THE EFFECTS OF AUDITORY DISCRIMINATION TRAINING ON GRADIENTS OF TONAL FREQUENCY GENERALIZATION

by

PATRICK R. CHITWOOD

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INTRODUCTION

The phenomenon of stimulus generalization, first systematically investigated by Pavlov (1927), has become the topic of an ever-growing body of literature. Basically, two positions exist concerning stimulus generalization, conceived as a process. The first, represented by Pavlov (1927) and Hull (1943) proposed that steep gradients of stimulus generalization were the result of a spread of decreasing excitation or habit strength from the conditioned stimulus, during acquisition. A second position, first expounded by Lashley and Wade (1946) and later revitalized by Prokasy and Hall (1963), denied the necessity of the term generalization. These theorists suggested that flat gradients of generalization reflected a failure of discrimination during testing. They further proposed that steep gradients may be the result of pre-experimental exposure to the test stimuli or a function of varying stimulus thresholds within the S during testing.

Unfortunately, both classes of theories possess inherent weaknesses. The approach of Pavlov and Hull, for example, has difficulty accounting for flat gradients, while that of Lashley and Wade and Prokasy and Hall is not convincing in its explanation of steep gradients of generalization. Further analyses of the utility of the concept of generalization as a process, however, have not been forthcoming. Instead, interest has focused on the effects of discrimination training upon the empirical generalization gradient.

For the most part, this interest has been with the direct effects of discrimination training (i.e., variations in the discrimination training procedure which engender corresponding variations in the degree of control exerted by stimuli along the training dimension). Recently, however, several experiments have investigated the indirect effects of discrimination training. In this class of experiments the dependent variable is the slope of a gradient along a stimulus dimension either absent or "irrelevant" during discrimination training. In these experiments the slope of the gradient indexes dimensional control, i.e., sloped gradients are indicative of varying degrees of control, while flat gradients reflect little or no control.

Three basic procedures have been utilized to assess the effects of discrimination training upon dimensional control. The first, represented by Hanson (1959), involves reinforcement of responding in the presence of one stimulus (S+) and non-reinforcement in the presence of a second stimulus (S-) which lies on the same physical stimulus dimension as S+. In general, _S_s receiving this intradimensional discrimination training (IAT) subsequently yield steeper gradients of generalization than _S_s receiving training only with S+ (single stimulus training, SST). A second method of evaluation has been described as interdimensional discrimination training (IET) by Switalski, Lyons, and Thomas (1966). Unlike IAT, this procedure requires that the S- during discrimination training be orthogonal to the dimension of S+ (e.g., S+ = red light, and S- = vertical line). Experiments of this nature also indicate that discrimination training enhances dimensional control relative to SST. The IAT and IET type experiments are typically concerned with direct effects. Honig (1969) has referred to a third type of experiment which is designed to evaluate the indirect effects of discrimination training upon dimensional control. Experiments of this form incorporate on the above discrimination training procedures as well as an additional phase, prior to generalization testing. Following discrimination training, either intradimensional or interdimensional, response acquisition is given to a stimulus on another dimension, and generalization tests along this dimension are subsequently administered. In this extradimensional discrimination training (ET) paradigm, the crucial comparison involves a group receiving true discrimination training (TD group) in the first phase, and a group for which S+ and S- are equally reinforced (pseudodiscrimination or PD group). In general, results from this kind of experiment indicate greater dimensional control for the TD group, that is, a steeper gradient. However, experiments which have incorporated this paradigm are few, and differences are not as apparent as those which employ only the IAT or IET paradigms. Indeed, with the ET paradigm, differences between gradient slopes of TD and PD groups are typically so slight as to require a large N for compelling comparisons.

It is of substantial importance to note that the majority of experiments which have evaluated dimensional control have employed visual stimulus dimensions (e.g., Switalski, *et al*., 1966; Thomas, Freeman, Svinicki, Lyons, and Burr, 1970; Lyons and Thomas, 1967; Lyons, 1969; and Honig, 1969, 1970). There exist data which suggest that quite different results may obtain from equivalent training procedures if auditory rather than visual stimuli are employed. As an example, pigeons trained to peck a key illuminated by a particular wavelength of light will subsequently yield steep gradients of wavelength generalization with modal responding to the training stimulus (cf. Riley, 1968). However, if a pigeon is trained to peck a key in the presence of a tone of a particular frequency, gradients of tonal frequency generalization are flat, e.g., Jenkins and Harrison (1960). Clearly, then, it is meaningful to question the cross-modal generality of experimental results regarding the effects of discrimination training upon dimensional control.

In spite of the limited nature of the available data, Thomas (1969) proposed that discrimination training effects a "set to discriminate" which fosters differential responding not only to stimulus dimensions included in training, but those not involved as well. In light of data which suggest basic differences between auditory and visual generalization gradients following single stimulus training (SST), and the lack of ET investigations which employed other than visual stimuli, Thomas' proposition appears to be somewhat premature. It was the purpose, then of the present research to investigate, via the ET paradigm, the effects of two types of auditory discrimination training, i.e., intradimensional and interdimensional, upon gradients of tonal frequency generalization.

Two restrictions were placed on the literature review that follows. First, the experiments to be described used only infra-human Ss, specifically pigeons unless otherwise noted. This restriction was imposed as a result of the limited nature of the relevant data. That is, while many experiments have investigated discrimination or generalization in several species (homo sapiens included) few have specifically studied the indirect effects of discrimination training upon gradients of generalization. A second limitation of this review concerns the types of discrimination training to be reviewed. Though there exist many variations of the basic discrimination procedures, only experiments involving interdimensional discrimination training (IET), intradimensional discrimination training (IAT) and extradimensional discrimination training (ET) procedures will be reviewed. This restriction is necessary in order to exclude those studies which have manipulated specific variables within the discrimination paradigm (e.g., the reinforcement schedule, amount of training, amount of reinforcement, etc.). Such studies tend to focus on those variables rather than the effects (direct or indirect) of discrimination training, per se, upon gradients of generalization.

INTRADIMENSIONAL DISCRIMINATION TRAINING (IAT)

A majority of the studies which have evaluated the influence of discrimination training upon dimensional control have been of the IAT variety. In such experiments, the S+ and S- lie on the same physical continuum. Following attainment of a discrimination criterion (typically when responses to S- are no more than 10% of those to S+) generalization tests along the training dimension are administered.

Hanson (1959) reported on the first investigation of this type. He trained 5 groups of *Ss* to peck a key illuminated by a 550 mu light for variable interval (VI) reinforcement. Four of the groups were then given discrimination training between the S+ of 550 mu and an S- of 555, 560, 570, or 590 mu, one value for each group. The fifth group did not receive discrimination training. Following the attainment of the discrimination criterion, all *Ss* were given wavelength generalization tests in which 11 different wavelengths were presented randomly. Highly ordered gradients (i.e., symmetrical about the mode) were obtained for all groups and for each individual S. For the 4 discrimination groups, the peak of the gradient was displaced from the S+ in a direction opposite that of S- (peak shift). Further, the gradients of these groups were steeper than that of the control, that is, the group receiving single stimulus training (SST). These results, then, suggest that IAT enhances dimensional control and indicate that the mode of the post discrimination gradient (PDG) will be displaced from the S+.

Honig, Thomas, and Guttman (1959) compared the effects of massed extinction to successive discrimination training. Their Ss received 10 days of VI 1 min training to a key illuminated by a 550 mu light. Following the last VI session, continuous extinction to 570 mu was given by presenting this stimulus for 1 min periods separated by 10 sec blackouts. One group received 20 min of extinction and a second, 40 min. On the next day each S was tested for wavelength generalization. Subsequent to this test, discrimination training began in which responding to the 550 mu light was reinforced on a VI 1 min schedule and responding to the S- (570 mu) was never reinforced. After 3 sessions of such training Ss were given a second test. Gradients obtained after massed extinction were flatter than those following discrimination training and did not show a peak shift.

However, the PDGs were quite steep and exhibited the characteristic peak shift. These results also suggest that IAT sharpens dimensional control.

