened gradually until the bird responded consistently on the VI-20" reinforcement schedule. Blackouts, the seven-second time-out period, were introduced at this point. It was found helpful to enrich the reinforcement schedule immediately before and after the first few blackouts. In cases in which the behavior seemed disrupted by the sudden plunge into darkness, blackouts were temporarily discontinued while VI-20" training was continued. This training procedure produced a minimum of "freezing" on the part of the pigeons, and in all but one case the birds were shaped and put on the VI schedule within two days.

During the experiment proper, 50% of the working periods were positive; 50% negative. Each session consisted of 52 37-second working periods each separated by a seven-second blackout. The sequence of positive and negative periods was random. Schedules in which the maximum number of successive positive periods plus the maximum number of successive negative periods was less than nine were eliminated. Only schedules with longer sequences of successive positive and negative periods were used in order to prepare the birds for later generalization testing. The generalization test was conducted during eight consecutive negative periods in an otherwise normal session.

The birds were introduced to this type of schedule over a period of four days as follows:

First Day - 25% periods negative - no more than 2 consecutive

Second Day - 50% periods negative - no more than 2 consecutive

Third Day - 50% periods negative - no more than 3 consecutive

Fourth Day - 50% periods negative - no more than 4 consecutive

This was followed by eight days of training on the regular schedule. This period is referred to as preliminary training (P.T.). Its purpose was to insure stable responding under the general conditions of the experiment. After response rates had become quite stable, discrimination training was begun.

Stage 1 Training.-- On the basis of their final rates during the preliminary training period the pigeons were divided into three matched groups--Group T and Group F each had eight subjects; Group U had four subjects. The conditions of training for each of these groups have already been described and are summarized in Figure 1. The birds were trained under their respective conditions for 45 days. The sequence of positive and negative periods was identical for all birds during a given session. Throughout the experiment the birds were run in the same box at approximately the same time each day. Sessions were conducted daily except on the few occasions on which this was impossible.

Generalization Testing 1.-- Following the first stage of training, generalization tests were carried out. These were conducted during "normal" training sessions except that the test stimuli were presented during eight consecutive negative periods within this session. The four tests, diagrammatically shown in Figure 1, were given to all the birds. These tests were: (a) a test for generalization on the dimension of tilt in the presence of the 1000 cycle tone; (b) a test on the dimension of tilt in the presence of the 320 cycle tone; (c) a test on the dimension of frequency of a 65 decibel tone in the presence of the vertical line; (d) a test on the dimension of frequency in the presence of the horizontal line. On each dimension eight stimuli were presented. The order of presentation was random. Four sessions later the test was repeated with the stimuli presented in reverse order. Responses during these two tests were averaged to produce the basic data used in the main analyses. This procedure minimized, but probably did not completely eliminate, effects due to order of presentation of the stimuli. Generalization testing took eight days. The procedure used was chosen to minimize extinction effects and keep the testing session as indistinguishable from training as possible.

The tests were given in the following two orders. Half of the subjects in each group were given one order; the remaining half were tested in the alternate order:

Order 1

Tilt-test in the presence of the 320 cycle tone.
Frequency-test in the presence of the horizontal line
Frequency-test in the presence of the vertical line
Tilt-test in the presence of the 1000 cycle tone

Order 2

Frequency-test in the presence of the horizontal line
Tilt-test in the presence of the 320 cycle tone
Tilt-test in the presence of the 1000 cycle tone
Frequency-test in the presence of the vertical line

The orders of testing were the same on the second administration of each test. Such a sequence permits comparison of the performance of the different groups on the same test but certain other comparisons would be difficult to interpret because of confounding. For example, differences in performance on the two frequency tests--that made in the presence of the vertical line and that made in the presence of the horizontal line--are the result of differences in line orientation confounded with order of testing.

Stage 2.-- Following the generalization tests the subjects were given two days continued training under their Stage 1 training condition. This was followed by the training shown in Figure 1 under Stage 2. Half of the subjects in Group F, the group whose training condition was frequency correlated during Stage 1, were given "double correlation" training during the second stage. This group is referred to in Figure 1 and in the following discussion as Group F-D. The first letter designates the training condition in effect during Stage 1. The second letter indicates the training condition in effect for the group during the second stage of training. Thus, for this group the letters F-D show that the training condition during Stage 1 was frequency correlated (F); the training condition during Stage 2 was "double correlation" (D). The remaining subjects in Group F were continued on their Stage 1 training condition. This group is, therefore, referred to as Group F-F. The original tilt correlated group, Group T, was similarly treated. Half of the subjects were shifted to "double correlation." According to the scheme described above this group is referred to as Group T-D. Tilt (T) was correlated during Stage 1 and "double correlation" training was given during Stage 2. The remaining subjects were continued on the original training condition. This group is referred to as Group T-T. All of the subjects in Group U were now trained under the "double correlation" condition. Consequently this group is referred to as Group U-D. Stage 2 training was continued for 45 sessions.

Generalization Testing 2.-- The tests given following the second stage of training were identical to those following Stage 1.

RESULTS

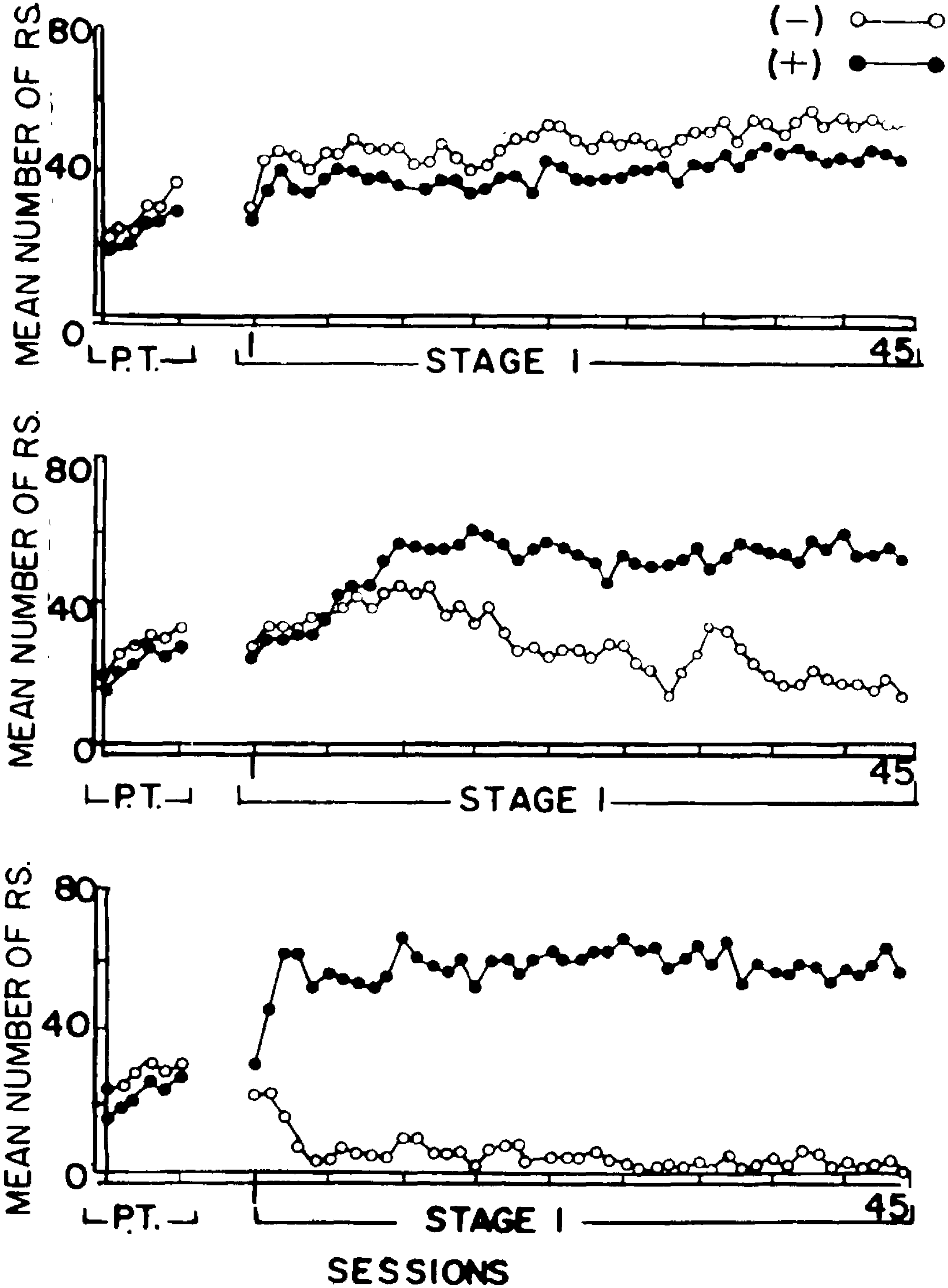
Training - Stage 1

The performance of the subjects during the first stage of training is shownin Figure 2. The mean number of responses per working period, plotted against training session, is shown separately for "positive" and for "negative" working periods. During positive periods, the VI-20" schedule was in effect. During negative periods, no reinforcements were given. The terms "positive" and "negative" do not refer to particular stimuli associated with reinforcement or non-reinforcement. Each graph also shows the results for the last six days of preliminary training (P.T.).

The curve for Group U is based upon the means of four subjects; the curves for Groups F and T are each based upon the performance of eight subjects. Although this manner of presentation is subject to the dangers inherent in averaging learning curves, an inspection of the individual curves reveals a high degree of similarity among individuals. The general characteristics of the individual curves are reflected in the group curves. Where exceptions have occurred they will be noted.

The upper graph in Figure 2 (2-A) shows the results for Group U. For this group the auditory and visual stimuli could not serve to identify positive and negative periods since each of the four stimuli was present as often during positive as during negative periods. The curves clearly show that no discrimination was formed. The fact that the response rate is higher during the negative periods than during the positive periods reflects the fact that during positive periods the subject stops responding occasionally to eat from the food magazine. The unvarying separation between the two curves indicates that a schedule

Figure 2. Performance during preliminary training (P.T.) and Stage 1 training is shown as a function of sessions of training. The mean number of responses emitted during the positive periods (filled circles) and the negative periods (open circles) are shown separately for each session. The curves showing the performance of Group U (four subjects) appear in Panel A. The curves showing the performance of Group F (eight subjects) appear in Panel B. The curves showing the performance of Group T (eight subjects) appear in Panel C.



(−)
(+)
MEAN NUMBER OF RS.
80
40
0
P.T.
1
STAGE I
45
MEAN NUMBER OF RS.
80
40
0
P.T.
1
STAGE I
45
MEAN NUMBER OF RS.
80
40
0
P.T.
STAGE I
45
SESSIONS

discrimination, based on the occurrence of reinforcements during the positive periods, was not formed (see Jenkins, 1965). The group curve shown mirrors the individual curves, although the latter show more irregularity and vary in the amount of separation between the two curves.

The middle graph (2-B) shows the results for Group F. For this group, as for Group U, each of the two orientations of the line appeared with equal frequency in positive and negative periods. But unlike the condition for Group U, the frequency of the 65 decibel tone was perfectly correlated with the two components of the multiple schedule. During and only during positive periods a tone of 1000 cps was present; during and only during negative periods a 320 cps tone was present.

As can be seen from Figure 2-B, the subjects did form a discrimination on the basis of tonal frequency. By the seventh session the average rate during positive periods exceeded that for negative periods. The separation in rate between positive and negative periods gradually increased as training continued. Early in the formation of the discrimination the separation of the two curves was due primarily to an increase in rate during positive periods. Later the rate during positive periods dropped slightly and leveled off. This leveling off occurred while the negative rate continued to drop. The gradual development of the discrimination was characteristic of all the birds in this group although there was no single pattern in changes in positive and negative rates. Two birds never increased their positive rates; their negative rates simply dropped. Some birds showed an initial increase in <u>both</u> positive and negative rates.

The lowest graph (2-C) shows the results for Group T. For this group the two auditory stimuli were uncorrelated, i.e., they appeared with equal frequency during positive and negative periods. The orientation of the line, however, was correlated with reinforcement. A vertical line appeared on the key during all positive periods; a horizontal line during all negative periods. The performance of the subjects in this group was clearly different from those in Group F (compare Figures 2-B and 2-C). Line tilt appears to be a more effective discriminative stimulus than tonal frequency. The negative rate for the group dropped below that of the positive on the first day of training. Only one of the birds did not clearly show the discrimination by the second day. The increase in positive rate appeared earlier and was sharper. Further, the increase in the positive rate occurred with every bird in this group. The rate during negative periods dropped quickly towards zero. While most birds continued to respond occasionally during a negative period, responding remained low. Contrast this to a mean response rate of about 18 per negative working period for subjects in Group F towards the end of Stage 1.

<u>Generalization Tests 1</u>

(a) <u>Gradients for line tilt in the presence of the 1000 cps tone</u>

The performance of Groups U, F, and T, on the tilt generalization test given in the presence of the 1000 cps tone is shown in Figures 3 and 4.

Figure 3 shows the mean number of responses per working period emitted in the presence of each of the eight test stimuli. The points at 180 degrees are duplicates of those for 0 degrees and have been added for symmetry. The gradient for Group U is based upon the performance of four subjects. The gradients for Groups F and T are each based on the performance of eight subjects.

Figure 4 shows simply the distribution of responses among the stimuli.

Figure 3. The performance of Groups U (solid line, open circles), F (dashed line, closed circles) and T (dotted line, triangles) on the tilt generalization test given in the presence of the 1000 cps tone is shown. The mean number of responses emitted in the presence of each of the test stimuli is plotted against these stimuli. The horizontal line (0^{o} or its duplicate 180^{o}) and the vertical line (90^{o}) were present during training for all groups.

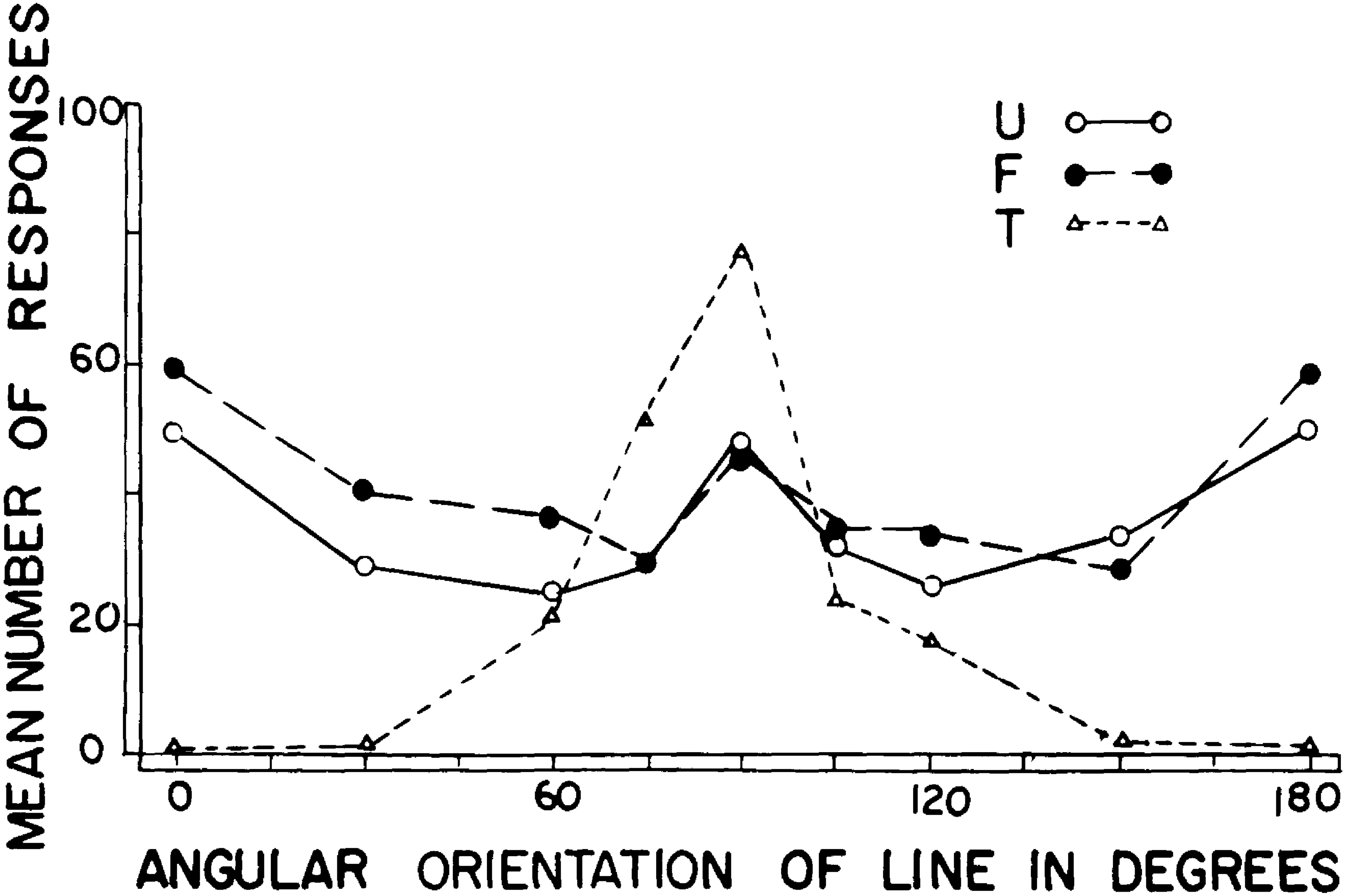

MEAN NUMBER OF RESPONSES
100
60
20
0
U
F
T
0
60
120
180
ANGULAR ORIENTATION OF LINE IN DEGREES

Figure 4. The performance of Groups U (solid line, open circles), F (dashed line, closed circles) and T (dotted line, triangles) on the tilt generalization test given in the presence of the 1000 cps tone is shown. The per cent of the total number of responses emitted during the test in the presence of each of the test stimuli is plotted against these test stimuli.