Thomas (1962) investigated wavelength generalization as a function of drive and discrimination training. His 3 groups of 18 _S_s each were maintained at 60, 70, and 80 percent of their free-feeding weights, respectively. All _S_s received 5 days of VI 1 min training with a key illuminated by a 550 mu light and were then tested for generalization. The three groups were then divided into 3 discrimination groups with the 550 mu as S+ and 590, 570, and 558 mu as the respective S-'s. During discrimination training, responding was reinforced on a VI 1 min and responding to the S- was never reinforced. Periodic generalization tests were given during the course of discrimination training, and following completion of the training. Results indicated that the discrimination was learned in less time if the S+ vs. S- difference was great, and suggested that increased drive enhanced the speed of discrimination learning. Further, the PDG's all exhibited peak shifts and were steeper than the gradients following SST.

Using the dimension of angularity, Bloomfield (1967) compared IAT and IET PDG's. Two groups of 5 _S_s each were trained to respond to a vertical line on a black surround for VI 1 min reinforcement. For one group, responding to the key with a 45^{o} line (S-) was not reinforced. Another group was not reinforced for responding in the absence of the line. The subsequently obtained gradients were steeper for the intradimensional group and, evidenced a peak shift. These results suggest that not only does IAT engender steep gradients, but gradients steeper than those obtained subsequent to IET, as well.

Chitwood and Griffin (1972) assessed the effects of response prevention in the S- of a tonal discrimination upon dimensional control. They trained 2 groups of 2 Ss each to respond for VI reinforcement in the presence of a 1500 Hz tone (S+). For the first group, presentations of this tone were alternated with presentations of a 500 Hz tone (S-) during which responses were never reinforced. For the second group the response key was retracted during the S- periods though the S- was still presented. After several sessions of such training, generalization tests were administered during which 8 tones, including the S+ and S-, were presented randomly. The first group yielded steep gradients while the second group produced flat gradients with no differential responding to any test values. These results also suggest that IAT is conducive to dimensional control.

The preceding review provides strong support for the gradient enhancing effects of intradimensional discrimination training. It seems clear, then, that IAT will result in gradients of generalization which are steeper than those following single stimulus training. The experiments to be reviewed in the following section suggest that this effect is not limited to situations in which discrimination training is conducted exclusively along a single stimulus dimension, as is the case in IAT.

INTERDIMENSIONAL DISCRIMINATION TRAINING (IET)

Interdimensional discrimination training (IET) differs from IAT in that the S+ and S- are on orthogonal dimensions, i.e., the stimuli are assumed to have no common dimension. Once a discrimination criterion has been satisfied, _S_s are tested for generalization along the dimension of S+.

The effects of IET on tonal frequency generalization were evaluated by Jenkins and Harrison (1960). They trained 2 groups of pigeons to peck a key in the presence of a 1000 Hz tone (S+) for VI reinforcement. For one group, periods of the S+ were randomly alternated with periods in which the tone was absent (S-), and key pecks were not reinforced. After a discrimination criterion was achieved, _S_s were given generalization tests. The second group experienced periods of S+ only but were tested in the same manner as the first group. The gradients of _S_s of the first group were steeply sloped while those of the second group were flat. Since it is assumed that the absence of tone constitutes a stimulus on a dimension orthogonal to that of tone, these results suggest that IET increases control to the tonal frequency dimension.

One aspect of the Jenkins and Harrison investigation has received considerable experimental concern. That is, why their _S_s which received only SST did not yield a steep gradient of generalization. It should be noted that in experiments employing visual dimensions such as wavelength, brightness, and line tilt, _S_s typically show steep gradients following SST. Hinemann and Rudolph (1963) report that gradients of luminosity generalization became progressively flatter as the size of the reinforced stimulus increases. Their results suggest that localization of the stimulus may play an important role in the development of steep gradients. Since the tone in the Jenkins and Harrison (1960) experiment was diffuse, this explanation seems tenable. Other investigators, however, have been concerned with the effects of pre-experimental exposure to the relevant stimulus dimension (e.g., Peterson, 1962; Tracy, 1970; Thomas, _et al_., 1968; and Riley, 1971). Though the disparity has not been adequately explained, the relevant issue for the present paper is that there exists a basic difference between gradients of generalization obtained along visual and tonal frequency dimensions, following SST.

Switalski, Lyons, and Thomas (1966) trained Ss to peck a key illuminated by a 555 mu wavelength of light for VI 1 min reinforcement. All Ss were then tested for generalization along the wavelength dimension. Following these initial tests, one group received equal reinforcement to randomly alternating stimuli of 555 mu and a white vertical line on a black surround. A second group was given discrimination training in which a VI 1 min was correlated with the 555 mu light (S+) and extinction was correlated with the vertical line (S-). These investigators found that in comparison to the single stimulus control condition, interdimensional non-differential training flattened the gradient, while inter-dimensional discrimination training steepened it. This latter finding has been confirmed by Lyons and Thomas (1967) who alternated blocks of non-differential training sessions with blocks of discrimination training sessions and tested for wavelength generalization after each block. Every S, without exception, showed a steepened gradient following discrimination training and a flat gradient following non-differential training.

Further support for the gradient-steepening effects of IET has been provided by Lyons (1969). He required 2 groups of 20 Ss each to respond to a key illuminated by a

555 mu light. One group was given SST to the 555 mu stimulus. A second group received discrimination training to 555 mu as S+ and a white vertical line on a black surround as S-. When tested for generalization along the wavelength dimension, the discrimination group yielded steeper gradients than the group receiving single stimulus training.

The experiments described above indicate that IET serves to sharpen control to the S+ dimension. One aspect of this review deserves further mention. That is, gradients subsequent to SST are quite different for tonal frequency and visual dimensions, in that those along the former dimension are flat while those found along visual dimensions are steep. Since SST and discrimination training both result in steep gradients with visual stimuli, sensitive comparisons between groups receiving these training conditions require large N's. However, differences between SST and discrimination groups are more readily apparent in experiments which involve tonal generalization. This analytical advantage is of primary importance in the following type of experiment, i.e., those involving extradimensional discrimination training.

EXTRADIMENSIONAL DISCRIMINATION TRAINING (ET)

The experiments to be reviewed in this section involve discrimination training (either IET or IAT) until a discrimination criterion is met, followed by response acquisition to a new dimension (via SST) and then, generalization testing along this new dimension. The discrimination training typically consists of reinforcing responses in the presence of one stimulus (S+) and extinguishing responding in the presence of a second stimulus (S-). Comparisons are made between the gradients of a group receiving true discrimination training (TD group) in the discrimination phase and a group which was equally reinforced in the presence of S+ and S- (pseudodiscrimination of PD group).

Honig (1969) conducted several experiments which were designed to investigate the effects of ET on dimensional control. In the first, 6 _S_s were given TD training between a white key (S+) and a pink key (S-). Six other _S_s received PD training with the same stimuli. Each TD _S_ was matched with a PD _S_ in terms of the number of discrimination sessions. Following this training, all Ss received SST with 3 vertical lines superimposed on a white background. Responses during this phase were reinforced on a VI schedule. Subsequent to 4 sessions of such training, Ss were tested for generalization along the dimension of line orientation. Gradients were steeper for the TD group than for the PD group. A third group receiving the same training as the TD group, except that blackouts were substituted for S- presentations, produced gradients with slopes intermediate between the TD and PD groups.

In a second experiment, 3 of the original TD Ss were given PD training (TD-PD group) while 3 of the PD Ss were given TD training (PD-TD group), with the white and pink colors. The remaining 3 Ss of each TD and PD group continued their original training. Following a second acquisition phase with the vertical lines, generalization tests were administered. The only marked effect was the steepened gradient for the PD - TD group. Honig interpreted these results as suggesting that ET enhances dimensional control. However, he pointed out that the TD Ss may have learned to attend specifically to the white key, and, since the vertical lines during testing were imposed on a white background some confounding could have occurred. For this reason, a third experiment was conducted. This investigation differed from the first in that the S+ and S- stimuli during TD and PD training were blue and green, respectively. Subsequently obtained gradients along the dimension of line tilt were steep for the TD group and essentially flat for the PD group. Two experiments which followed replicated these results and also demonstrated that repeated dimensional acquisition and testing markedly increases the slope of the generalization gradient (i.e., increased dimensional control).

Freeman (1967) trained one group of Ss to discriminate between a white vertical line on a black surround (S+) and a line angled 30° from the horizontal (S-). A second group received PD training with these stimuli. All Ss were then given 5 sessions of SST with a white vertical line superimposed on a 555 mu (green) background. During this second phase, a third group which received only this SST was added. Generalization tests along the wavelength continuum revealed steeper gradients for the TD group than the essentially identical gradients of the PD and single stimulus groups.

Thomas, Freeman, Svinicki, Burr, and Lyons (1970) reported several experiments which evaluated the effects of ET on dimensional control. In the first, 10 Ss received TD training and 10 Ss, PD training to alternating stimuli of 555 mu (S+) and 606 mu (S-). Next, both groups were given 5 sessions of SST to a white vertical line superimposed on a 555 mu surround. Generalization tests along the line tilt dimension yielded steeper gradients for the TD than for the PD group. In their second experiment, 15 _S_s were given TD training and 15 _S_s, PD training to a vertical white line on a black surround as S+ and a 30° line as S-. Next, all _S_s received 10 sessions of SST with a white vertical line on a 555 mu surround. Results indicated steeper gradients of wavelength generalization for the TD group.

Their third experiment involved the simultaneous presentation of the training and testing dimensions. Fifteen TD _S_s and 15 PD _S_s received training with a white vertical line on a 555 mu surround as S+ and the same line on a 538 mu surround as S-. Generalization gradients along the dimension of angularity (color absent) were steeper for the TD group than for the PD group. A fourth experiment was a replication of the third except that the training dimension was line angle and the test dimension was wavelength. Again, gradients of the TD _S_s proved steeper than those of PD _S_s.

In the final experiment, Thomas _et al_., (1970) trained 40 _S_s to respond to a key illuminated by a 555 mu light. The _S_s were then randomly assigned to TD, PD and SS groups.

The TD and PD groups were given training in which the S+ was a horizontal chamber floor and the S- was the chamber floor tilted 10°. Gradients of wavelength generalization were steeper for TD *S*s with no differences between the gradients of the PD and SS *S*s.

Rheinhold and Perkins (1955) have provided evidence for the ET effect in rats. They reinforced one group of rats for traversing a smooth black runway and never reinforced them for running in a rough black runway. A second group received intermittent reinforcement of the positive stimulus only, while a third group was reinforced for runs in both the positive and negative runway. The *S*s were then tested for generalization to a smooth white runway. The first group yielded a steeper gradient than the other groups. The authors interpreted their results as suggesting that discrimination training engenders a "set to discriminate" along many stimulus dimensions. A later experiment, Perkins, Herschberger, and Weyant (1959) confirmed these results.

Finally, a study by Klipec (reported in Thomas, 1969) suggests that the effects of ET may be cross-modal. This author trained 11 TD and 11 PD *S*s with white noise as S+ and its absence as S-. The response key was illuminated by a 555 mu light during both S+ and S-. While not statistically significant, gradients along the wavelength dimension were steeper for TD _S_s than for PD _S_s.

The above experiments indicate that ET sharpens control to stimulus dimensions either absent or irrelevant during discrimination training. However, it should be emphasized that, without exception, these studies evaluated gradients of generalization along visual stimulus dimensions only. Furthermore, the comparisons between PD and TD groups required relatively large sample N's because of the small differences between two sloped gradients.

Clearly, further investigation of the effects of discrimination training upon dimensional control is needed. As the preceding literature review indicates, a majority of the experiments concerned with this area have assessed gradients of generalization along visual dimensions. Results of such experiments indicate that dimensional control is enhanced as a result of discrimination training. With respect to the direct effects of discrimination training (i.e., IAT and IET experiments) there is evidence that discrimination training generates equivalent results with both auditory and visual dimensions. An obvious question, then, is, are similar results obtained from auditory and visual ET experiments. That is, can the indirect effects of discrimination training be observed in an auditory ET paradigm. The present research will attempt to answer this question.

A second question concerns the type of discrimination training given in the first phase of an ET paradigm. With the exception of Klipec (1969), ET experiments have employed intradimensional discrimination training. As Klipec's results were not statistically significant, there is reason to investigate the effects of an interdimensional discrimination in the first phase of the ET paradigm. The present research was designed to provide information relevant to this issue.

STATEMENT OF THE PROBLEM

Since the suggestion of Rheinhold and Perkins (1955) that discrimination training results in control by more than one stimulus dimension, substantial evidence has accrued to support such a position. On the whole, research indicates that Ss exposed to IET, IAT, and ET exhibit greater behavioral control by stimuli of dimensions involved (and not involved) in discrimination training, than Ss receiving no such training. The number of investigations which have supported this finding are many, while negative studies are rare. These data led Thomas (1969) to his "set to discriminate" hypothesis, which states that discrimination training fosters differential responding, i.e., dimensional control, to stimulus dimensions involved and not involved in discrimination training. The validity of such a hypothesis, however, is open to question as it finds support almost exclusively from experiments which manipulated only visual dimensions. A second limitation of the supporting data is that the majority of the ET experiments have incorporated an intradimensional discrimination in the first phase. Therefore, the question remains whether the same results obtain when an interdimensional discrimination is employed in the first phase. Supporting data from an ET experiment which investigated intradimensional and interdimensional discrimination along an auditory stimulus dimension, would lend strong support to Thomas' hypothesis.

While similar results have been obtained with both tonal and visual stimuli in the IAT and IET experiments, it has been empirically demonstrated that SST (a necessary component of ET) with these stimuli does not yield equivalent results. For this reason, it is uncertain whether an auditory ET paradigm which employed SST with tone would result in steep gradients of tonal frequency generalization.

According to Thomas' hypothesis, discrimination training (either interdimensional or intradimensional) with an auditory dimension should foster dimensional control to tonal frequency, subsequent to SST with tone. Since SST alone with visual stimuli results in steep gradients, ET paradigms employing visual SST must compare two sloped gradients, i.e., those of the TD and PD groups. Due to the relatively small difference between the slopes of the gradients, a large N is required for sensitive comparisons.

The necessity for using a large number of *S*s is, however, eliminated in an auditory ET experiment since *S*s which do not receive TD training should yield flat gradients of tonal frequency generalization subsequent to SST with this dimension.

As a result of the almost exclusive use of visual stimuli in ET experiments, there is an increasing need for investigation with other stimulus modalities. The present experiment was designed to investigate the following propositions:

1) Intradimensional discrimination training with two differing click frequencies will result in reliable control by the tonal frequency dimension.

2) Interdimensional discrimination training with one click frequency value as the S+ and the absence of any experimentally manipulated auditory stimulus as S-, will produce effects similar to those of intradimensional discrimination training following single stimulus training with tonal frequency.

3) Pseudodiscrimination training with click frequencies in both intradimensional and interdimensional forms will result in little or no dimensional control (i.e., flat gradients) by tonal frequencies following single stimulus training with tone.

4) Single stimulus training to tone, alone, would result in flat gradients of tonal frequency generalization.

METHOD

Subjects

The _S_s consisted of 15 naive male Silver King pigeons maintained at approximately 70% to 80% of there free-feeding weights. All _S_s had free access to water in their home cages.

Apparatus

A standard operant-conditioning chamber with interior dimensions 37.5 cm x 30 cm x 32 cm was used. A transluscent response key, 1.5 cm in diameter, located 20 cm from the left edge and 27 cm from the bottom of the chamber, served as the response operandum. A 115 V ac 15 W light mounted behind the panel provided illumination of the key. A 115 V ac 15 W white house light, projecting into the chamber and centered 5 cm from the left edge and 5 cm from the bottom of the chamber provided illumination in the experimental space. Reinforcement consisted of 4.0 sec access to mixed grain via a solenoid operated magazine through a 6 cm x 5 cm aperture centered 15 cm from the left edge and 11 cm from the floor of the chamber. During reinforcement, the key light, house light, and all experimentally manipulated stimuli were extinguished. A fan mounted to the side of the chamber provided ventilation and masking of extraneous noise. All experimental conditions were governed by appropriate relay circuitry in a separate room.