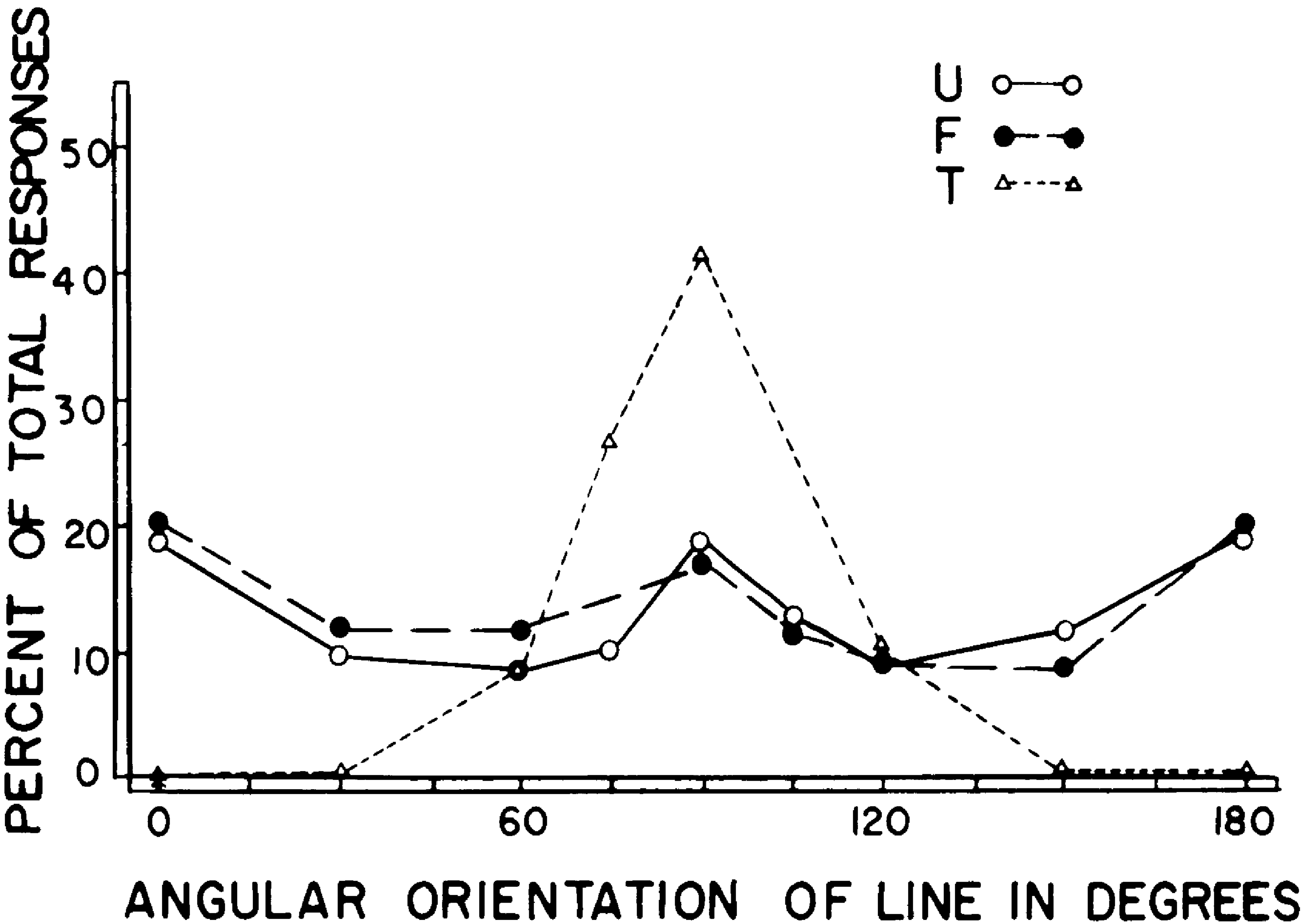

PERCENT OF TOTAL RESPONSES
0
10
20
30
40
50
U
F
T
0
60
120
180
ANGULAR ORIENTATION OF LINE IN DEGREES

Table 1 - Analyses of Variance on Number of Responses Emitted in the Presence of Each of the Eight Stimuli Presented During Generalization Tests 1 .

A - Tilt Generalization Test in the Presence of the 1000 cps Tone

	Group U	Group F	Group T
F(Between Stimuli)	5.85***	3.24**	15.02***
Degrees of Freedom	7 & 21	7 & 49	7 & 49

B - Tilt Generalization Test in the Presence of the 320 cps Tone

	Group U	Group F	Group T
F(Between Stimuli)	2.13	1.66	17.11***
Degrees of Freedom	7 & 21	7 & 49	7 & 49

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

The number of responses emitted in the presence of each stimulus was expressed as a per cent of the total number of responses emitted during the test. This was computed separately for each subject and a group average was obtained.

Of the three groups only Group T was reinforced differentially for responses in the presence of the two tilted lines. As pointed out previously, for this group the vertical line (tilt 90°) was positive. The horizontal line (tilt 0° or 180°) was negative. If key pecking had come under the control of angular orientation of the line a decremental gradient on this dimension would be expected. As can be seen by reference to Figures 3 and 4 such a decremental gradient was found for Group T. To ascertain whether the deviation of the gradient from a horizontal line might be attributed to variability, an analysis of variance (line tilt vs. subjects) was made for this group. An $F_{(\text{between stimuli})}$ of 15.02 was obtained. With seven and 49 degrees of freedom this is highly significant ($p < 0.001$), and indicates that the gradient is not horizontal.

Table 1-A summarizes the outcome of this analysis of variance as well as the analyses for Group F and U. For all three groups the effect of stimuli upon response rate was significant. As a glance at Figure 3 or 4 shows, however, in the case of Groups F and U this is not due to a decremental gradient similar to that shown by Group T. Rather, there appear to be two decremental gradients, one with a peak at the vertical line (tilt 90°) and one with a peak at the horizontal line (tilt 0° or its duplicate 180°). These decremental gradients are clearest in the case of Group U; note the occurrence of the minimum rate in the presence of the 60° and 120° tilts, the two test stimuli most unlike the vertical and horizontal lines.

(b) Gradients for line tilt in the presence of the 320 cps tone

All birds were given generalization tests along the dimension of line orientation in the presence of the 320 cps tone as well as in the presence of the 1000 cps tone. The performance of the three groups on the test made in the presence of the 320 cps tone is shown in Figure 5.

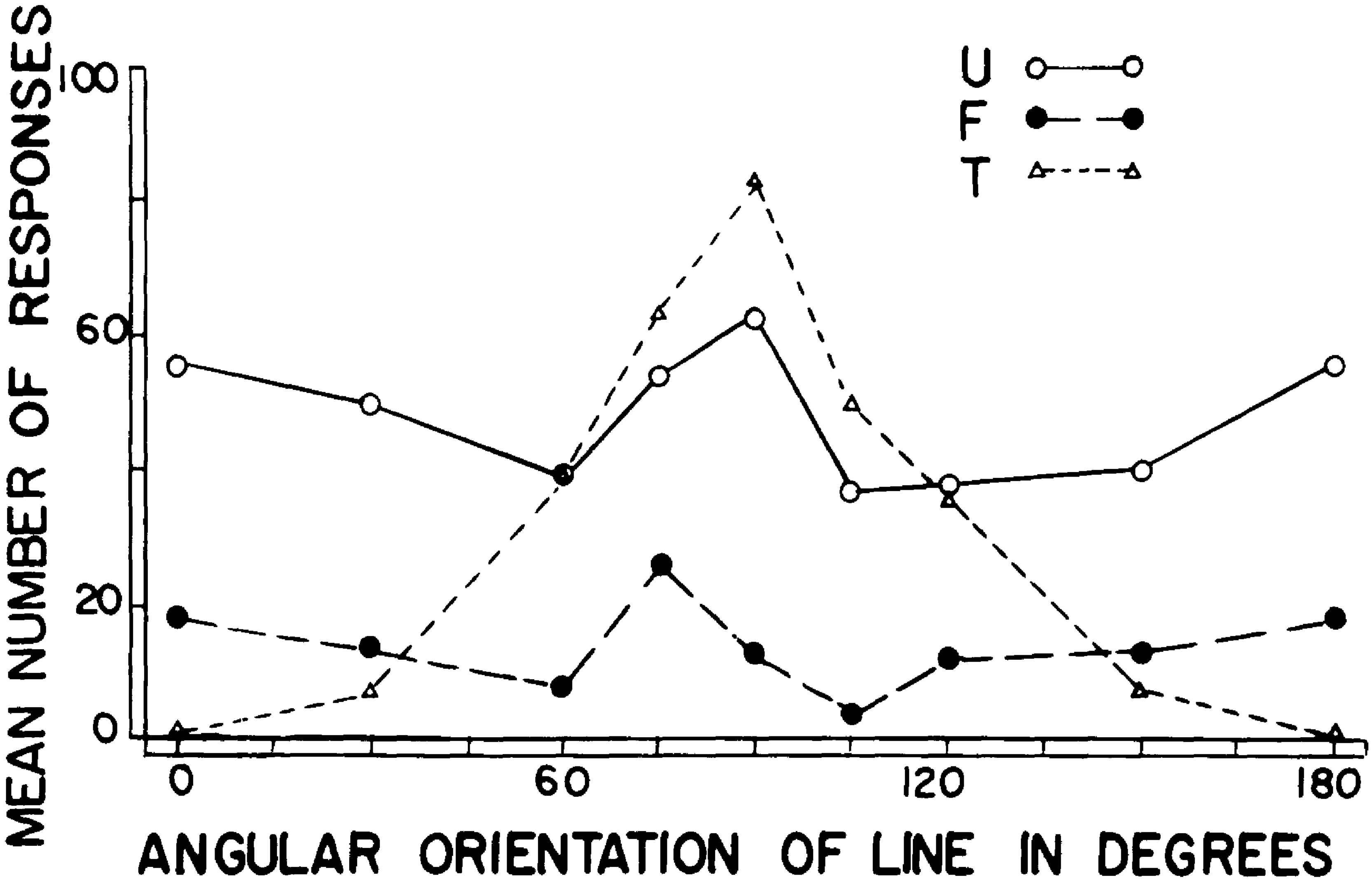
For Groups U and T the auditory stimuli were not differentially associated with positive and negative periods. Thus the frequency of the tone would not be expected to affect the form of the gradient. A comparison of Figures 3 and 5 shows that this expectation is borne out. The gradients that appear in Figure 5 for Groups U and T are very similar in form to those shown in Figure 3. Outcomes of analyses of variance are shown in Table 1-B. For Group T the effect of stimuli was highly significant ($p < 0.001$). The effect of stimuli for Group U just failed to be significant at the .05 confidence level.

For Group F the gradient obtained in the presence of the 320 cycle tone is displaced downward and flattened in comparison to that obtained for this group in the presence of the 1000 cps tone. As shown in Table 1-B, the effect of stimuli upon response rate failed to be significant ($p > 0.05$). The depression in rate is not unexpected since, for this group, the 320 cps tone was the negative stimulus.

(c) Gradients for tonal frequency in the presence of the vertical line

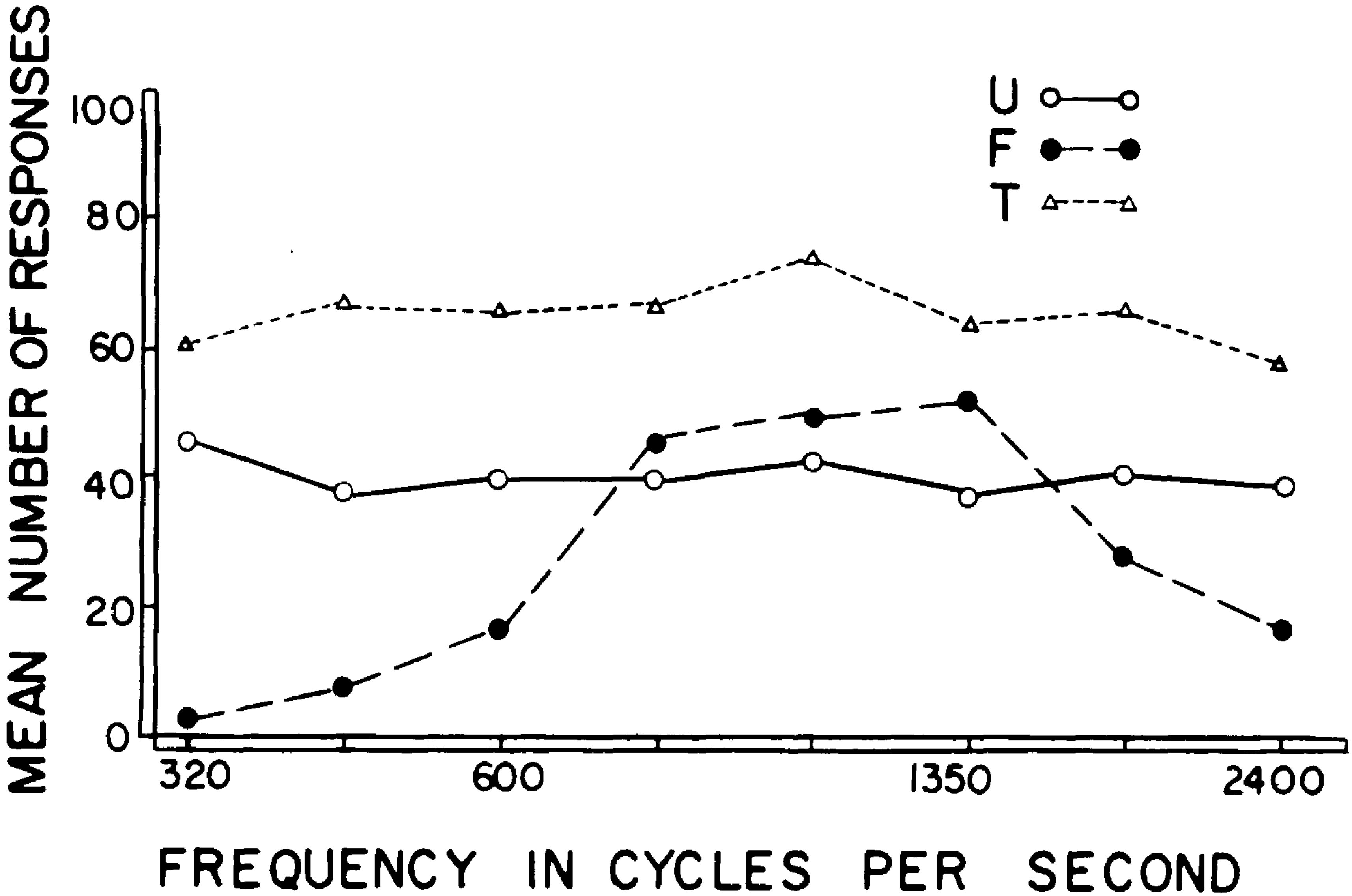
The results of the generalization tests along the frequency continuum, given in the presence of the vertical line, are summarized in Figures 6 and 7 and in Table 2-A. The only group that received differential training with respect to the auditory stimuli is Group F. The gradient for this group is decremental with high response rates occurring in the presence of the 800, 1000, and 1350 cps tones. Only on the

Figure 5. The performance of Groups U (solid line, open circles), F (dashed line, closed circles) and T (dotted line, triangles) on the tilt generalization test given in the presence of the 320 cps tone is shown. The mean number of responses emitted in the presence of each of the test stimuli is plotted against these stimuli. The horizontal line (0^{o} or its duplicate 180^{o}) and the vertical line (90^{o}) were present during training for all groups.



U
F
T
MEAN NUMBER OF RESPONSES
100
60
20
0
0
60
120
180
ANGULAR ORIENTATION OF LINE IN DEGREES

Figure 6. The performance of Groups U (solid line, open circles), F (dashed line, closed circles) and T (dotted line, triangles) on the frequency generalization test given in the presence of the vertical line is shown. The mean number of responses emitted in the presence of each of the test stimuli is plotted against these stimuli. The 300 cps and the 1000 cps tones were present during training for all groups.



MEAN NUMBER OF RESPONSES
100
80
60
40
20
0
U
F
T
320
600
1350
2400
FREQUENCY IN CYCLES PER SECOND

Figure 7. The performance of Groups U (solid line, open circles), F (dashed line, closed circles) and T (dotted line, triangles) on the frequency generalization test given in the presence of the vertical line is shown. The per cent of the total number of responses emitted during the test in the presence of each of the test stimuli is plotted against these stimuli.

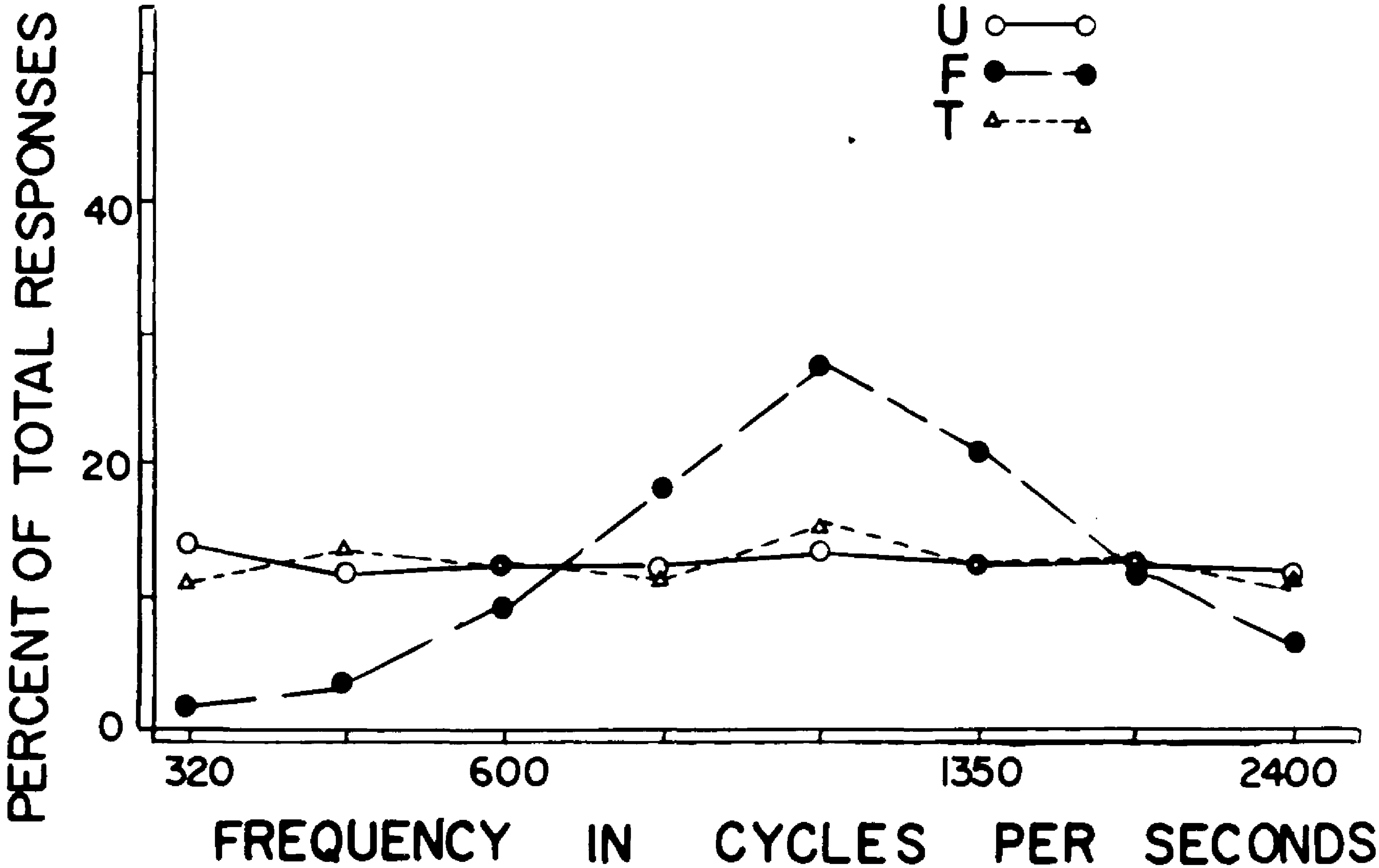

U
F
T
PERCENT OF TOTAL RESPONSES
40
20
0
320
600
1350
2400
FREQUENCY IN CYCLES PER SECONDS

Table 2 - Analyses of Variance on Number of Responses Emitted in the Presence of Each of the Eight Stimuli Presented During Generalization Tests 1

A - Frequency Generalization Test in the Presence of the Vertical Line

	Group U	Group F	Group T
F(Between Stimuli)	1.54	7.95***	1.07
Degrees of Freedom	7 & 21	7 & 49	7 & 49

B - Frequency Generalization Test in the Presence of the Horizontal Line

	Group U	Group F	Group T
F(Between Stimuli)	1.45	4.42**	1.00
Degrees of Freedom	7 & 21	7 & 49	7 & 49

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

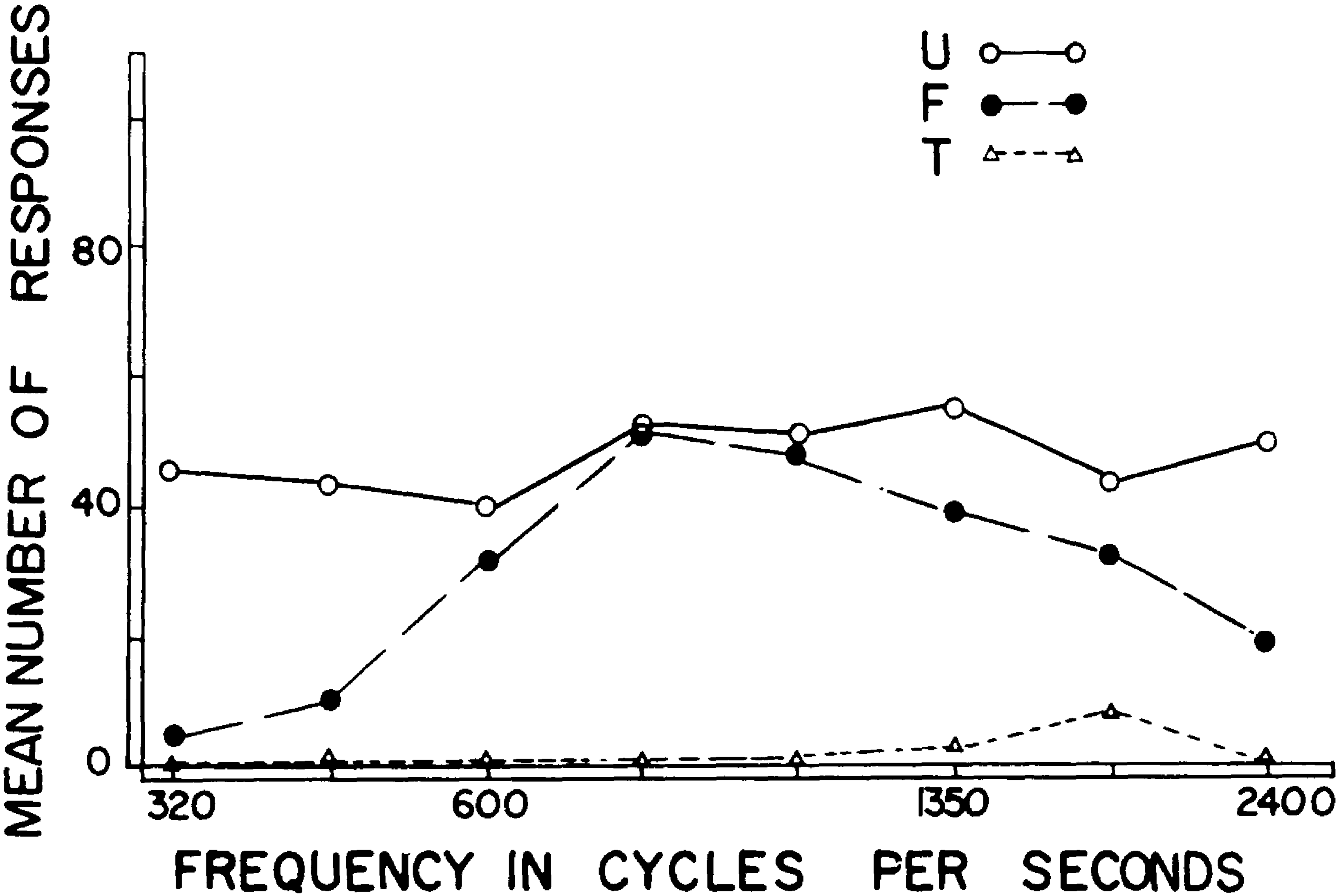
"per cent total" plot (Figure 7) is the maximum at 1000 cps, the positive stimulus. Inspection of the individual gradients shows a maximum for one subject at 800 cps, for three at 1000 cps, and for four at 1350 cps. An analysis of variance (frequency vs. subjects) showed the effect of stimuli upon response rate to be highly significant ($p < 0.001$). In spite of the indeterminate peak, fewer responses occurred in the presence of the negative stimulus, the 320 cps tone, and in the presence of the other tones substantially different from the positive one.

Both the graphs and the statistical tests show the frequency gradients for Groups U and T to be essentially horizontal lines. The contrast between this result and that of the tilt generalization tests should be noted. Where tilt was the uncorrelated stimulus dimension there was, nonetheless, strong evidence of the development of stimulus control by tilt. Two decremental gradients, one around each of the line orientations present during training, were seen in the tilt gradients for both Group U and F. No such effect was found where frequency was the uncorrelated dimension.

(d) Gradients for tonal frequency in the presence of the horizontal line

The results of the tests for generalization along the frequency continuum are summarized in Figure 8 and in Table 2-B. These tests echo the findings of the tests made in the presence of the vertical line. A decremental gradient is found for Group F. For this group, an analysis of variance shows the effect of stimuli to be significant ($p < 0.01$). The gradients for Groups U and T are essentially horizontal (Figure 8). The difference in response rate in the presence of the various tones is insignificant (Table 2-B).

Figure 8. The performance of Groups U (solid line, open circles), F (dashed line, closed circles) and T (dotted line, triangles) on the frequency generalization test given in the presence of the horizontal line is shown. The mean number of responses emitted in the presence of each of the test stimuli is plotted against these stimuli. The 320 cps and the 1000 cps tones were present during training for all groups.


U
F
T
MEAN NUMBER OF RESPONSES
80
40
0
320
600
1350
2400
FREQUENCY IN CYCLES PER SECONDS

Changes in Response Rates During Generalization Testing 1

During the first series of generalization tests, four gradients were obtained for each bird. Each gradient was based upon performance during two testing sessions. The second session was identical to the first except that the order of presentation of the test stimuli was reversed and the test occurred four days later. These tests were used to determine whether or not "extinctions" occurred during testing. A comparison of the mean number of responses on the first and second subtests appears in Table 3. The two tilt tests and the two frequency tests are shown for each group. In general, fewer responses occurred during the second test than during the first. In most cases, however, this difference was not statistically significant ($p > 0.05$). The difference was significant only for Group T on the tilt tests. The possibility exists that subjects in Group T learned to "identify" the unreinforced tilt tests by the appearance of tilts other than those present during training. Thus, while this testing procedure does not seem to result in extinction, the possibility exists that continued testing may result in discrimination of the test from the regular training session.

Training - Stage 2

For the second stage of training there were five groups as follows:

1. Group U (now to be referred to as Group U-D) was placed on "double correlation", i.e., whereas previously neither tilt nor frequency were differentially correlated with reinforcement now both sets of stimuli were correlated with reinforcement. The vertical line and the 1000 cps tone were always present during positive periods; the horizontal line and the 320 cps tone were always present during negative periods.

Table 3 - Effects of Earlier Generalization Subtests on Number of Responses Emitted on Later Subtests During Generalization Tests 1

Tilt Generalization Tests

Group	Test in Presence	Mean # R's 1st Subtest	Mean # R's 2nd Subtest	Difference	Significance t	df
U	320 cps tone	405.3	350.5	54.8	2.94	3
	1000 cps tone	306.3	241	65.3	2.10	3
F	320 cps tone	88.5	127.1	38.6	.42	7
	1000 cps tone	324.9	299.9	25.00	.82	7
T	320 cps tone	398	177.4	160.6	2.82*	7
	1000 cps tone	279.4	109.5	169.9	3.50**	7

Frequency Generalization Tests

Group	Test in Presence	Mean # R's 1st Subtest	Mean # R's 2nd Subtest	Difference	Significance t	df
U	Vertical line	429.3	323.5	105.8	1.55	3
	Horizontal line	331.3	312.8	62.1	1.63	3
F	Vertical line	225.6	244.9	19.2	.39	7
	Horizontal line	229.3	210.8	18.5	.71	7
T	Vertical line	26.9	3.8	23.1	2.29	7
	Horizontal line	530.6	507	23.6	.32	7

* P<0.05
** P<0.01

2. Group F was divided into two subgroups, with four subjects in each group. Four subjects continued training identical to that of Stage 1 and will be referred to as Group F-F, the "frequency to frequency correlated" group.

3. The other four members of Group F were placed on "double correlation" as defined under (1.) above. This group will be referred to as the "frequency to double correlated group," Group F-D.

4. Group T was similarly divided into two subgroups. Half of the subjects continued training identical to that of Stage 1. This group will be referred to as the "tilt to tilt correlated group", Group T-T.

5. The remainder of the subjects in Group T were put on "double correlation" training. This group will be referred to as the "tilt to double correlated group", Group T-D.

The three "double correlated" groups were treated identically during Stage 2. They differed only in regard to the nature of their training during Stage 1.

Performance of these five groups during the last days of Stage 1 training, generalization testing, and all of the second stage of training is shown in Figures 9, 10, and 11. The mean number of responses emitted during negative and during positive working periods is plotted against sessions.

The mean number of responses during the non-test parts of testing sessions, and during two regular Stage 1 training sessions following testing, are included in Figures 9, 10, and 11 to show the effects of generalization testing upon performance. Performance during these sessions may be compared to that during the last ten days of Stage 1 training also shown for each group. There appears to be little, if any, effect of testing upon the performance of Groups U (Figure 9) and

Figure 9. Performance during the final 10 days of Stage 1 training, generalization testing and Stage 2 training is shown as a function of sessions of training. The mean number of responses emitted during the positive periods (filled circles) and the negative periods (open circles) are shown separately for each session. The curves showing the performance of Group U-D (four subjects) appear in this figure.