Stimuli

The auditory stimuli were of two types; click frequency and tonal frequency. Click stimuli were provided by a Grayson-Stadler Electronic Timer (No. E5350A). Fifty msec pulses from this component were delivered through a 2 ohm resistance. Clicks were of two frequencies: 5 clicks per sec and 1 click per sec. Under certain conditions, all experimentally manipulated auditory stimuli were absent (designated NCF). Tones were provided by a Beltone Audiometer and consisted of the following frequencies: .50, .75, 1.0, 1.5, 2.0, 3.0, and 4.0 kHz. All tones were delivered at approximately 80 to 93 db, spl, in the chamber. Both clicks and tones were supplied to Ss through a 6 ohm speaker mounted on top of the chamber and centered 15 cm from each edge. No stimuli, either visual or auditory were presented during reinforcement or time out (TO).

Procedure

Prior to training, 3 Ss were randomly assigned to each of groups TD1, TD2, and TD3, and 2 Ss to each of groups PD3 and SST. Groups PD1 and PD2 were assigned one S each (see Table 1).

Preliminary training: All Ss were trained to peck the illuminated response operandum via reinforcement of successive approximations to a discrete key peck. Following the establishment of a discrete response, Ss received two sessions of continuous reinforcement (CRF) training. During the next three sessions, Ss were given training with a variable interval (VI) 15 sec schedule of reinforcement. Concurrent with this training the S+ stimuli were introduced. For groups TD1 and TD3, this stimulus was a click frequency of 5/sec. For group TD2 the S+ stimulus was NCF. A 1.5 kHz tone was correlated with this training for group SST. Presentations of these S+ periods were interrupted every 45 sec by a 7 sec TO. Both CRF and VI training sessions terminated with the collection of 50 reinforcements.

True discrimination training: Subsequent to 3 sessions of VI 15 sec training, Ss were exposed to a multiple VI 30 sec - extinction (Mult VI- Ext) schedule. For these groups the VI component remained correlated with the designated

TABLE 1

Showing Group Labels, Discriminative Stimuli,

and Number of Subjects for Each Group

Type of Discrimination	Group	Stimuli S+	Stimuli S-	No. of Ss
Interdimensional	TD1	5/sec	NCF	3
"	TD2	NCF	5/sec	3
Interdimensional (Pseudo)	PD1	5/sec	NCF	1
"	PD2	NCF	5/sec	1
Intradimensional	TD3	5/sec	1/sec	3
Intradimensional (Pseudo)	PD3	5/sec	1/sec	2
None	SST	1.5 kHz	none	2

S+ stimulus, and a second stimulus correlated with Ext (S-) was introduced. For group TD1 this stimulus was NCF, for TD2, the S- was 5 clicks per sec, and for TD3 the S- was 1 click per sec. The 7 sec TO continued to be presented every 45 sec, irrespective of the component in effect. Each daily session consisted of 15, 45 sec presentations of both the S+ and S- stimuli, according to a quasi random sequence. Reinforcement was given only during S+ periods and never during S- periods. This training continued for 15 sessions. On the sixteenth session the duration of the S+ and S- components was increased to 2 min each in order to facilitate discriminative performance. With the exceptions of P7 and P11 this type of training continued until the response rate to S- was no more than 10% of that to S- (10/1, S+, S-) during any two of three consecutive sessions. As a result of the poor discriminative performance of P7 and P11, the duration of the S- component was further increased to 4 min. This procedure was instituted on session 32 for P7 and on session 42 for P11. Before reaching the discrimination criterion, subject P7 received seven such sessions followed by 8 sessions in which the duration of S+ and S- both were 2.0 min. Subject P11 received 9 sessions with 4.0 min extinction components, followed by three regular sessions of 2.0 min in both S+ and S-, before reaching criterion.

<u>Pseudodiscrimination (PD) training</u>: All *S*s of the PD groups received training identical to the TD groups with two exceptions. First, no auditory stimuli were presented during the three VI 15 sec sessions and second, the VI reinforcement program was effective for only half of the S+ periods as well as half of the S- periods. Extinction was effective during the remaining periods. The S+ and S- stimuli for the PD groups were NCF and 5 clicks per sec for PD2, 5 clicks per sec and NCF for PD1 and 5 clicks per sec and 1 click per sec for PD3. For the one *S* of group PD1, training was carried out for a number of sessions equal to the mean number required by *S*s of group TD1 to reach the discrimination criterion. For the PD2 *S*, training continued for the mean number of sessions required by *S*s of group TD2 to reach criterion. Both *S*s of the PD3 group received training for the mean number of sessions required by the *S*s of group TD3 to meet the discrimination criterion.

<u>Single stimulus training (SST)</u>: Subjects of this group continued training with a VI 30 sec schedule of reinforcement in the presence of the 1.5 kHz tone for the mean number of sessions required by *S*s of the TD groups to meet the discrimination criterion.

Dimensional acquisition: Following the completion of the training criteria, *S*s of the TD and PD groups received four 30 min sessions of single stimulus training. During these sessions, responses to the illuminated key in the presence of a 1.5 kHz tone were reinforced on a VI 30 sec schedule. Every 60 sec working period was interrupted by the 7 sec TO. There were no presentations of any experimentally manipulated auditory stimuli, other than the tone, during these sessions.

Testing: On the day following the fourth session of dimensional acquisition (or the final session for *S*s of the SST group) *S*s were given 10 min more of training with the tone and then a generalization test was carried out under extinction conditions. The test stimuli consisted of the seven tones, each presented once within each of the seven randomized series. Stimulus presentations were 45 sec each with a 7 sec TO intervening between presentations.

RESULTS

The total number of sessions and minutes in S+ and S- required for each *S* to reach criterion are presented in Table 2. Since the duration of a session was not constant in all cases due to changes in the duration of the S- component, the most meaningful data are the total minutes in S+. Group TD1 required an average of 496.86 min in S+ (26 sessions) to reach criterion, while group TD2 required an average of 822.29 min (38 sessions) and TD3 an average of 901.06 min (39 sessions). These differences suggest that intradimensional discrimination tasks may be more difficult than interdimensional discriminations. The finding that the TD1 group required less time than the TD2 group to learn the discrimination indicates that a presence-absence discrimination may be less difficult when the distinguishing feature of the discrimination is associated with the reinforced component. This effect has also been reported with visual stimuli and was termed the "feature-positive effect" (Jenkins and Sainsbury, 1969).

TABLE 2

Subjects, Training Conditions, Number of Sessions and Total Minutes in S+ and S- Required to Reach Criterion

Subject	Group	Number of Sessions	Total Min (S+)	Total Min (S-)
P1	TD1	28	558.45	584.24
P2	TD1	21	357.03	381.05
P3	TD1	29	574.71	651.10
P4	PD1	26	504.13	584.88
P5	TD2	26	496.06	578.52
P6	TD2	41	899.37	1033.84
P7	TD2	47	1071.44	1508.31
P8	PD2	38	883.64	895.65
P9	TD3	34	708.69	807.59
P10	TD3	32	690.71	867.52
P11	TD3	53	1303.80	1840.99
P12	PD3	39	911.39	898.98
P13	PD3	39	929.82	876.36
P14	SST	35	986.52	None
P15	SST	35	974.00	None

Since group TD1 also required less time than TD3, the possibility exists that an interdimensional auditory discrimination is less difficult than an intradimensional auditory discrimination. This is to be expected, as the latter requires a discrimination between values of a particular stimulus rather than between its presence or absence. It should be emphasized, however, that both of the above speculations are made with caution as a comparison of the mean minutes required in S+ for all discrimination groups proved non-significant ($F = 1.84$, $\underline{p} > .20$, $df = 2.6$).

While the present experiment was not primarily concerned with the data arising from discrimination training, the data are of particular interest when compared with results of visual discrimination tasks (Hanson, 1959). Using a multiple VI 1.0 min - Ext schedule with 1.0 min components, Hanson trained 4 groups of 6 pigeons each to discriminate between an S+ of 550 mu, and an S- of 550 mu, 560 mu, 570 mu, or 590 mu. Although the actual values were not presented, the approximate mean number of minutes in S+ required to reach a discrimination criterion for each of the 4 groups was 210 min, 190 min, 195 min, and 180 min, respectively. It will be noted that in every case these means are less than those of the present experiment. Probably the most valid comparisons are between Hanson's means and that of the TD3 group, since Ss of this group also learned an intradimensional discrimination. The 901.06 min mean of the TD3 group suggests a difference between visual and auditory discriminations. Since the present experiment employed a procedure which should have facilitated discrimination learning (Mult VI 30 sec- Ext, with 2.0 min components) it appears that the difference in Hanson's data and the present may reflect a basic difference in the difficulty of auditory and visual discriminations for pigeons.

Of major interest are the generalization test data. Percentages of total responding to each test stimulus for all Ss are presented in Table 3). Also presented is the total number of responses occurring during each test. It will be noted that Ss P1, P2, and P5 received two tests each. In the case of P1 and P5, the second tests were administered due to the unusual and unexpected form of the first gradients. For P2 a second test was performed since the first test involved only six rather than seven presentations of each stimulus due to a clerical error. Each of these second tests was administered following retraining of the previous discrimination to a one session 10/1, S+, S- criterion, and was preceded by a total of 30 min of dimensional acquisition to the 1.5 kHz tone.

TABLE 3

Percentage of Total Responding to Each Test Stimulus and Total Number of Responses During Each Test for all Subjects

Subject	Group	Stimuli .50	.75	1.0	1.5	2.0	3.0	4.0	Total R's
P1	TD1	13.0	13.0	16.4	15.6	12.9	12.0	16.9	1580
*P1	TD1	24.8	6.9	1.9	16.7	18.5	17.3	13.8	718
P2	TD1	36.9	7.6	9.7	39.5	1.7	0.4	4.2	238
*P2	TD1	5.7	5.1	13.0	31.2	9.3	13.2	22.3	983
P3	TD1	10.3	17.2	15.8	19.5	15.1	10.0	11.9	1177
P4	PD1	14.7	14.3	15.7	15.0	15.7	14.1	10.3	3101
P5	TD2	16.9	18.4	24.0	12.6	8.0	10.1	9.8	1047
*P5	TD2	6.2	6.1	15.0	29.5	18.5	20.8	3.4	1078
P6	TD2	10.1	16.8	13.9	18.6	16.9	13.2	10.3	1206
P7	TD2	16.8	14.8	15.8	19.9	17.6	10.3	4.8	1012
P8	PD2	15.3	14.1	15.1	14.6	15.5	13.2	11.9	1892
P9	TD3	10.8	14.0	23.3	25.0	10.2	6.3	10.2	949
P10	TD3	19.3	14.8	15.0	18.9	17.0	7.1	7.5	702
P11	TD3	22.8	9.9	15.6	16.9	14.0	12.0	8.6	1171
P12	PD3	16.1	16.2	14.5	16.6	17.5	11.2	7.8	1744
P13	PD3	16.1	15.1	13.6	15.3	14.8	13.3	11.8	1394
P14	SST	14.8	15.4	15.1	14.6	13.7	14.3	12.1	2828
P15	SST	16.6	14.3	14.8	14.6	15.4	12.7	11.7	1772

* Results of the second of two tests. (see text)

Relative generalization gradients for TD1 and PD1 _S_s are presented in Figure 1. The gradients of two of the three _S_s of group TD1 (P2 and P3) have their peak at 1.5 kHz and are steeper than that of the PD _S_, P4. Although subject P1 did not exhibit a peak at 1.5 kHz during either test, the second test suggests some control by .50 kHz and 1.5 kHz. With respect to the two gradients for P2, the second is probably the more reliable, as the first is based on only 238 responses and 6 presentations of each stimulus as opposed to 983 responses and 7 presentations for the second test.

Gradients for _S_s of the TD2 and PD2 groups are presented in Figure 2. Again, of the three TD _S_s, two (P6 and P7) produced steep gradients with the peak at 1.5 kHz on the first test. The second test for subject P5 indicates substantial control by tone with the peak of the gradient at 1.5 kHz. The control _S_ for this group, P8, received pesudo-discrimination training, and, as is obvious from Figure 2d, produced a relatively flat gradient with little or no control by the tonal dimension.

The gradients for _S_s receiving intradimensional discrimination training are presented in Figure 3. While P9 is the only TD _S_ to exhibit a steep gradient with a primary peak

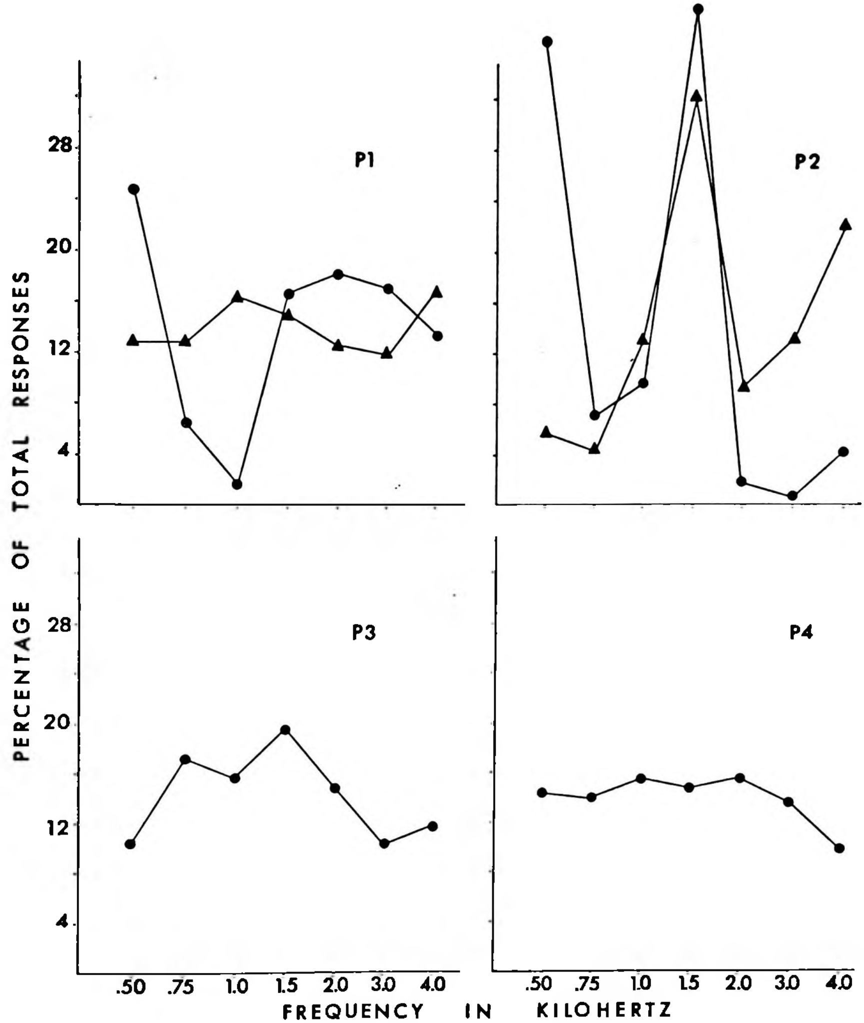

Figure 1. Percentage of total responses to each test stimulus following IET with a 5/sec click as S+ and its absence as S-, and SST with a 1.5 kHz tone. Circles indicate first and triangles second test.