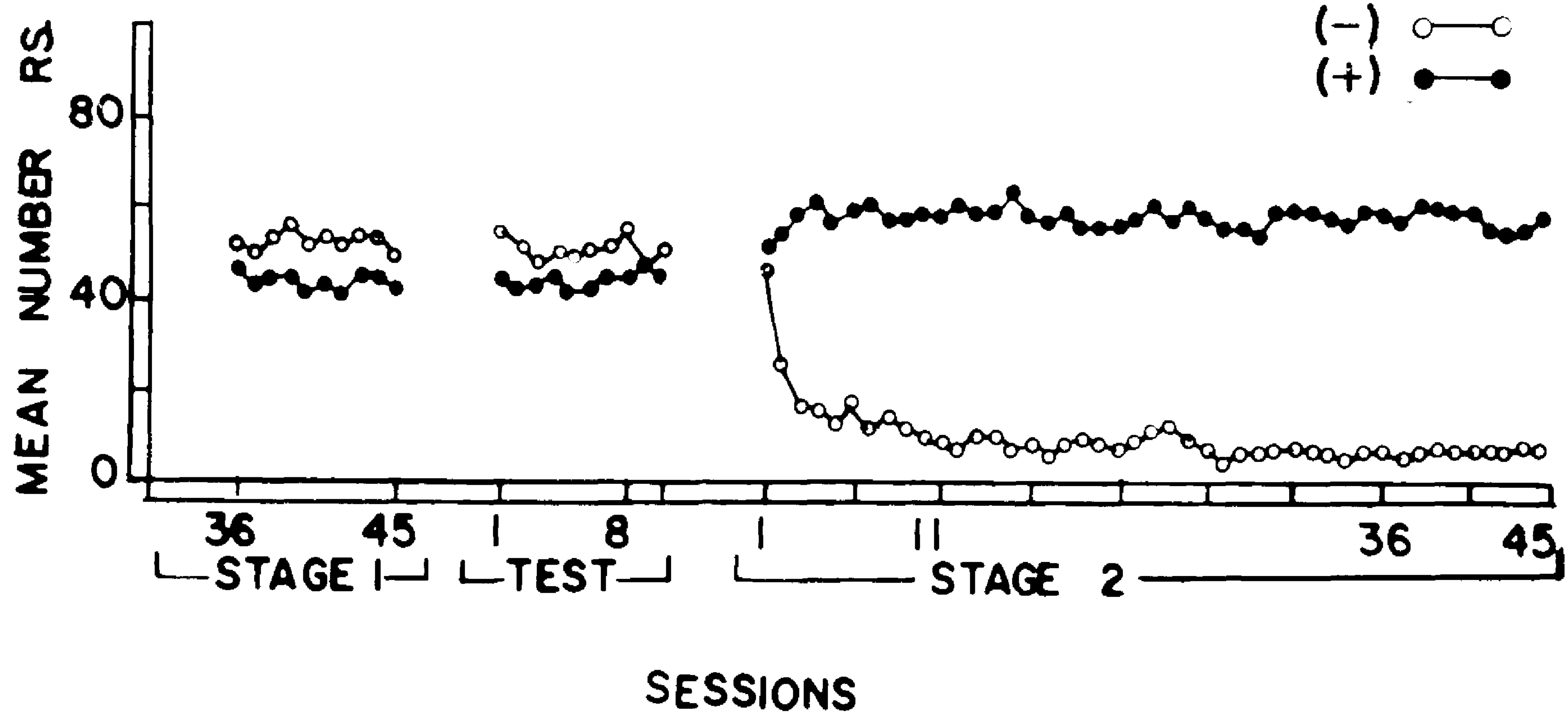
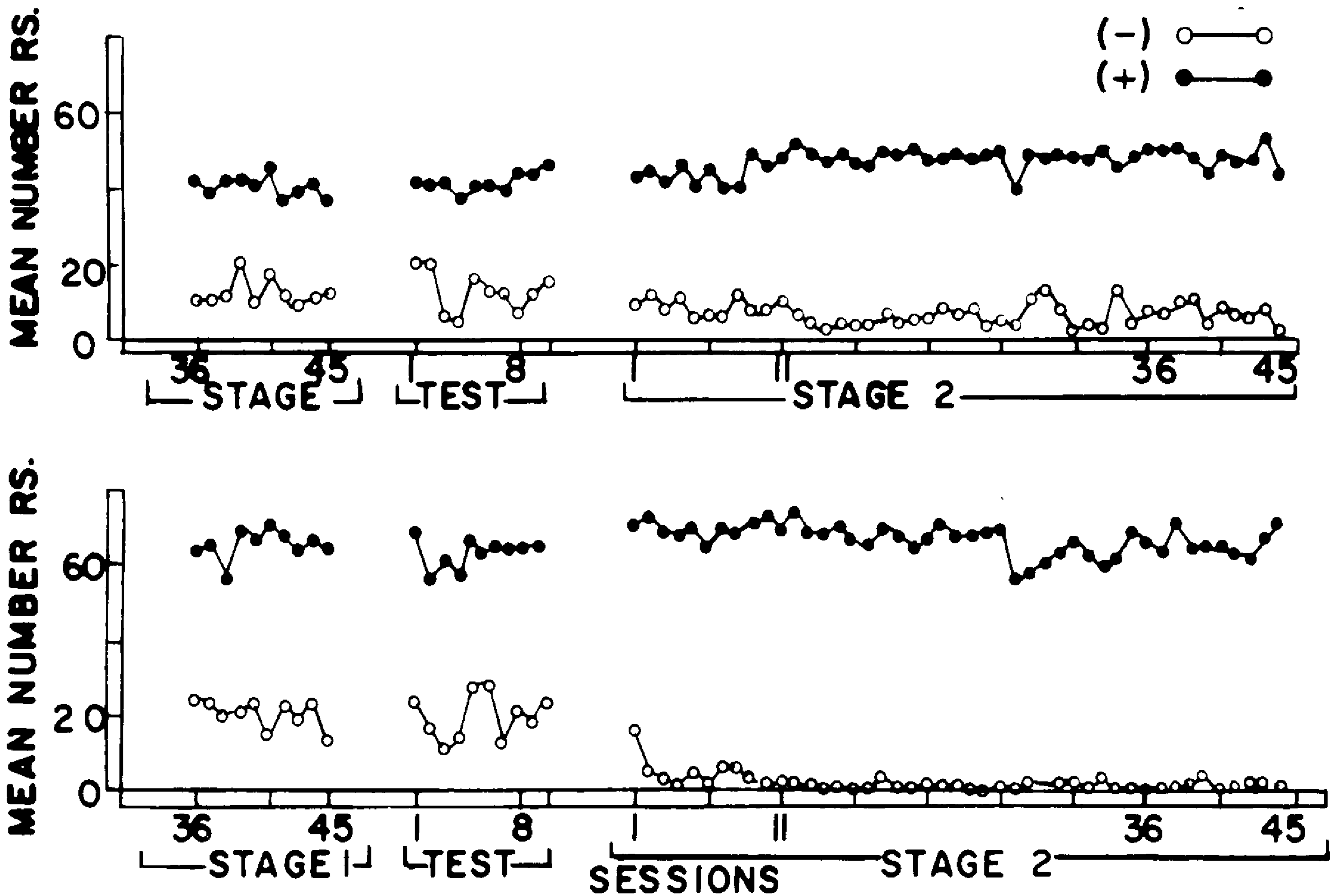
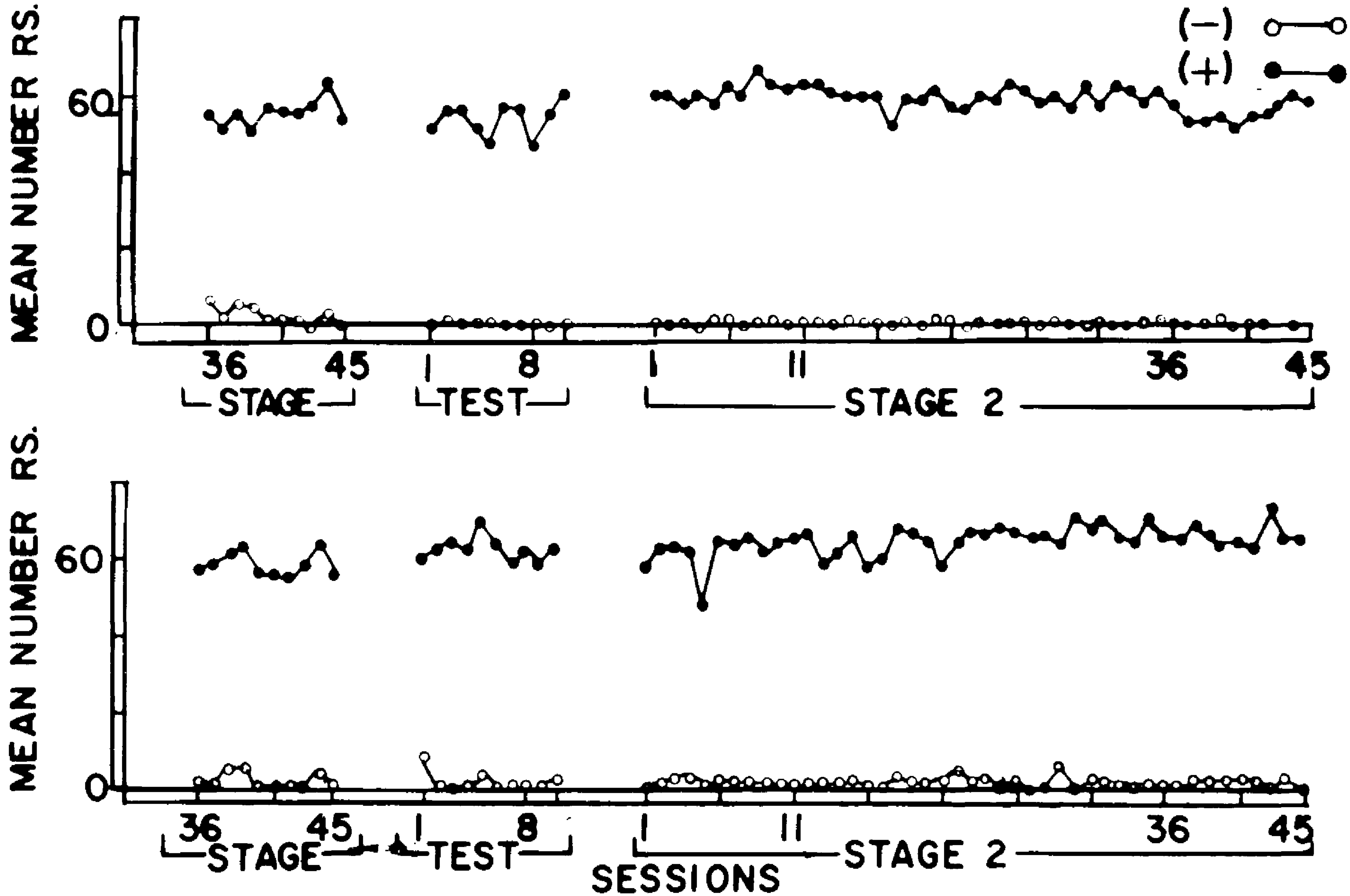

(−)
(+)
MEAN NUMBER RS
80
40
0
36
45
1
8
1
11
36
45
STAGE 1
TEST
STAGE 2
SESSIONS

Figure 10. Performance during the final 10 days of Stage 1 training, generalization testing and Stage 2 training is shown as a function of sessions of training. The mean number of responses emitted during the positive periods (filled circles) and the negative periods(open circles) are shown separately for each session. The curves showing the performance of Group F-F (four subjects) appear in Panel A. The curve showing the performance of Group F-D (four subjects) appear in Panel B.



(−)
(+)
MEAN NUMBER RS.
0
20
60
36
45
STAGE
TEST
8
STAGE 2
MEAN NUMBER RS.
0
20
60
36
45
STAGE I
TEST
1
8
11
SESSIONS
STAGE 2

Figure 11. Performance during the final 10 days of Stage 1 training, generalization testing and Stage 2 training is shown as a function of sessions of training. The mean number of responses emitted during the positive periods (filled circles) and the negative periods (open circles) are shown separately for each session. The curves showing the performance of Group T-T (four subjects) appears in Panel A. The curve showing the performance of Group T-D (four subjects) appears in Panel B.


MEAN NUMBER RS.
60
0
(−)
(+)
36
45
STAGE
1
8
TEST
1
11
36
45
STAGE 2
MEAN NUMBER RS.
60
0
36
45
STAGE
1
8
TEST
1
11
36
45
STAGE 2
SESSIONS

F (Figure 10). On the other hand, responding during the negative periods appears to have decreased slightly for Group T (Figure 11).

Figure 10 shows the results for Groups F-F and F-D. Response rates for Group F-F did not change substantially from the last ten days of Stage 1 training, through generalization testing, through Stage 2 training (see Figure 10-A). The separation between the two curves increased slightly with continued training during Stage 2, but this improvement in the discrimination is hardly noticeable.

The subjects in Group F-D, on the other hand, showed a substantial change in performance: the mean response rate during negative periods dropped close to zero (see Figure 10-B). It would appear that the additional cue provided, the correlation of tilt with reinforcement, is responsible for this decrease in response rate during negative periods.

The results for groups T-T and T-D are shown in Figure 11. As can be seen from Figure 11-A, the performance of Group T-T changed little from the end of Stage 1 throughout Stage 2. The performance of Group T-D is indistinguishable from that of Group T-T (compare Figures 11-A and 11-B). On the basis of these acquisition data it is impossible to determine whether or not the correlation of frequency with reinforcement resulted in any control of the subject's behavior by frequency.

<u>Generalization Tests 2</u>

The generalization tests given after completion of Stage 1 were repeated after the second stage of training. The results were as follows:

(a) <u>Gradients for line tilt in the presence of the 1000 cps tone</u>

The results of these tests are summarized in Table 4-A and in

Figure 12. The mean number of responses emitted in the presence of each of the eight orientations of the line presented during the test is shown for each group. The generalization gradients obtained following the first stage of training (dashed lines--open circles) and those obtained following the second stage of training (solid line--filled circles) are shown together, although the present discussion involves only a consideration of the latter.

Figure 12 shows decremental gradients with maximum rates occurring in the presence of the vertical line (tilt 90°) and mimimum rates in the presence of the horizontal line (tilt 0° or 180°) for all groups trained with tilt correlated during Stage 2. An analysis of variance (tilt vs. subjects) showed the effect of stimuli to be significant ($p < 0.01$) for all four groups.

The shape of the generalization gradient of Group F-F (Figure 12 F-F) clearly differed from the others. It suggests two decremental gradients with maxima at the vertical and horizontal lines. However, the effect of stimuli upon response rate for this group was not significant ($p > 0.05$).

(b) <u>Gradients for line tilt in the presence of the 320 cps tone</u>

The results of these tests are summarized in Table 4-B and in Figure 13. Again, decremental gradients with the peak response rates occurring in the presence of the vertical line were obtained for all groups having tilt correlated during the second stage of training.

The gradient for Group F-F (Figure 13 F-F) lies lower than that obtained in the presence of the 1000 cps tone. This was to be expected since the 320 cps tone was the negative stimulus for subjects

Figure 12. Generalization gradients on the dimension of angular orientation of the line (tilt) made in the presence of the 1000 cps tone. The gradients obtained before (dotted lines) and after (solid lines) the second stage of training are shown. The mean number of responses emitted in the presence of each of the test stimuli is plotted against stimuli. The gradients for Groups F-D, F-F, T-D, T-F and U-D appear in separate panels.

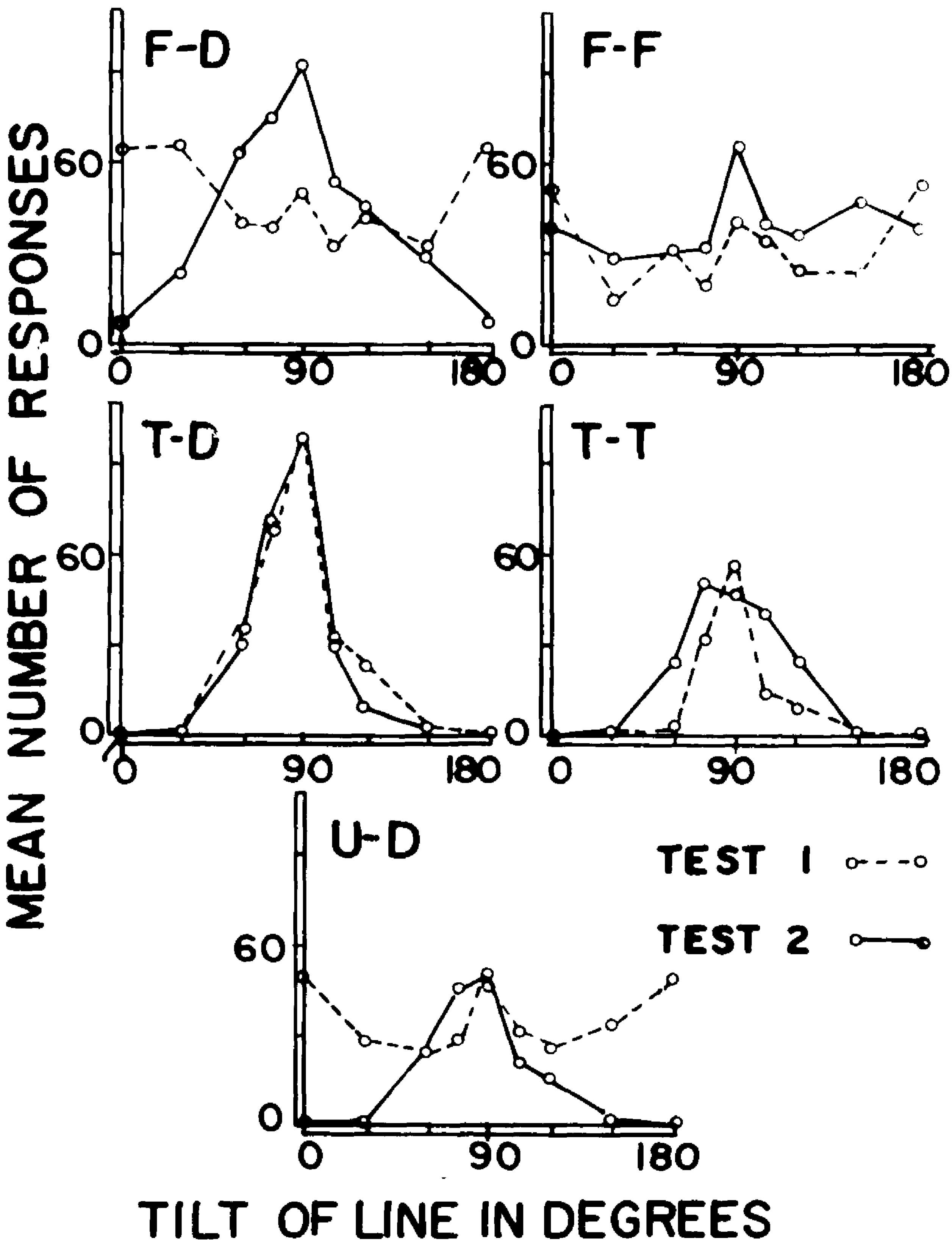

F-D
F-F
T-D
T-T
U-D
60
0
90
180
MEAN NUMBER OF RESPONSES
TILT OF LINE IN DEGREES
TEST 1
TEST 2

Figure 13. Generalization gradients on the dimension of angular orientation of the line (tilt) made in the presence of the 320 cps tone. The gradients obtained before (dotted lines) and after (solid lines) the second stage of training are shown. The mean number of responses emitted in the presence of each of the test stimuli is plotted against stimuli. The gradients for Groups F-D, F-F, T-D, T-T and U-D appear in separate panels.