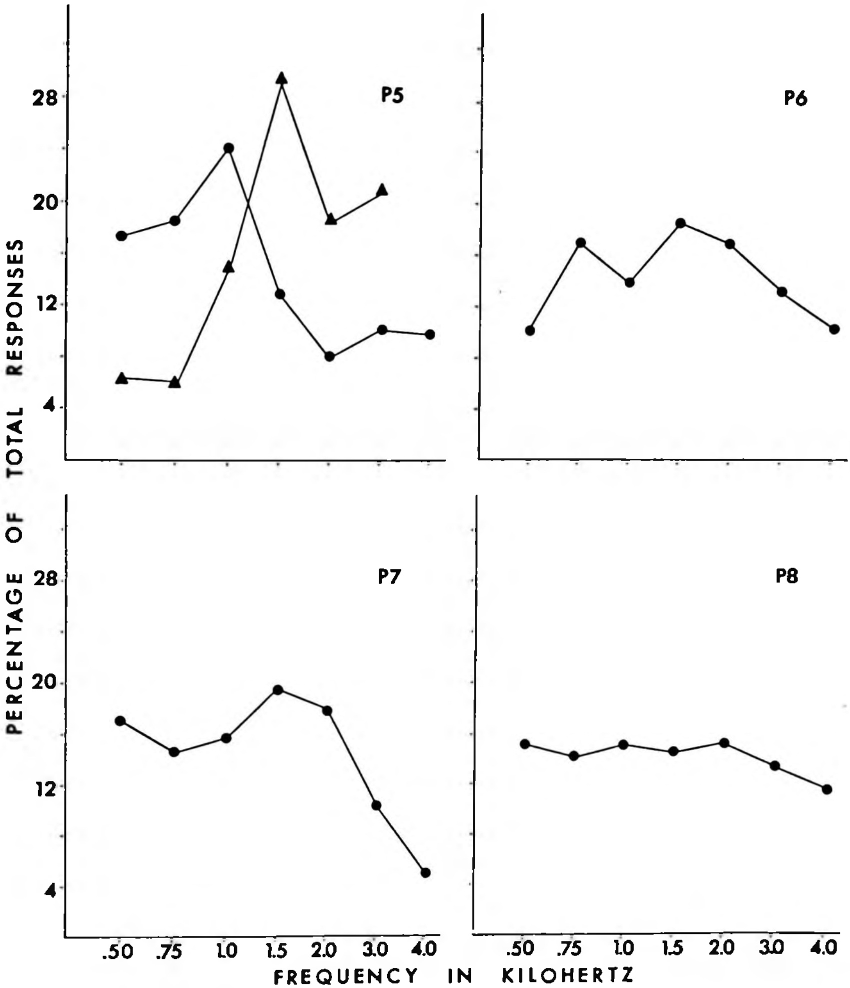

Figure 2. Percentage of total responses to each test stimulus following IET with a 5/sec click as S- and its absence as S+, and SST with a 1.5 kHz tone. Circles indicate first and triangles second test.

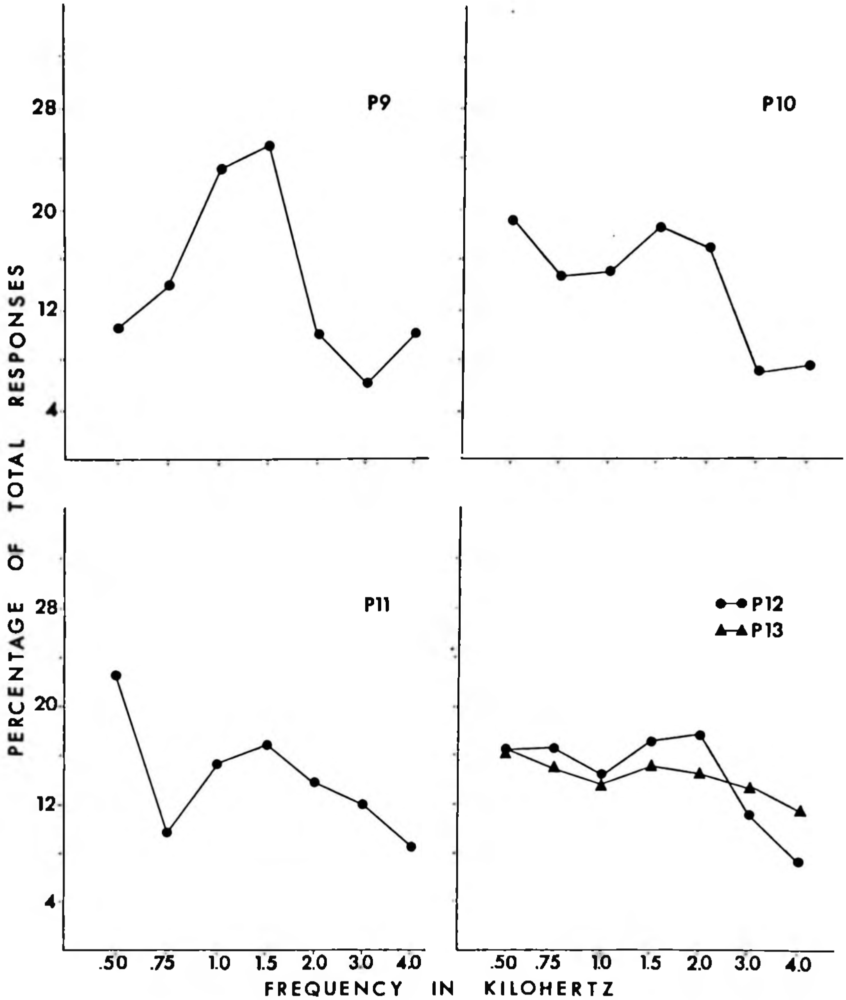

Figure 3. Percentage of total responses to each test stimulus following IAT with a 5/sec click as S+ and a 1/sec click as S-, and SST with a 1.5 kHz.

at 1.5 kHz, P10 and P11 had a secondary peak at this point. It can be seen from the gradients of these latter two _S_s that all other points, with the exception of .50 kHz, are less than that of 1.5 kHz. The gradient of P13 is similar to those of P4 and P8 in that it does not exhibit a peak at 1.5 kHz and is relatively flat. However, the gradient for P12 suggests some control by 3.0 and 4.0 kHz. These small percentages, however, are primarily the result of very little responding during two of the 7 presentations for both stimuli. As the finding of small percentages at the 3.0 and 4.0 kHz points was not limited to P12, more attention will be given to the matter later.

Subjects P14 and P15 received single stimulus training with 1.5 kHz. Gradients for these _S_s are presented in Figure 4. Clearly, these data indicate little evidence of control by the tonal dimension. It will be noted that there is similarity between these gradients and those of the PD _S_s (P4, P8, P12, and P13). The relatively flat gradiants of all these _S_s are indicative of a lack of dimensional control.

The mean gradients for the TD and PD groups are presented in Figure 5. For all _S_s, but P2, the first gradients were used in this analysis. The second gradient was employed in the case of P2 as it appears that the data from that