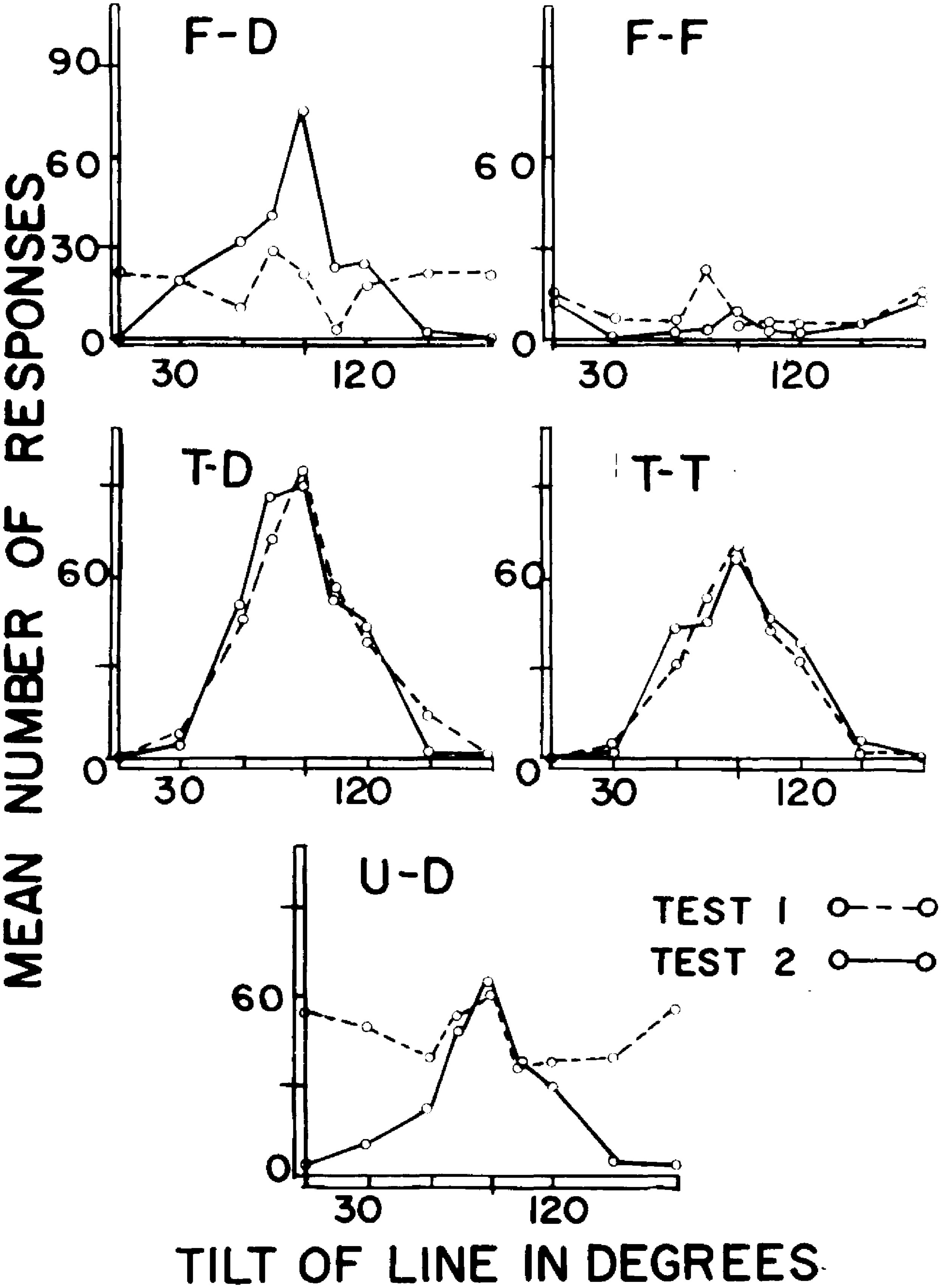

F-D
F-F
T-D
T-T
U-D
90
60
30
0
6 0
30
120
TEST 1
TEST 2
MEAN NUMBER OF RESPONSES
TILT OF LINE IN DEGREES

Table 4 - Analyses of Variance on Number of Responses Emitted in the Presence of Each of the Eight Stimuli Represented During Generalization Tests 2

A - Tilt Generalization Test in the Presence of the 1000 cps Tone

	Group U-D	Group F-D	Group T-D	Group F-F	Group T-T
F(Between Stimuli)	12.69***	4.83**	6.74***	1.96	8.68***
Degrees of Freedom	7 & 21	7 & 21	7 & 21	7 & 21	7 & 21

B - Tilt Generalization Test in the Presence of the 320 cps Tone

	Group U-D	Group F-D	Group T-D	Group F-F	Group T-T
F(Between Stimuli)	7.70***	4.03**	9.30***	1.34	13.11***
Degrees of Freedom	7 & 21	7 & 21	7 & 21	7 & 21	7 & 21

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

in this group. Enough responses, however, were emitted to show maxima in the presence of the vertical and horizontal lines. Again two decremental gradients are suggested.

The results of the analyses of variance (Table 4-B) show the effect of stimuli upon response rate to be significant ($p < 0.01$) for all but Group F-F.

(c) Gradients for tonal frequency in the presence of the vertical line

The generalization gradients for frequency in the presence of the vertical line appear as solid lines in Figure 14. The gradients, mean number of responses against stimuli, are shown for each group separately. The results of the analyses of variance (frequency vs. subjects) for the effect of stimuli upon response rate are summarized in Table 5-A.

Group F-F (Figure 14 F-F) shows a clear decremental gradient with the maximum response rate occurring in the presence of the 1000 cps tone, the positive stimulus for this group, and the minimum rate in the presence of the 320 cps tone, the negative stimulus. For this group the effect of stimuli upon response rate was significant ($p < 0.001$).

The gradient for Group F-D (Figure 14 F-D) suggests the decremental gradient found previously for this group. However the effect of stimuli upon response rate failed to be significant ($p > 0.05$). Examination of the individual gradients shows the gradients of two of the birds to be clearly decremental in shape, while those of the other two birds are very irregular. Performance of the latter two birds on the tilt-tests, however, gives evidence that frequency continued to exert a differential effect on their performance. These birds responded substantially more during the tilt-test made in the presence of the 1000 cps tone than during the test made in the presence of the 320 cycle tone.

Figure 14. Generalization gradients on the dimension of tonal frequency (cps) made in the presence of the vertical line. The gradients obtained before (dotted lines) and after (solid lines) the second stage of training are shown. The mean number of responses emitted in the presence of each of the test stimuli is plotted against stimuli. The gradients for Groups F-D, F-F, T-D, T-T and U-D appear in separate panels.

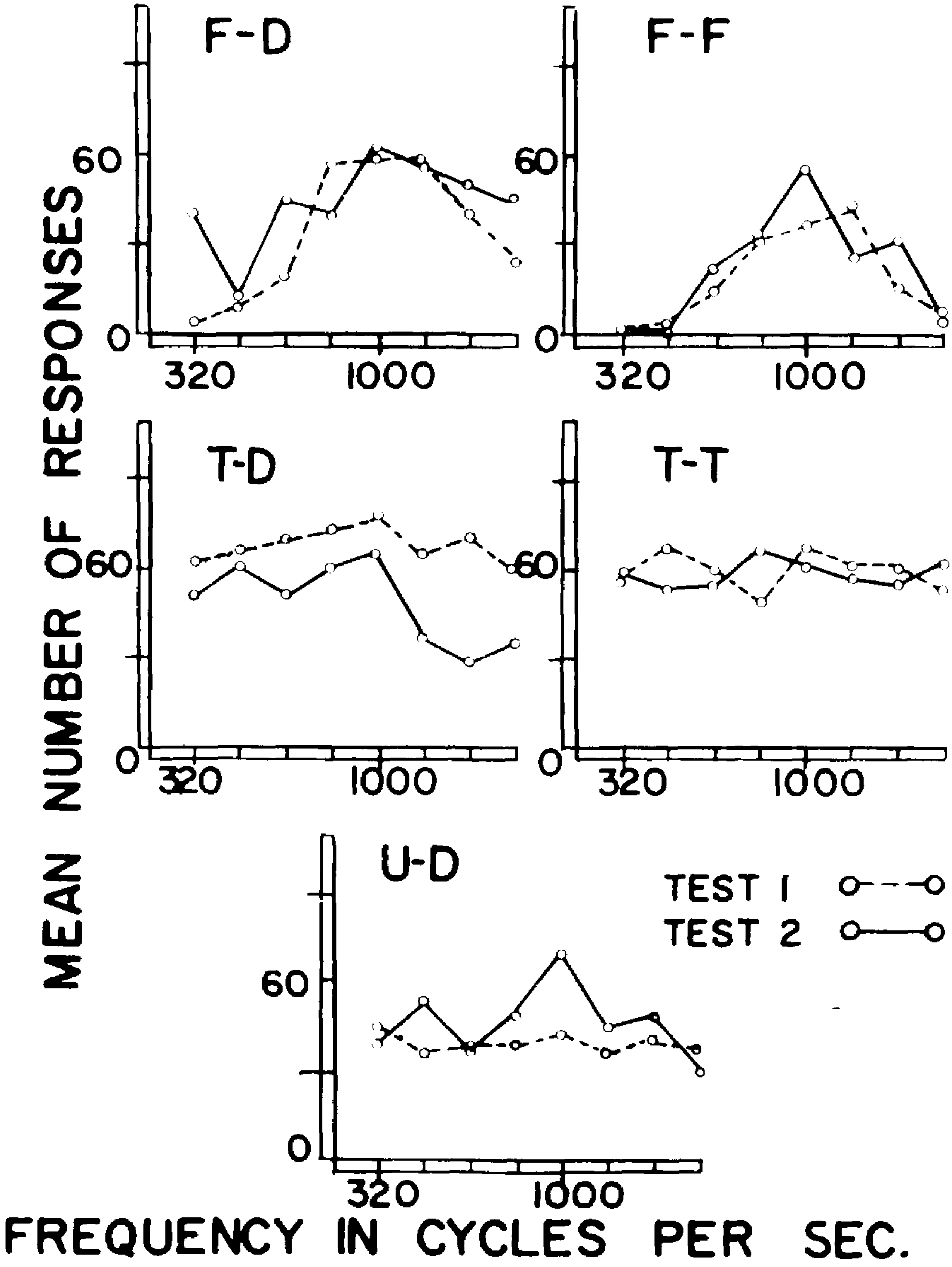

F-D
F-F
T-D
T-T
U-D
MEAN NUMBER OF RESPONSES
60
0
320
1000
TEST 1
TEST 2
FREQUENCY IN CYCLES PER SEC.

Figure 15. Generalization gradients on the dimension of tonal frequency (cps) made in the presence of the horizontal line. The gradients obtained before (dotted lines) and after (solid lines) the second stage of training are shown. The mean number of responses emitted in the presence of each of the test stimuli is plotted against stimuli. The gradients for Groups F-D, F-F, T-D, T-T and U-D appear in spearate panels.

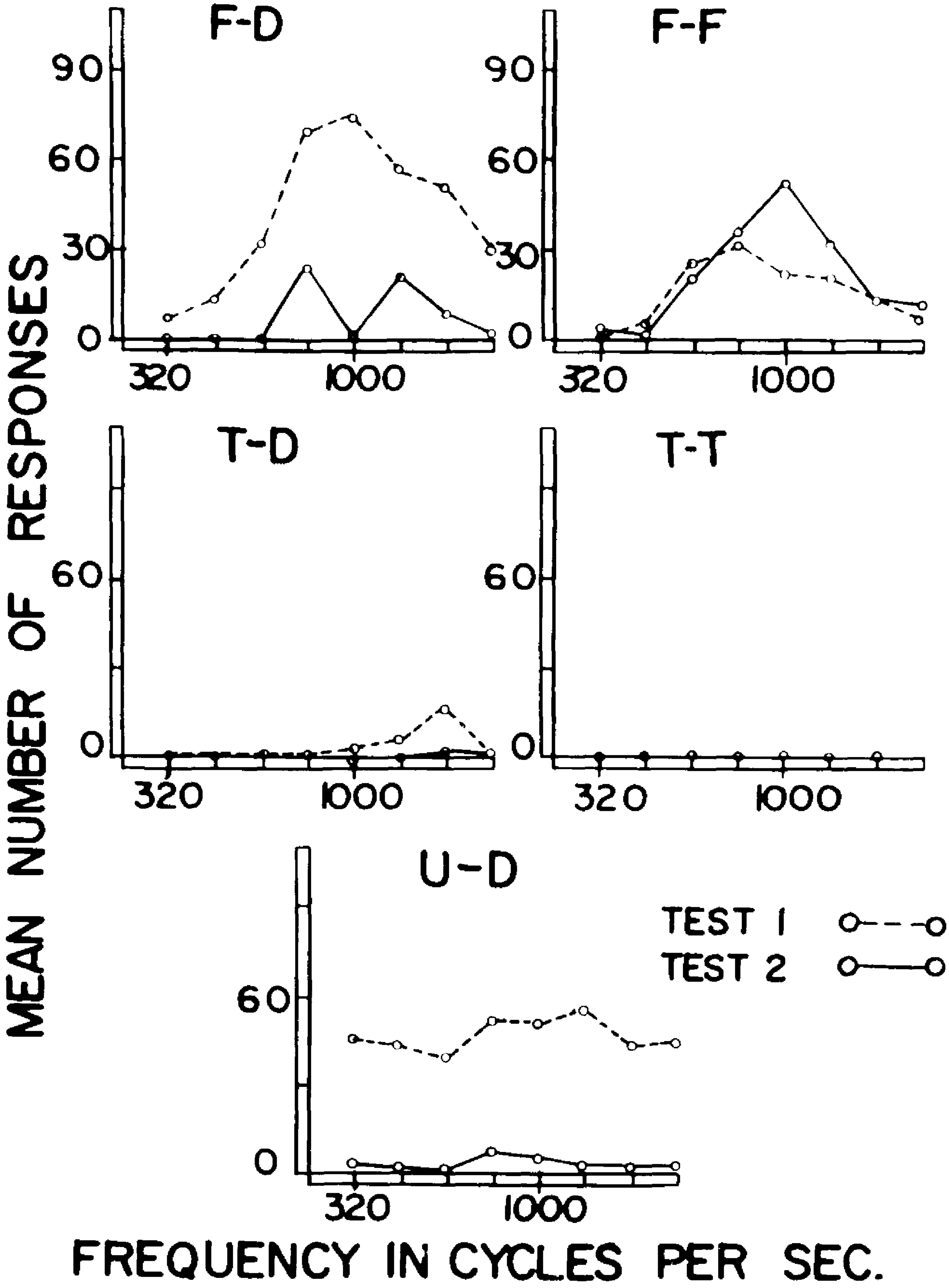

F-D
F-F
T-D
T-T
U-D
90
60
30
0
320
1000
MEAN NUMBER OF RESPONSES
TEST 1
TEST 2
FREQUENCY IN CYCLES PER SEC.

Table 5 - Analyses of Variance on Number of Responses Emitted in the Presence of Each of the Eight Stimuli Presented During Generalization Tests 2

A - Frequency Generalization Test in Presence of the Vertical Line

	Group U-D	Group F-D	Group T-D	Group F-F	Group T-T
F(Between Stimuli)	2.65*	2.22	1.52	7.00***	0.36
Degrees of Freedom	7 & 21	7 & 21	7 & 21	7 & 21	7 & 21

B - Frequency Generalization Test in Presence of the Horizontal Line

	Group U-D	Group F-D	Group T-D	Group F-F	Group T-T
F(Between Stimuli)	2.06	1.89	--	3.95**	--
Degrees of Freedom	7 & 21	7 & 21	7 & 21	7 & 21	7 & 21

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

The gradients for Group T-D and Group T-T are essentially horizontal lines as shown by the analysis of variance (Table 5-A) and the graphs for these groups (Figures 14 T-D and T-T). The correlation of frequency with reinforcement following training with frequency uncorrelated, tilt correlated does not seem to result in differential responding to frequency.

The peak response rate for Group U-D (Figure 14 U-D), on the other hand, occurred in the presence of the 1000 cps tone. The analysis of variance performed on these data showed a significant ($p < 0.05$) effect of stimuli upon response rate. Correlation of both frequency and tilt following training with these stimuli uncorrelated seems to result in control by frequency as well as by tilt.

(d) Gradients for tonal frequency in the presence of the horizontal line

The results of these tests are summarized in Figure 15 and in Table 5-B. The gradients for Group T-D (Figure 15 T-D) and Group T-T (Figure 15 T-T) are horizontal lines. Analyses of variance were not made on the data for these two groups since almost no responses occurred during the tests.

The gradient for Group U-D (Figure 15 U-D) is also essentially flat. The effect of stimuli upon response rate for this group was found to be insignificant ($p > 0.05$).

While the gradient for Group F-D (Figure 15 F-D) did not show control by frequency, it should be noted that of the three double correlated groups, subjects in Group F-D responded most during the test. In discrimination performance fewer responses were emitted by these subjects during negative periods than by subjects in Group U-D (compare

Figures 9 and 10-B). The horizontal line plus the 320 cps tone seems to "suppress" responding during negative periods more effectively than the horizontal line alone.

The gradient for Group F-F (Figure 15 F-F) is clearly decremental with the maximum number of responses occurring in the presence of the 1000 cps tone. For this group the effect of stimuli upon response rate was significant ($p < 0.01$).

Comparison of Generalization Gradients Before and After the Second Stage of Training

Of primary interest in the present experiment is the effect of correlating a pair of stimuli with positive and negative periods after a discrimination has already been established on the basis of another set of stimuli. Since the analysis of these effects is based in part upon a comparison of the gradients obtained at the end of Stages 1 and 2, it is necessary to consider the effects upon the generalization gradients of the continued training during Stage 2 and the previous testing. These effects will be considered first. In the next section the effects of "double correlation" upon the shape of the gradient for the stimulus dimension correlated with reinforcement from the beginning of Stage 1 will be taken up. This will be followed finally by a discussion of the effects of "double correlation" upon the gradient for the previously uncorrelated stimulus dimension.

(a) Effects of generalization testing and continued training on the shape of the generalization gradients for tilt and for frequency

In the case of the gradient for tilt the effect of giving a generalization test followed by a period of further discrimination training without any change in the experimental conditions may be seen by examining the two tilt gradients for group T-T. The gradients for this group obtained in the presence of the 1000 cps tone are shown in Figure 12 T-T. The gradients obtained in the presence of the 320 cps tone are shown in Figure 13 T-T. Analyses of variance (stimuli x tests x subjects) were performed on these data and the results are shown in Table 6. The differences between the gradients following Stage 1 (dotted lines) and Stage 2 (solid lines) were not significant. In Table 6 this is shown as an insignificant F for the interaction between tests and stimuli.

In the case of the gradient for tonal frequency, a comparable analysis may be made on the basis of the two sets of gradients obtained for Group F-F. The frequency gradients for this group, before and after the second stage of training, appear in Figures 14 F-F and 15 F-F. The former is the frequency gradient in the presence of the vertical line; the latter is the gradient in the presence of the horizontal line. It will be seen that the gradients following the second stage of training are slightly sharper. While this difference in shape was not statistically significant, the generalization gradients and the discrimination data (see Figure 10-A) both suggest that continued training during Stage 2 sharpens stimulus control by tonal frequency.

The discrepancy between these findings and those for the dimension of tilt reflects the fact that for the tonal stimuli the response rates had not reached asymptotic levels at the end of the first stage of training, while for the visual stimuli they had.

(b) <u>Effects of "double correlation" upon the shape of the gradient for the stimulus dimension correlated with reinforcement throughout training</u>

Consider first the results of Group T-D, the group that was trained

Table 6 - <u>Comparison of Tilt Generalization Gradients Before and After the Second Stage of Training</u>

A - <u>Tilt Generalization Test in the Presence of the 1000 cps Tone</u>

Group	F (Between Blocks)	df	F (Between Stimuli)	df	F (Interaction tests x Stimuli)	df
F-D	0.09	1, 3	2.53*	7, 21	5.89**	7, 21
T-D	1.45	1, 3	9.97***	7, 21	0.28	7, 21
T-T	4.06	1, 3	11.01***	7, 21	2.21	7, 21

A - <u>Tilt Generalization Test in the Presence of the 320 cps Tone</u>

Group	F (Between Blocks)	df	F (Between Stimuli)	df	F (Interaction Tests x Stimuli)	df
F-D	4.20	1, 3	3.07*	7, 21	2.42	7, 21
T-D	0.09	1, 3	8.50***	7, 21	0.89	7, 21
T-T	0.07	1, 3	19.98***	7, 21	0.70	7, 21

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

to discriminate between two tilted lines first, and was then given "double correlation" training. The gradients for tilt, determined before and after "double correlation", are almost identical for this group. This is true of the test given in the presence of the 1000 cps tone (Figure 12 T-D) and that given in the presence of the 320 cps tone (Figure 13 T-D). The analysis of variance (Table 6) performed on these data confirms the absence of any change; the F for interaction of tests by stimuli was less than 1 in both cases. It appears that the tilt gradient was not affected by the introduction of the two correlated auditory stimuli during Stage 2 of training. Comparison with the results of Group T-T, discussed earlier in this section, supports this conclusion. It was shown that continued training and the effects of earlier tests did not change the gradient for Group T-T. Had there been a sharpening in the gradients for this control group one would not be able to conclude that introduction of the correlated auditory stimuli did not affect the tilt gradient.

The effect of "double correlation" upon the frequency gradient for Group F-D may be evaluated by examining the generalization gradients for this group (Figures 14 F-D and 15 F-D). Consider first the frequency generalization gradient obtained in the presence of the vertical line (Figure 14 F-D)) The gradient for Group F-D before "double correlation" was clearly decremental. The correlation of the visual stimuli seems to have resulted in a flattening of the gradient although the auditory stimuli remained correlated. In contrast, the results of Group F-F, suggest that continued training with frequency correlated but tilt uncorrelated results in a sharpening of the frequency gradient. A three-way analysis of variance performed on these data (Table 7) showed the effect of stimuli upon response rate for both groups considered together to be signif-

Table 7 - Comparison of the Frequency Generalization Gradients Before and After the Second Stage of Training

A- Frequency Generalization Test in the Presence of the Vertical Line

Group	F Between Blocks	df	F Between Stimuli	df	F Interaction Tests X Stimuli	df
F_D	1.14	1 3	4.76**	7 21	1.47	7 21
T_D	7.20	1 3	1.48	7 21	0.80	7 21
F_F	0.12	1 3	10.14***	7 21	1.45	7 21

B - Frequency Generalization Test in Presence of the Horizontal Line

Group	F Between Blocks	df	F Between Stimuli	df	F Interaction Tests X Stimuli	df
F_D	0.35	1 3	4.59**	7 21	1.72	7 21

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

icant ($p < 0.01$). Although the gradient following "double correlation" looks flatter, this change in the gradient, as shown by the interaction between tests and stimuli, was not significant ($p > 0.05$).

The effect of "double correlation" upon the frequency gradient for Group F-D is much more clear on the test made in the presence of the horizontal line (Figure 15 F-D) than on the test made in the presence of the vertical line (Figure 14 F-D). In the latter case a flattening of the gradient is suggested. In the former case no evidence of control by frequency is seen, i.e, almost no responses occurred in the presence of the positive stimulus, the 1000 cps tone. This merely reflects the fact that the shape of the generalization gradient is not an "abstract" measure of control by a given stimulus dimension. It is, rather, a reflection of control by the dimension in a particular situation.

(c) Effects of "double correlation" upon the shape of the gradient for the previously uncorrelated stimulus dimension

Groups T-D and F-D were given very similar experimental treatments. The only difference was whether the auditory or visual stimuli were correlated with reinforcement during Stage 1 of training. The effects of Stage 2 training upon the shape of the gradient for the previously uncorrelated stimulus dimension will be considered first for Group T-D.

An inspection of Figures 14 T-D and 15 T-D shows no clear effect upon the frequency gradient of correlating the auditory stimuli with reinforcement following training with the visual stimuli correlated. Response rates were not differentially affected by the auditory stimuli either before or after "double correlation" training. These observations are borne out by the analysis of variance performed on these data (see Tables 5 and 7-A).

Where tilt was the uncorrelated dimension during Stage 1, as was the case for Group F-D, the effects of "double correlation" are quite different. The correlation of tilt with reinforcement during Stage 2 led to a dramatic change in the shape of the gradient for this dimension. This is seen both in the presence of the 1000 cps tone (Figure 12 F-D) and the 320 cps tone (Figure 13 F-D). An analysis of variance showed this change to be significant ($P < 0.01$) in the former case. In the latter case this change approached significance at the .05 confidence level (Table 6). The relatively flat but double peaked gradients found at the end of Stage 1, gave way to clear <u>single</u> peaked gradients with maximum response rates in the presence of the vertical line. That frequency as well as tilt exerted control over the subject's behavior is shown by the fact that substantially more responses occurred on the tilt-test made in the presence of the positive auditory stimulus (Figure 12 F-D) than on that made in the presence of the negative one (Figure 13 F-D).

Comparison of Generalization Gradients Following "Double Correlation" Training

To evaluate the effects of Stage 1 training upon the development of stimulus control following training with both dimensions correlated the generalization gradients of Groups U-D, F-D and T-D were compared.

The gradients obtained on the tilt generalization tests will be considered first. Figure 16 is a plot of the mean number of responses emitted in the presence of each of the eight line orientations during the tests made in the presence of the 1000 cps tone. Although the gradients were obtained following identical Stage 2 training, it appears that the Stage 1 training condition does affect the shape of the tilt-gradient. The gradients were ordered in steepness with the steepest gradient produced by subjects in Group T-D. The gradient for Group U-D was intermediate in steepness while that of Group F-D was flattest. An analysis of variance (groups x stimuli x subjects) performed on these data shows the differences in the shapes of these curves to be insignificant (F = .898, with 14 and 63 df, P > 0.05).

Figure 17 is a plot of the per cent of the total number of responses emitted in the presence of each of the test stimuli. The same ordering among the gradients is seen but the differences are less marked. Inspection of the individual data showed that the two subjects in Group F-D whose response rates were highest yielded the flattest gradients. Thus, these subjects contributed disproportionately to the gradient for Group F-D that appears in Figure 16.

The results of the tilt generalization tests given in the presence of the 320 cps tone appear in Figure 18. The ordering in the steepness of the tilt-gradients made in the presence of the 1000 cps tone is not recovered here.

Figures 19 and 20 make possible a comparison of the performance of Groups U-D, F-D and T-D on the frequency generalization tests in the presence of the vertical line. Figure 19 is a plot of the mean number of responses against stimuli. Figure 20 shows the percentage of the total number of responses emitted in the presence of each of the test stimuli. An analysis of variance (groups x stimuli x subjects) did not show a significant difference in the shape of these three curves (F = 1.685, with 14 and 63 df, P > 0.05). However, while the hypothesis that the differences in shape observed were due to chance could not be rejected at the .05 confidence level, the probability was less than .10 that these were chance differences.

Figure 21 shows the frequency gradients of Groups U-D, F-D and T-D obtained in the presence of the horizontal line. The horizontal line was the negative stimulus for all three groups following Stage 2 training. Since so few responses were made during the test, possible differences in shape could not be evaluated by an analysis of variance.

Figure 16. Comparison of performance of Groups U-D (solid lines, open circles), F-D (dashed lines, filled circles) and T-D (dotted lines, triangles) on the tilt generalization test in the presence of the 1000 cps tone. Performance on the tests following Stage 2 training is shown. The mean number of responses emitted in the presence of each of the angular orientations of the line presented during testing is plotted against these test stimuli.

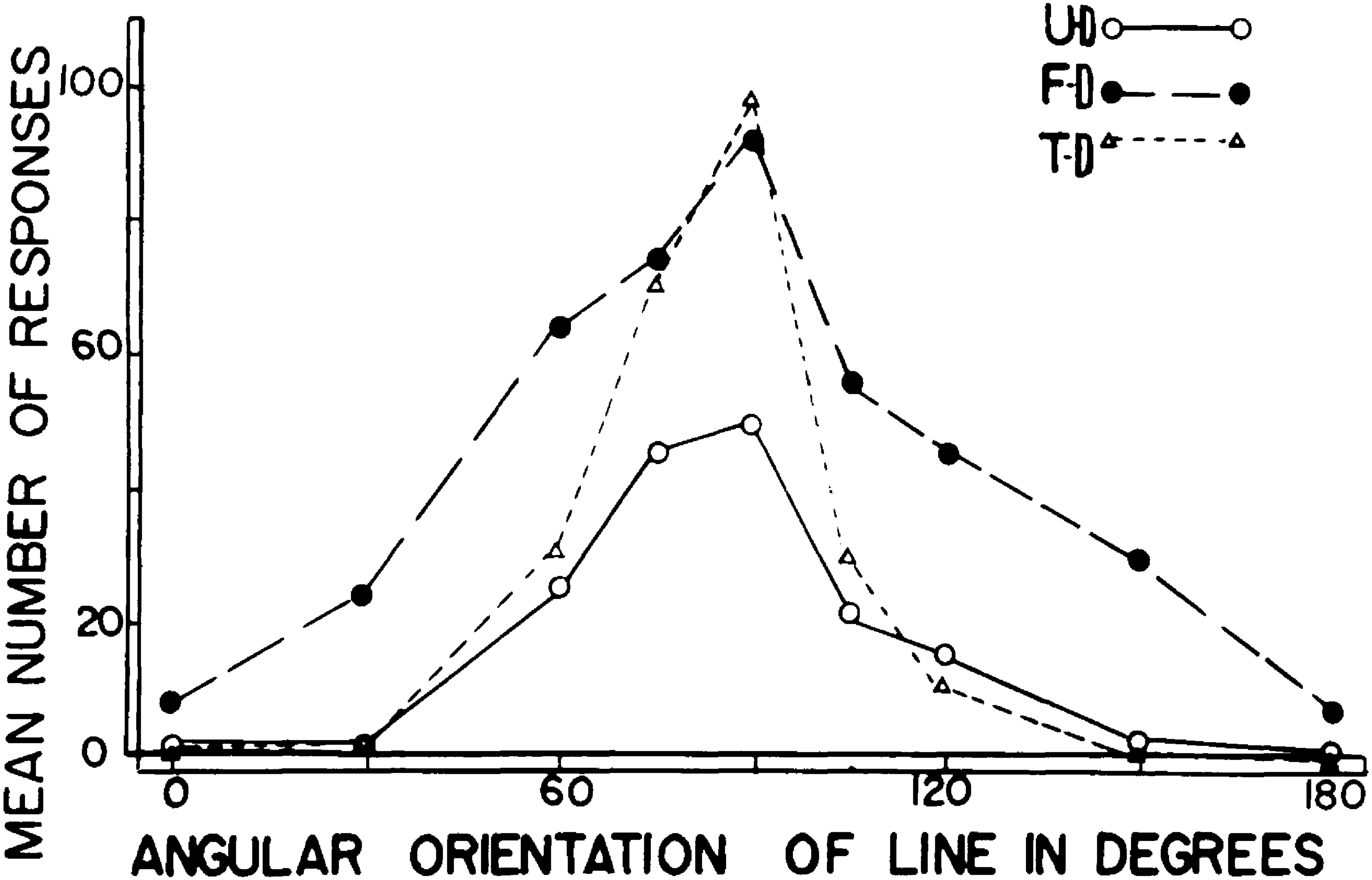
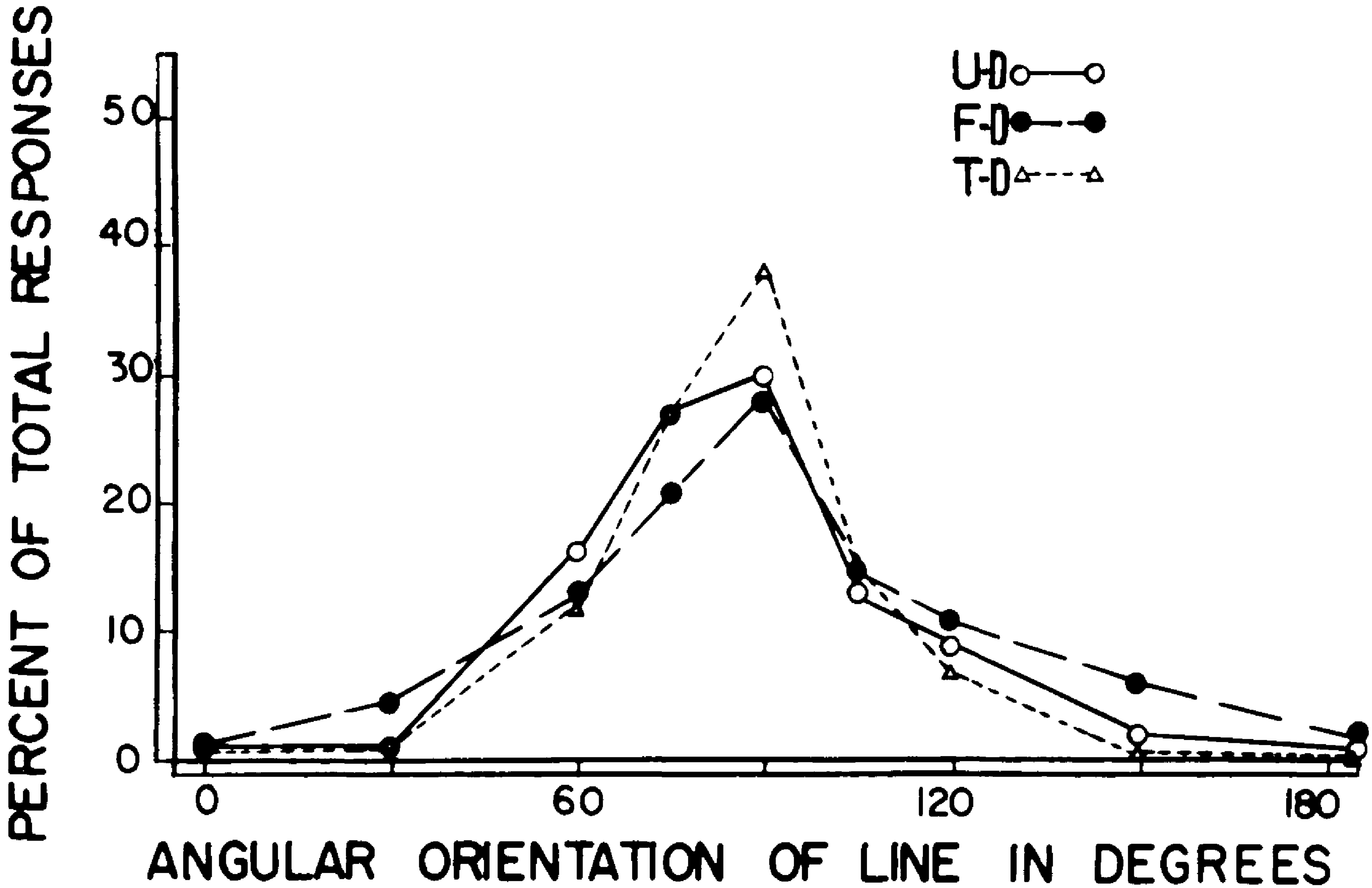

U-D
F-D
T-D
MEAN NUMBER OF RESPONSES
100
60
20
0
0
60
120
180
ANGULAR ORIENTATION OF LINE IN DEGREES

Figure 17. Comparison of performance of Groups U-D (solid lines, open circles), F-D (dashed lines, filled circles) and T-D (dotted lines, triangles) on the tilt generalization test in the presence of the 1000 cps tone. Performance on the tests following Stage 2 training ("double correlation" for these three groups) is shown. The per cent of the total number of responses emitted during the test in the presence of each of the test stimuli is plotted against these test stimuli.

59a



U-D
F-D
T-D
PERCENT OF TOTAL RESPONSES
50
40
30
20
10
0
0
60
120
180
ANGULAR ORIENTATION OF LINE IN DEGREES

Figure 18. Comparison of performance of Groups U-D (solid lines, open circles), F-D (dashed lines, filled circles) and T-D (dotted lines, triangles) on the tilt generalization test in the presence of the 320 cps tone. Performance on the tests following Stage 2 training ("double correlation" for these three groups) is shown. The mean number of responses emitted in the presence of each of the angular orientations of the line presented during testing is plotted against these test stimuli.