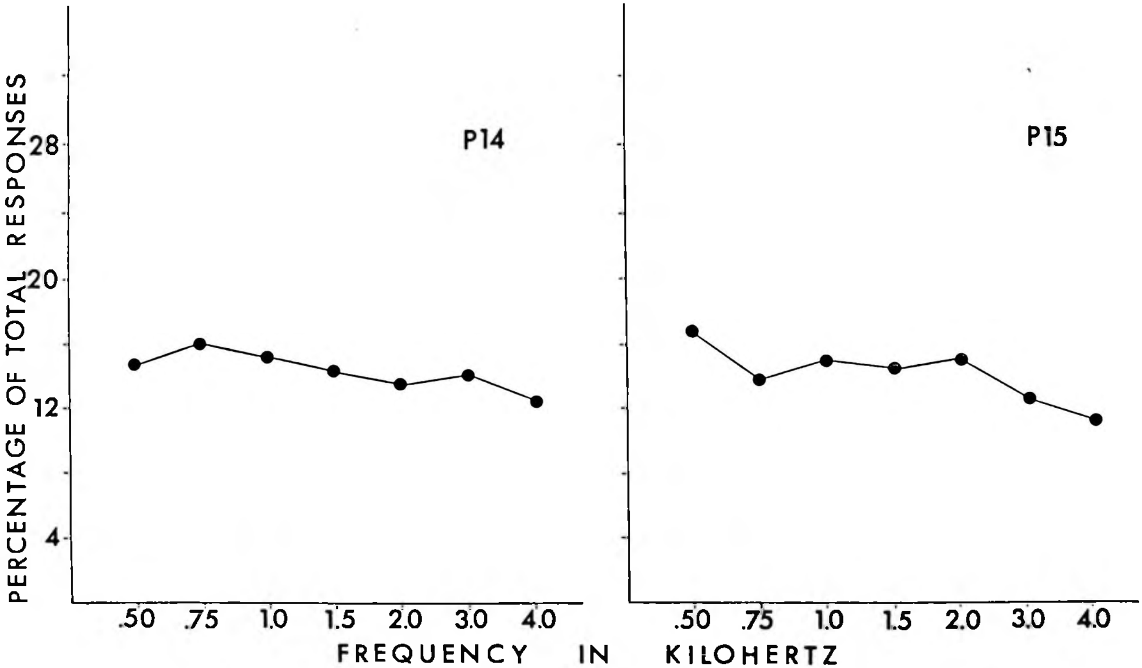

Figure 4. Percentage of total responding to each test stimulus following single stimulus training with 1.5 kHz.

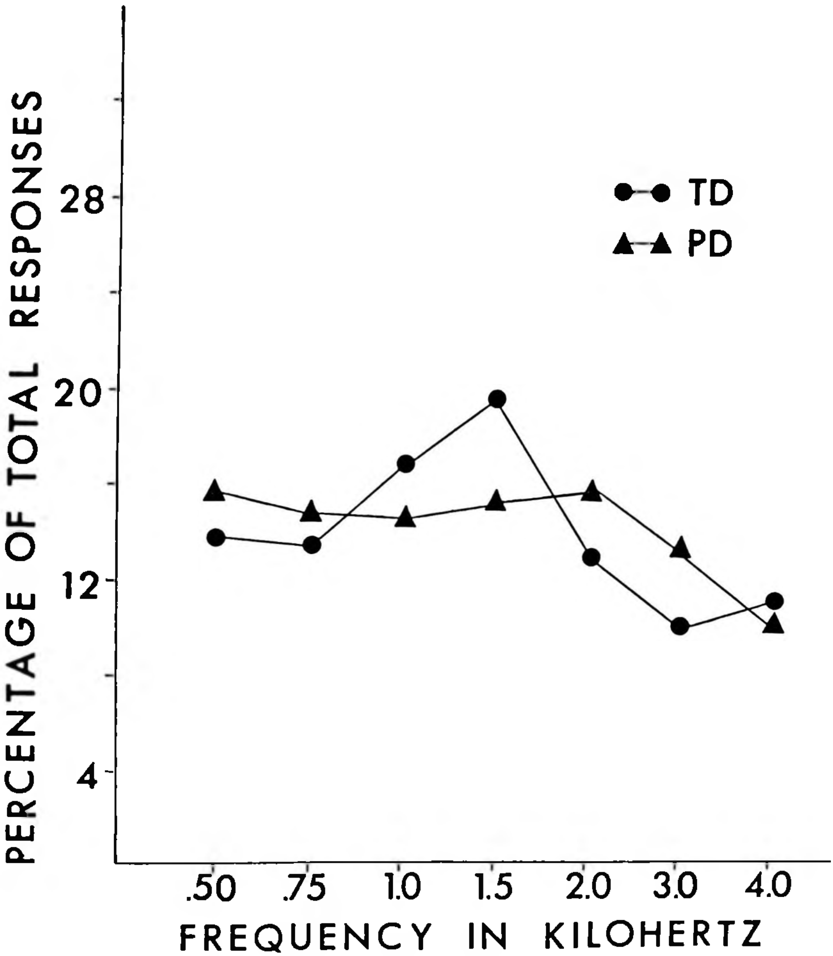

Figure 5. Mean percentage of total responses to each test stimulus for TD and PD groups. Mean of TD group is based on 9 subjects and that of PD group is based on 4 subjects.

test are more representative and do not inflate the value at 1.5 kHz. This figure indicates that the mean gradient for *S*s of the TD groups is steep with a primary peak at 1.5 kHz, while that of the PD group is relatively flat, with the exception of the points at 3.0 kHz and 4.0 kHz. It should be pointed out that these latter two deviations are somewhat exaggerated due to the gradient of P12.

A comparison of the mean percentages of total responding to 1.5 kHz between the TD and PD groups proved significant ($t = 2.47$, $p < .025$, $df = 11$). This comparison is, of course, open to criticism since all *S*s of the TD groups (as well as *S*s of the PD groups) did not experience the same treatments, and only one of the seven test stimuli was used in the analysis. Nevertheless, it points to the same conclusion that can be drawn from inspection of the individual gradients. That is, discrimination training with click frequency results in control by the tonal dimension, while pseudodiscrimination training with the same stimuli results in little or no control by tone.

Since five of the nine TD *S*s exhibited a primary or secondary peak at .50 kHz, on either the first or second test, it was decided to examine certain auditory stimuli in the chamber. This investigation indicated that, while in operation, the solenoid which controlled the grain magazine produced a noise composed predominately of .063 kHz -92 db, .50 kHz -72 db, and 1.0 kHz -76.5 db. Although this finding is only descriptive, it suggests that the primary and secondary peaks at .50 kHz for Ss P1, P2, P7, P10, and P11 may be the result of adventitious pairings of low frequency tones with the presentation of grain during reinforcement.

One other finding deserves mention. In all cases the gradients of the PD and SST Ss have their minima at 4.0 kHz. Since Ss of the SST and PD group showed the effect, the result seems to be unrelated to click frequency experience but, rather, are a function of the tonal frequency dimension. While these are the only supportive data available, it is suggested that tones in the range of 3.0 and 4.0 kHz may possess some degree of inhibitory control independent of relevant experimental manipulations. It is worthwhile to mention that a similar phenomenon has been reported with a visual stimulus. Schadler and Thomas (1972) have demonstrated excitatory control (in pigeons) by a vertical line independent of any training with the line. It is, therefore, the opinion of this author that the slope toward 3.0 kHz and 4.0 kHz for Ss of the PD group, does not represent control by the tonal dimension brought about by experience with click frequency.

A final possibility exists as an explanation of some of the aberrant data. It will be noted that body weights were not as closely controlled as was desired. This unfortunate result was largely due to unavoidable extreme temperature fluctuations between the home cage and the experimental chamber. Therefore, it is possible that weight changes may have produced higher or lower than normal response levels on test days, and thus produced flatter or steeper gradients, respectively.

DISCUSSION

The principal findings of the present experiment were concerned with differences between gradients of _S_s receiving TD and PD training. In the majority of cases it was found that _S_s receiving intradimensional or interdimensional TD training produced gradients which were steeper than those of _S_s receiving PD training. In addition, gradients of the TD _S_s were steeper than those of _S_s receiving single stimulus training.

The present results are completely consistent with Thomas' hypothesis that discrimination training enhances dimensional control by all stimulus dimensions. Though this hypothesis was apparently based upon extradimensional experiments involving only intradimensional TD and PD training, the present data suggest that ET experiments which employ interdimensional TD and PD training yield similar results. It will be recalled that Klipec (1969) did not produce conclusive results regarding the effects of interdimensional discrimination training in an ET experiment.

Since the present experiment demonstrated that interdimensional TD training (with the distinguishing discriminative feature associated with either S+ or S-) led to greater dimensional control than comparable PD training. Klipec's failure to obtain conclusive results may have been due to the use of a relatively insensitive measure. That is, Klipec employed wavelength as the testing dimension and was required, therefore, to compare two steep gradients. The present experiment, however, was not subject to this problem, as comparisons involved steep and flat gradients.