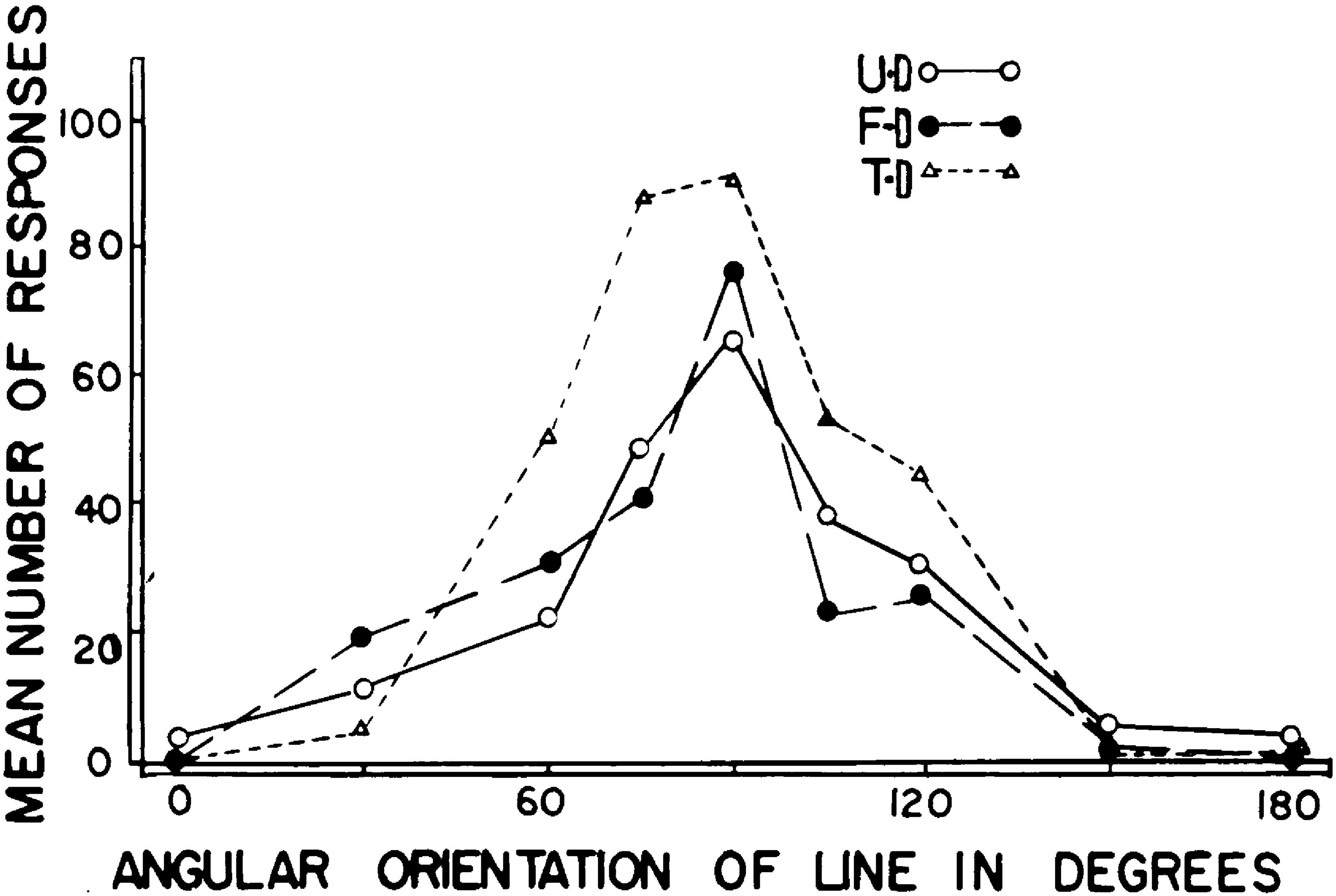

MEAN NUMBER OF RESPONSES
100
80
60
40
20
0
0
60
120
180
ANGULAR ORIENTATION OF LINE IN DEGREES
U-D
F-D
T-D

Figure 19. Comparison of the performance of Groups U-D (solid lines, open circles), F-D (dashed lines, filled circles) and T-D (dotted lines, triangles) on the frequency generalization test in the presence of the vertical line. Performance on the tests following Stage 2 training ("double correlation" for these three groups) is shown. The mean number of responses emitted in the presence of each of the tones presented during testing is plotted against these test stimuli.

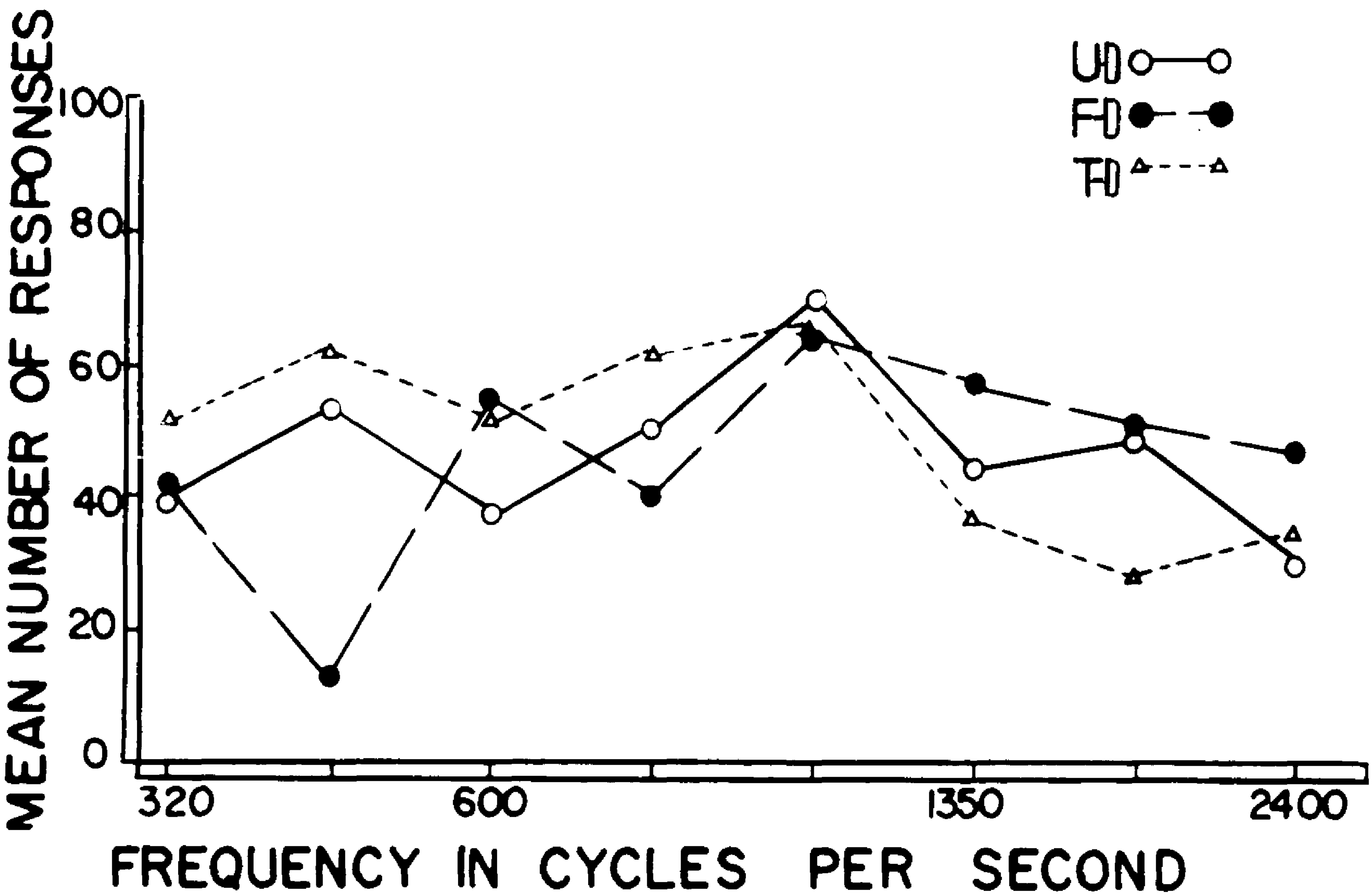

UD
FD
TD
100
80
60
40
20
0
MEAN NUMBER OF RESPONSES
320
600
1350
2400
FREQUENCY IN CYCLES PER SECOND

Figure 20. Comparison of the performance of Groups U-D (solid lines, open circles), F-D (dashed lines, filled circles) and T-D (dotted lines, triangles) on the frequency generalization test in the presence of the vertical line. Performance on the tests following Stage 2 training ("double correlation" for these three groups) is shown. The per cent of the total number of responses emitted during the test in the presence of each of the test stimuli is plotted against these test stimuli.

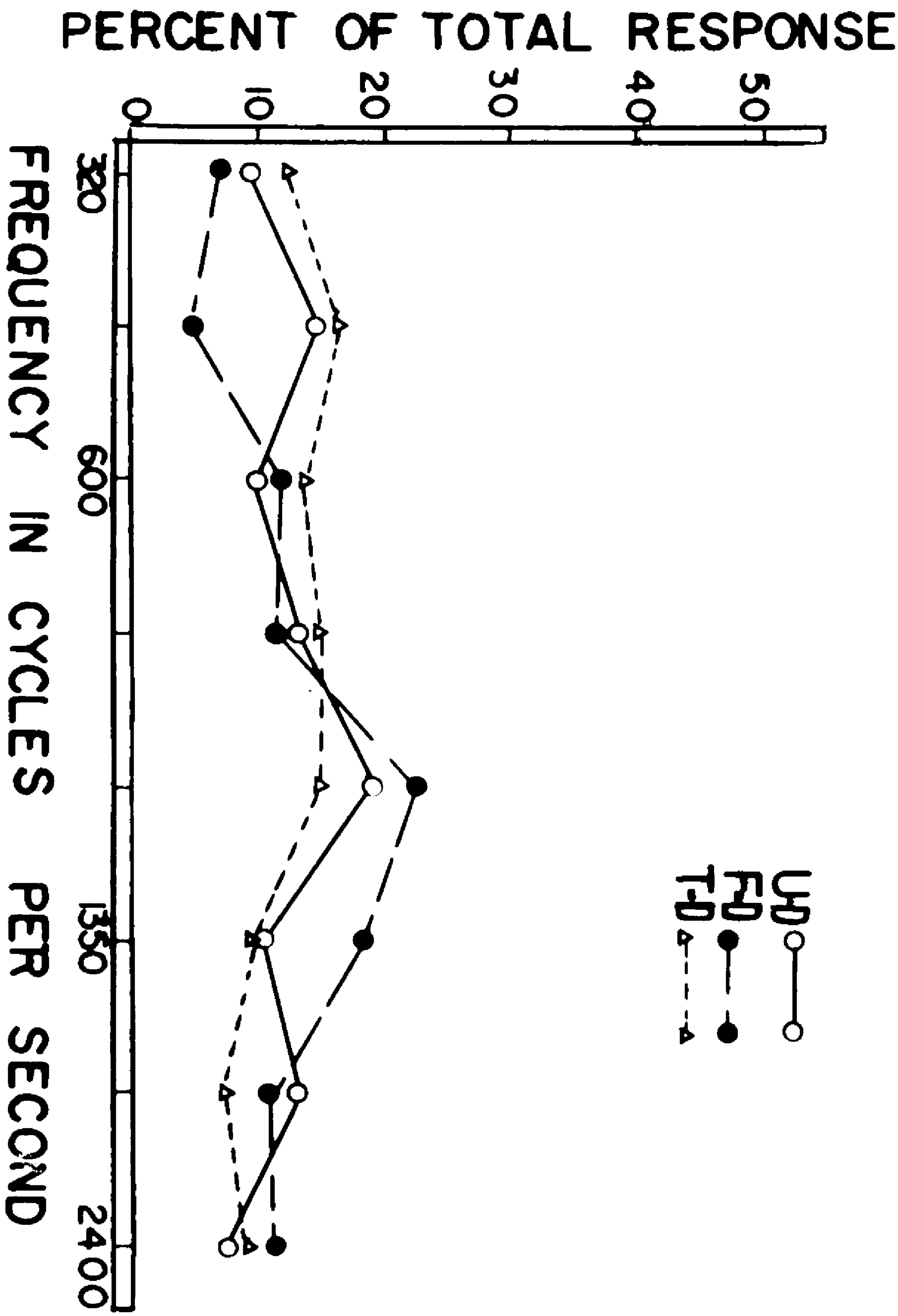
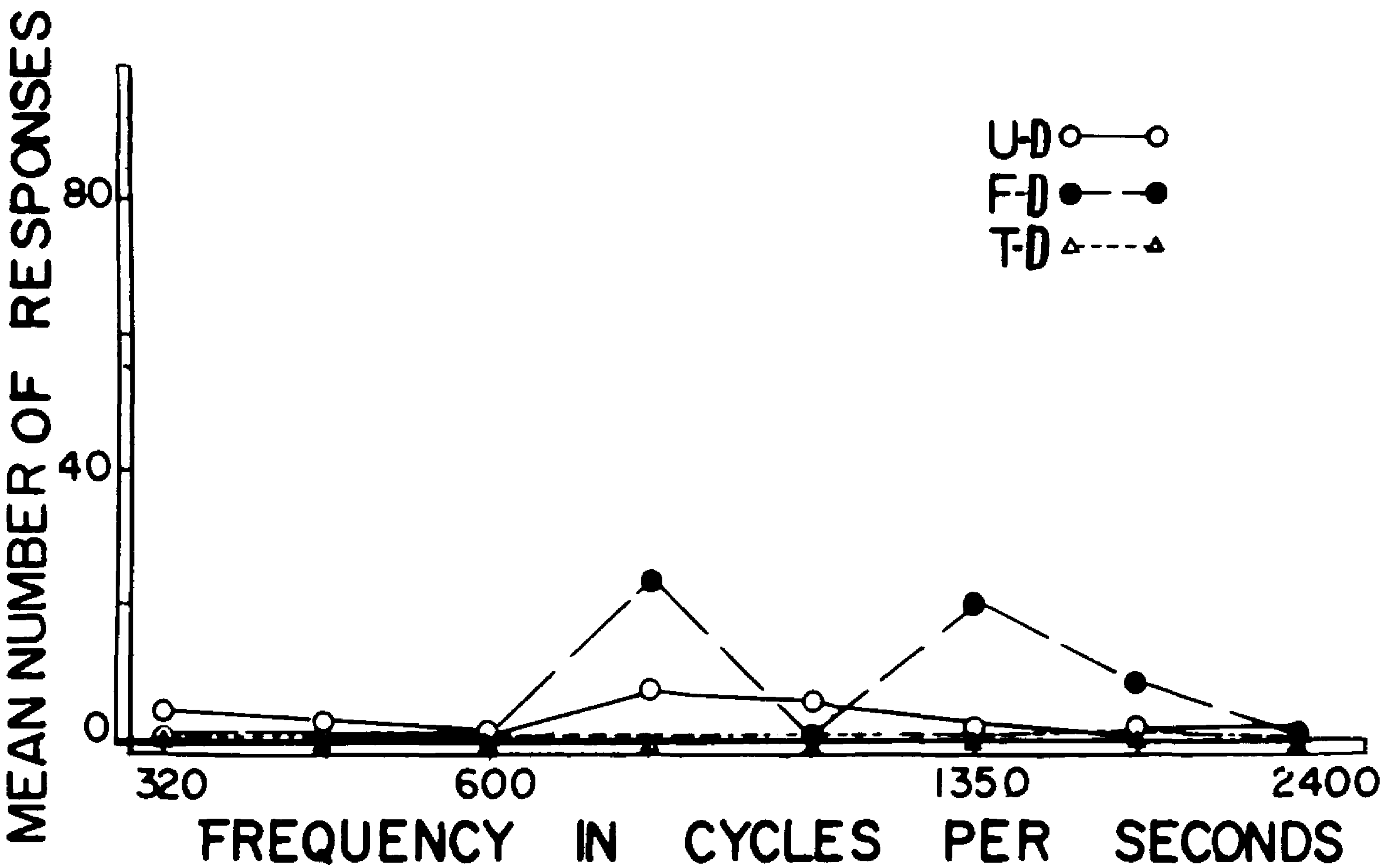

PERCENT OF TOTAL RESPONSE
0
10
20
30
40
50
FREQUENCY IN CYCLES PER SECOND
320
600
1350
2400
UD
FD
TD

Figure 21. Comparison of the performance of Groups U-D (solid lines, open circles), F-D (dashed lines, filled circles) and T-D (dotted lines, triangles) on the frequency generalization test in the presence of the horizontal line. Performance on the tests following Stage 2 training ("double correlation" for these three groups) is shown. The mean number of responses emitted in the presence of each of the tones presented during testing is plotted against these test stimuli.


MEAN NUMBER OF RESPONSES
80
40
0
U-D
F-D
T-D
320
600
1350
2400
FREQUENCY IN CYCLES PER SECONDS

DISCUSSION

The experimental design provided for perfect symmetry in the treatment of the two stimulus dimensions. The lack of symmetry in the <u>effects</u> of this treatment is the most striking finding of the experiment. During the first stage of training, perfect correlation of the two values on either stimulus dimension with positive and negative periods did lead to control of key pecking by this dimension. The effect of the subsequent introduction of an additional stimulus dimension, also perfectly correlated with reinforcement, was seen to depend upon the stimuli involved. Control by tonal frequency did not preclude the development of control by tilt, but control by tilt did preclude the development of control by frequency. The latter case will be discussed first.