In reference to the results of intradimensional TD and PD training, this experiment has provided generality for Thomas' hypothesis in that it has demonstrated that differences between TD and PD groups are not limited to visual stimuli. Within this context the pertinent issues arises in comparisons of the intradimensional TD gradients of this experiment which those of other intradimensional ET experiments. In the present, unfortunately, only 3 Ss received intradimensional TD training and, therefore, are the only Ss which could serve in a fair comparison. A second problem with such comparisons is that data of the typical ET experiment are presented in the form of mean gradients of a large number of Ss, thus rendering individual subject comparisons impossible. Finally, since wavelength or line tilt are the typical dimensions of generalization employed in such experiments, there exists the problem of equating these dimensions with that of tonal frequency if worthwhile comparisons are to be made. Clearly, this is not possible in the present case. It appears, then, that comparisons between intradimensional TD gradients of the present experiment and those of other ET experiments would be virtually meaningless.

Thomas, Freeman, Svinicki, Burr, and Lyons (1970) have suggested that much of the data which support Thomas' "set to discriminate" or "general attentiveness" hypothesis are directly contradictory to Selctive Attention Theory as proposed by Sutherland (1964) and MackIntosh (1965). It is necessary to note that the only ET experiments which bear on this issue are those in which the training and testing dimensions are simultaneously presented during TD and PD training (e.g., a red key as S+ and a green key as S- with a white vertical line superimposed on each). Thomas et al. have indicated that Selective Attention Theory would predict that Ss which learned the color discrimination (TD group) would learn less about (or attend less to) the vertical line that Ss which did not learn the discrimination (PD group). Given the assumption that a steeper gradient (along the line tilt dimension) would reflect greater learning about or attention to the test dimension, it is clear from experiments of this nature that the prediction of Selective Attention Theory is not supported. Thomas *et al*. have taken the finding of the steeper gradient for the TD group to be supportive of a position that, given a discrimination task, *S*s attend to all stimulus dimensions rather than attending more to one and necessarily, less to another.

While Thomas *et al*. have interpreted their data as contrary to Selective Attention Theory, it is of importance to note several major differences between studies which support their position and those which support Selective Attention Theory. In the majority of experiments which strengthen the Thomas *et al*. position, pigeons were trained on a successive discrimination task and the slope of a generalization gradient was used as a measure of attention to a dimension. In contrast, experiments which support the Selective Attention position, have typically used rats trained on a simultaneous discrimination with the number of trials to learn a new discrimination used as the relevant measure (e.g., Goodwin and Lawrence, 1955; Reid, 1953; and Lawrence, 1952). Due to these differences, it is the opinion of the author that before meaningful comparisons between the two positions can be made, such procedural discrepancies must be resolved.

A recent study (Turner and MackIntosh, 1972) has taken such an approach. These investigators performed an ET experiment which suggests that the data supporting the Thomas *et al*. position may be interpreted without resorting to a "set to discriminate" hypothesis. They gave two groups of pigeons TD training and two groups PD training with a vertical line superimposed on a blue background as S+ and on a green background as S-. For one TD and one PD group, further TD training was given with a red S+ and a yellow S- (no line present). All groups then received generalization testing along the dimension of line orientation. The obtained gradients suggested that relative to TD training, PD training tended to flatten the gradient. In addition, this effect was counteracted by the subsequent TD training along an irrelevant dimension. The authors suggested that PD training allowed irrelevant stimuli to control responding during testing, while TD training had the effect of suppressing the control exerted by these irrelevant stimuli. Further, they interpreted their results as evidence that PD *S*s do not learn less about the testing dimension, and thus, TD training does not establish a "general attentiveness" or a "set to discriminate".

Though Turner and MackIntosh may have a valid criticism of the Thomas _et al_. position, with respect to the typical TD - PD comparison, their argument appears to have two weaknesses. First, they do not offer even tentative identification of the "irrelevant stimuli" controlling PD responding during testing. Since the only illumination in the chamber was provided by the key, it must be assumed that the irrelevant stimuli (if visual) were in some manner associated with the key. Because the background of key was dark during testing, the identification of these irrelevant stimuli becomes quite difficult. A second weakness concerns the steep gradient of the PD group which received subsequent TD training with color. It is not clear how the authors are able to account for this steepened gradient without invoking some variety of the "set to discriminate" hypothesis. That is, how does discrimination training with color steepen a gradient of line orientation. While further information regarding these problems is needed, the important point for the present paper is that there exists two possible interpretations of differences between TD and PD groups.

It has been pointed out previously that SST with tone results in a flat gradient, while SST with visual stimuli typically yields a steep gradient. This finding when coupled with the indication of a difference between the difficulty of auditory and visual discriminations suggests that the pigeon may "enter" the discrimination situation with responding controlled by visual stimuli. In support of this position is the consideration that the key-peck is the typical operant for pigeons. Obviously, S must view the key in order to respond, and, because the key is usually darkened with the onset of reinforcement, visual cues may acquire strong conditioned properties. Studies concerned with auto-shaping of the pigeon's key-peck, e.g., Brown and Jenkins (1969), indicate that this is very likely the case. Further evidence for the controlling properties of visual cues has been provided by Miles (1969). His investigation convincingly demonstrated that, given a discrimination task which could be mastered on the basis of either auditory or visual cues, pigeons discriminated on the basis of the latter.

Also of relevance are the recent investigations of Seligmann (1969), Revusky (1971), and Garcia, McGowan and Green (1972). While these authors do not address themselves specifically to the present issue, their work points to a common conclusion; that certain stimulus-response associations may be learned more readily than others. It is suggested, then, that the pigeon may learn the association of a visual stimulus with the key-peck response before learning the association of an auditory stimulus with the same. Thus, when required to learn an auditory discrimination, the pigeon's responding must first come under the control of auditory rather than visual stimuli. Secondly, the S must learn to discriminate different aspects of the relevant auditory stimuli. Given a visual discrimination task, however, S needs only to discriminate differences in the relevant visual stimuli. It is, therefore, hardly surprising that, for the pigeon, visual discriminations are less difficult than auditory discriminations.

Within this line of reasoning, the following interpretation of the present results is proposed. True discrimination (TD) training with click-frequency requires Ss to respond on the basis of auditory cues. Therefore, during testing, differential responding occurrs to the changing auditory stimuli and steep gradients resulted. On the other hand, PD training does not require responding to come under the control of auditory stimuli, and thus, may allow irrelevant visual cues (such as the key) to control responding. During testing of these Ss, no differential responding occurs since visual cues remained unchanged. Subjects which receive single stimulus training also not required to respond on the basis of auditory cues and, therefore, perform much like the PD _S_s during testing.

It seems reasonable to conclude, then that the present experiment can be taken as supportive of either the "set to discriminate" hypothesis or of a position which suggests that discrimination training merely eliminates the stimulus control possessed by cues which are irrelevant to the discrimination task. In order to clearly support one of the positions to the exclusion of the other, more definitive research is necessary. Such research, it appears, should take the direction of the simultaneous testing of several stimulus dimensions. Such research could indicate the extent to which certain stimuli overshadow control by other stimuli, and provide an assessment of possible enhanced discriminative abilities.

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APPENDICES

Intensities of Auditory Stimuli Used

During Training and Testing

Stimulus	Intensity in db. (spl)
500 Hz	93
750 Hz	82
1000 Hz	80
1500 Hz	80
2000 Hz	84
3000 Hz	80
4000 Hz	80
click (5/sec)	95

Summary of Analysis of Variance for Differences

Between Minutes to Criterion for

the Three TD Groups

Source	Sum of Squares	DF	MS	F	P
Between	275684.00	2	137842.0	1.849	.20
Within	447302.00	6	74550.31		
Total	722986.00	8			

Mean Percentages of Total Responding to

all Test Stimuli for TD and PD Groups

Group	Stimuli (kHz)						
	.50	.75	1.0	1.5	2.0	3.0	4.0
TD	13.9	13.7	16.9	19.8	13.4	10.4	11.3
PD	15.8	14.8	14.7	15.2	15.9	12.9	10.3