Following "double correlation" training, Group T-D, the group trained with tilt correlated during Stage 1, failed to show any evidence of control by tonal frequency. Variation in the frequency of the tone over a wide range--from 320 to 2400 cps--did not affect response rate. Yet control by frequency was seen in the behavior of another group of subjects, Group U-D. This group was treated in all respects like Group T-D <u>except</u> that neither tilt nor tonal frequency was correlated with reinforcement preceding "double correlation" training. In addition, control by frequency was also shown in the behavior of Group F. These subjects were trained with frequency correlated, tilt uncorrelated for the length of time (45 days) that the above two groups were given "double correlation" training. Thus, the present experiment provides evidence for "selectivity" in the control of behavior by tonal frequency following training during which the two tones were perfectly correlated with presence and absence of reinforcement respectively. It is just such selectivity in stimulus control which is frequently referred to as "attention" or explained as due to the effects of "selective attention" during training.

The importance of differential reinforcement in the development of stimulus control has already been discussed. The conditions presumed to insure the occurrence of differential reinforcement with respect to the two tones were provided during Stage 2 for Groups T-D and U-D. Nonetheless, tonal frequency failed to gain control over the behavior of Group T-D. Perhaps differential reinforcement under some conditions is not a sufficient condition for the development of stimulus control. It is this sort of finding that has led some investigators to postulate the existence of some sort of "filtering" mechanism which blocks the development of control by certain stimuli under certain circumstances. Selective stimulus control has been attributed to such processes as the development of "observing responses" (Wyckoff, 1952), "receptor orienting responses" (Spence, 1960), "attentional responses" (Zeaman and House, 1963; Lovejoy, 1965), "mediating responses" (Kendler and Kendler, 1962) as well as processes such as "learning to switch in the relevant analyzer" (Sutherland, 1959). These accounts may be called for in some cases. However, a closer examination of the present data shows that they may perhaps be accounted for without invoking any such processes.

The effect upon response rate of Stage I training with tilt as the correlated dimension was dramatic. Early in training the number of responses emitted during negative periods, that is in the presence of the horizontal line, dropped nearly to zero and remained there through all subsequent training. This then was the situation during Stage 2, when two tones of different frequency were correlated with reinforcement, and thus were given the potential of serving as discriminative stimuli. As a result, while the 320 cps tone was present during all negative periods, the earlier training made differential reinforcement in regard to frequency negligible. Since very few responses were emitted during negative periods, non-reinforcement of the response in the presence of the negative tone rarely occurred. Reinforcement did occur in the presence of the positive tone, but, as discussed previously, reinforcement in the presence of the positive stimulus alone does not appear to be a sufficient condition for the development of stimulus control.

In the case of Group U-D, on the other hand, the two tones were correlated with reinforcement at a time when responding during negative periods was high. Responses were emitted by subjects in this group in the presence of the negative tone as well as in the presence of the positive one. Effective differential reinforcement was provided and, as a subsequent generalization test showed, the behavior came under the control of tonal frequency.

The above suggestion that the amount of effective differential reinforcement is of major importance in the development of stimulus control is supported by a consideration of the behavior of Group F. The frequency gradient obtained following Stage 1 for Group F is steeper than the gradient obtained following Stage 2 for Group U-D. These two groups had an equal number of trials during which frequency was correlated with reinforcement. Yet, sharper control by frequency resulted from training with only the frequency dimension correlated. One possible explanation is that Group U-D had previous experience with frequency uncorrelated, and that this in some way reduced the effectiveness of later correlation of this dimension with reinforcement. This possibility cannot be ruled out. However, the effect may well have resulted from differences in the amount of effective differential reinforcement with respect to the dimension of tonal frequency. Introduction of tones and tilts together as discriminative stimuli resulted in a faster reduction of response rate during negative periods than the introduction of tones alone. No doubt this reflects the fact that discriminations based on tilt alone develop much more rapidly than discriminations based on frequency alone. The important point is that Group U-D made fewer unreinforced responses in the presence of the negative tone than Group F. In this sense Group U-D may be said to have had less differential reinforcement than Group F.

The outcome of the Newman and Baron (1965) experiment described previously may also be analyzed in these terms. It will be recalled that control of the behavior by angular orientation was demonstrated following training in which <u>only</u> presence-absence of a vertical line was differentially associated with reinforcement. A group treated identically, but with color also differentially associated with reinforcement, did not respond differentially to angular orientation of the line during generalization testing.

In his analysis of these results Baron (1965) suggests that color is higher in the pigeon's "cue attending hierarchy". "Attention" was drawn to tilt only if tilt stimuli were associated with presence and absence of reinforcement while color stimuli were not. Such training conditions result, it is suggested, in a "modification of the attending hierarchy." A more parsimonious account may be possible. Analysis of the data shows that the group that could learn the discrimination on the basis of color did so extremely rapidly. Thus little differential reinforcement with respect to the more difficult tilt dimension occurred. On the other hand, in the absence of a color difference, the discrimination could be formed only on the basis of the presence or absence of the line. This discrimination developed more slowly. Much responding occurred in the absence of the line, hence, there was much more differential training with respect to the tilt dimension, and, as the subsequent test showed, much more control by this dimension.

The above analysis has emphasized the possible importance of effective differential reinforcement, especially the actual occurrence of unreinforced responding in the absence of the positive stimulus, rather than the mere occurrence of the negative stimulus in the experimental situation, as a factor in the development of selective stimulus control. The discussion has focused on correlations between amount of effective differential reinforcement with respect to a stimulus dimension and the sharpness of control gained by that dimension. Whether the correlations mean that amount of differential reinforcement is indeed the governing variable in the experiments that were discussed is difficult to determine.

It appears that in experiments that follow the design of the present one or that of Newman and Baron these correlations are virtually inevitable. The establishment of a discrimination on the basis of one stimulus dimension is reflected in a reduction in responding in the presence of the negative stimulus on this dimension. Subsequent correlation of another dimension with this dimension and with reinforcement necessarily results in response rates in the presence of the new negative stimulus that are lower than would be found without the pretraining.

It is interesting to consider whether any manipulation which increases the "saliency" of one dimension of a compound stimulus and thus facilitates the development of the discrimination changes the amount of effective differential reinforcement with respect to the _other_ dimension under study. For example, had the wavelength difference been smaller in Newman and Baron's experiment (1965), the color discrimination might have developed more slowly, in which case more responding would have occurred in the absence of the line, and, perhaps more control by line tilt would have been evidenced.

It was shown above that pretraining a discrimination on the basis of _tilt_ prevented the subsequent development of control by tonal frequency. The effects of pretraining on _frequency_ upon the subsequent development of control by tilt were in sharp contrast to this.

Preceding "double correlation" training, Group F-D showed a fairly flat but double peaked tilt-gradient with maximum responding in the presence of the two line orientations present during Stage 1 training. Following training with both tilt and frequency correlated with reinforcement, a single-peaked, decremental gradient was seen with the maximum number of responses emitted in the presence of the now positive tilt, the vertical line. This change in the shape of the gradient was shown by an analysis of variance to be significant.

A decremental gradient was shown, following Stage 2 training, by Group U-D as well. Thus, control by both tilt and frequency was found following double correlation either if both dimensions were uncorrelated during Stage 1, or if frequency was correlated during Stage 1. A comparison of the tilt and the frequency gradients, of course, is impossible since the stimuli on the tilt and frequency dimensions cannot be measured in the same units. It is possible, however, to compare the tilt gradients of these groups in order to assess the effects of differences in Stage 1 training on control by tilt. A plot of the mean number of responses emitted in the presence of each of the line orientations present during testing showed an ordering of the gradients--the steepest gradient was that of Group T-D, the gradient of Group U-D was intermediate in steepness, and the flattest gradient was that of Group F-D. However, the suggestion that pretraining on frequency results in a flatter tilt-gradient was not borne out by further evidence. An analysis of variance did not show the differences in the shapes of these curves to be significant. Moreover, only the tilt generalization test made in the presence of the positive auditory stimulus showed the ordering mentioned above.

The effects of pretraining on the dimensions of tilt and of frequency then are not symmetrical. Following Stage 2 of training, Group F-D showed control by tilt, but Group T-D did not show control by frequency. The differences may be attributable to differences in the discriminative performance preceding the introduction of the second correlated stimulus dimension. As pointed out above, frequency was introduced at a stage of acquisition when few responses occurred during negative periods. Tilt, on the other hand, was introduced at a stage when the number of responses emitted during negative periods was substantial. Subjects in Group F towards the end of Stage 1 responded an average of approximately 18 times per negative period. Thus, pretraining on frequency did not preclude effective differential reinforcement with respect to the tilt stimuli when these were finally correlated with reinforcement. On the other hand, pretraining on tilt did preclude effective differential reinforcement with respect to tonal frequency, since virtually no responses were emitted in the presence of the negative stimuli during Stage 2 of training.

A subsidiary finding, but one of considerable interest, is the effect of "double correlation" upon the generalization gradient along the single dimension that was correlated during Stage 1.

No effect was seen upon the tilt-gradient of Group T-D, i.e., the gradients measured after Stages 1 and 2 were virtually identical. This is not surprising since the auditory stimuli did not affect the behavior of these subjects in any other way.

In contrast, correlation of tilt had clear effects upon the behavior of subjects pretrained on frequency, Group F-D. Responding during negative periods dropped rapidly towards zero. Before correlated training on tilt, control by this dimension was reflected in a double peaked gradient with maximum response rates occurring in the presence of the horizontal and vertical lines. Following training with tilt correlated, the maximum number of responses occurred in the presence of the now positive orientation of the line--the vertical; the minimum number occurred in the presence of the now negative line orientation--the horizontal.

For this group, the frequency generalization gradient, measured in the presence of the positive visual stimulus, was somewhat flatter at the end of Stage 2 than at the end of Stage 1. An analysis of variance showed this change in shape to be insignificant. Further, the frequency gradient for this group obtained in the presence of the negative visual stimulus at the end of Stage 2 was clearly depressed relative to the one obtained at the end of Stage 1. Although a few bursts of responses occurred, almost no responses occurred in the presence of the positive auditory stimulus. Thus, control by frequency was in no way shown in this gradient although other evidence indicated that such control was not lost.

It was noted in several places above that the auditory and visual stimuli differed markedly in their effectiveness as discriminative stimuli, e.g., there are large differences in the rate at which discriminations based on these sets of stimuli develop. Why these differences exist is not fully understood. However, the experiment by Heinemann and Rudolph (1963) suggests that they may arise in part from the manner in which the stimuli are presented. It is noted that stimuli appearing on the response manipulandum, in the present experiment and in theirs on the key, may be subject to differential reinforcement. The response is reinforced if it is emitted in the presence of the key; it is not reinforced when emitted in its absence. This is quite different from reinforcement contingencies in effect when the stimulus is diffuse as would be true of a tone present during the entire working period. In this case, the presentation of reinforcement does not depend on the presence or absence of the tone. Jenkins and Harrison (1960) have demonstrated that in order for such a diffuse stimulus to gain control, two values of the stimulus must be presented--one when the behavior is reinforced; the other when it is not reinforced. Reinforcement in the presence of the 1000 cps tone did not bring the behavior under the control of frequency, while reinforcement of the response in the presence of the 1000 cps tone and non-reinforcement in its absence did.

The present experiment supports the conclusions of these experimenters. The two stimuli present during training, the 320 and the 1000 cps tones, were not correlated with reinforcement during Stage 1 for Groups T and U. This did not mean that reinforcement did not occur in their presence. The two tones were present as often during positive periods as during negative periods. Responding in their presence during positive periods was, of course, reinforced. Nonetheless, the generalization tests following this training failed to show any control by tonal frequency.

This is in direct contrast to the effect found for tilt. Tilt was not correlated with reinforcement during Stage 1 for Groups F and U. However, as was the case with frequency, since the horizontal and vertical lines were present during half of the positive periods, reinforcement did occur in their presence. The tilt generalization tests following Stage 1 revealed control by tilt for these groups. The groups trained with tilt uncorrelated showed double peaked gradients--response rates were highest in the presence of the two tilts present during training, the horizontal and the vertical lines. The finding of such double peaked gradients is not in any way unusual. Kalish and Guttman (1957) found such gradients after training with reinforcement in the presence of two key colors. Of interest, rather, is the fact that such gradients were not found for frequency in a situation in which both groups were treated alike _except_ with respect to the stimulus dimension involved in the analysis.

Heinemann and Rudolph (1963) suggest that the control of behavior so readily acquired by visual stimuli on the key may be due to the unintentional provision of differential reinforcement.

> "Some discriminative training must inevitably occur in any situation in which the stimulus is a fairly small visual area and the required response is a movement that is directed with respect to this stimulus, such as pecking at the stimulus, or walking or jumping through a door upon which the stimulus appears, or turning at a choice-point marked by the stimulus." (page 657).

They suggest that in the Skinner box

> "Such differential training occurs most obviously while the animal is being taught to peck the key by the method of successive approximation. During this phase of training, behavior such as holding the head at the appropriate height, moving the head forward, and so forth, is reinforced when it occurs near the key (when the visual stimulus is likely to be imaged on _S_'s retinas), while similar behavior goes unreinforced if it occurs in some place other than the immediate vicinity of the key (when the visual stimulus is much less likely to be imaged on the _S_'s retinas)." (page 654).

The greater readiness with which stimuli on the key gain control over behavior is probably due, in a large part, to differential reinforcement such as that described above. However, the effectiveness of such stimuli in controlling behavior may not be due simply to such reinforcement. The demonstrations by Terrace (1963 a, b) of "errorless learning" of a discrimination show that control by stimuli appearing on the key may develop without the occurrence of non-reinforced responses in the absence of these stimuli.

In summary, the major findings of the present experiment can readily be explained in terms of differences in effective differential reinforcement. The relationship between this, and the development of stimulus control, has been discussed in detail above. A correlation has been observed between the amount of effective differential reinforcement with respect to a given dimension of a compound stimulus and the subsequent control over behavior by this stimulus dimension. Further research is needed to determine whether or not this observed correlation is indicative of a causal relationship between effective differential reinforcement and stimulus control.

SUMMARY

An analysis was made of the effects of training a subject to discriminate between two stimuli upon later development of a discrimination between two further stimuli that are redundant, i.e., each of which is always associated with one of the already discriminated stimuli. Also studied were the effects of differences in the ease of the first discrimination upon the development of the second.

The stimulus dimensions chosen for study were the angular orientation of a black line, and the frequency of a tone. During the first stage of training, two stimuli from one of these dimensions were correlated with reinforcement and non-reinforcement respectively. Two stimuli from the other dimension were also present during this phase of training but were not differentially correlated with reinforcement. After a discrimination was developed, further training was given with both stimulus dimensions correlated with reinforcement.

The behavior studied was the key-pecking response of the pigeon maintained on a variable interval schedule of reinforcement. The subjects were 20 white Carneau pigeons maintained at 85% of their free-feeding weight.

Following stabilization the birds were divided into three matched groups. The two tilts and the two tones were present during training for Group U but these stimuli were not correlated with reinforcement. Group T (eight subjects) was trained with the vertical line present during all positive periods and the horizontal line present during all negative periods. The two tonal stimuli were present but these were not

correlated with reinforcement. Group F (eight subjects) was trained with the 1000 cps tone present during all positive periods, and the 320 cps tone present during all negative periods. For this group the two line orientations were present but these were not correlated with reinforcement. Forty-five days of training were given to each group. During Stage 2 three groups were trained with both stimulus dimensions correlated with reinforcement, i.e., the 1000 cps tone and the vertical line were present during all positive periods, the 320 cps tone and the horizontal line were present during all negative periods. Half of the subjects in Groups F and T were continued on their Stage 1 training condition. For all groups Stage 2 of training continued for 45 days.

Following Stages 1 and 2, generalization tests were given to all subjects. Two tests in which the angular orientation of the line was varied were made--one in the presence of the 1000 cps tone, the other in the presence of the 320 cps tone. Two tests in which the frequency of the 65 decibel tone were varied were made--one in the presence of the vertical line, one in the presence of the horizontal line. Performance of the various groups on these tests were compared.

The major results were as follows:

1. Training of a discrimination on the basis of tilt during Stage 1 prevented development of control by frequency during Stage 2.

2. Training of a discrimination on the basis of frequency during Stage 1 did not prevent the development of control by tilt during Stage 2.

3. Control by one dimension was not "erased" with the subsequent development of control by another dimension.

4. Behavior came under the control of the dimension of tilt more readily than it came under control of the dimension of frequency.

These effects were interpreted in terms of differences in _effective_ differential reinforcement. The degree of control gained by the previously uncorrelated stimulus dimension during the second stage of training was found to be directly related to the number of unreinforced responses made in the presence of the negative stimulus during Stage 2. The rate of responding to the negative stimulus, in turn, reflects the rate attained at the end of the first stage of training. In this sense it can be said that the rates of responding attained near the end of Stage 1 of training determine the amount of effective differential reinforcement received during Stage 2.

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AUTOBIOGRAPHICAL STATEMENT

The candidate, Sheila Chase, was born in New York City on August 30, 1935. She attended City College of New York and graduated cum laude in 1957. Graduate education included work at City College (M.A. 1962), the New School for Social Research and Brooklyn College. While obtaining her graduate education she worked as a research assistant and taught at Brooklyn College. During part of this time she held a Public Health predoctoral fellowship and a New School Scholarship.

Her research activities have included work on concept formation, problem solving, tracking and operant conditioning. In the areas of problem solving and concept formation her work has included a study of discriminative control of "set", and the conditions governing "learning without awareness."