77-21,388

MAYS, Mary Zohnez, 1952-
DISCRIMINATION AND GENERALIZATION USING TIME AS A DISCRIMINATIVE STIMULUS.

The University of Oklahoma, Ph.D., 1977
Psychology, experimental

Xerox University Microfilms, Ann Arbor, Michigan 48106

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

DISCRIMINATION AND GENERALIZATION USING TIME AS A DISCRIMINATIVE STIMULUS

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

MARY Z. MAYS

Norman, Oklahoma

1977

DISCRIMINATION AND GENERALIZATION USING TIME

AS A DISCRIMINATIVE STIMULUS

APPROVED BY

This dissertation is dedicated to

GIANPAULO MENNONNA

in the hope that he will use his talents wisely,

and to

JOHN PAUL DENSFORD, Ed. D.

and

MURIEL REECE DENSFORD, M. Ed.

whose aspirations for me formed in large measure,

the incentive value of this goal.

ACKNOWLEDGEMENTS

The author would like to express her gratitude to all those who contributed to this dissertation: Roger L. Mellgren, (who so successfully shaped my early efforts) Roger S. Fouts, (who always provided just the right touch) Robert F. Weiss, (whose wisdom and rigor have been an unending source of enlightenment) Michele S. Mondani, (who taught me to keep things in perspective) W. Alan Nicewander, (who taught me the value of cortical inhibition) N. Jack Kanak, (who ran interference for me on a number of occasions) Dick Rubrecht, (who so patiently prepared my apparati) and Nabil F. Haddad and Phillip C. Thompson, (who so willingly and faithfully contributed their time and their thoughts to the running of these experiments).

A special thanks should be given to:

Diana, Bob, Ray, and Jim - without their laughter this and related projects would never have been completed,

Jeff - for telling me about FIM,

Jim - for showing me his version of the Boysen way of life,

Sally - for showing me her version of the Boysen way of life,

Marla - for liking me from the moment she met me,

Michele - for always arriving at the perfect solution,

Nabil - for his sensitivity,

Simon and Burny - for their unconditional love,

and Randy.

TABLE OF CONTENTS

Abstract

Literature in support of temporal discrimination in animals was used to justify the use of temporal discrimination procedures as a means of investigating the functional similarity of interoceptive and exteroceptive stimuli. This study was an attempt to explore the relative merits of two types of discrimination tasks, conditional discrimination and go-no go discrimination, in a single experiment. Rats were run in a Grice-type discrimination box. Speed and choice data were recorded for both types of discrimination. Stimulus durations of 3 and 30 seconds were used as discriminative stimuli. Rats successfully mastered the go-no go discrimination, but not the conditional discrimination. Rats were tested over stimulus durations of 3, 6, 15, 18, 27, 30, and 40 seconds in a subsequent generalization test. Generalization gradients similar to those obtained for exteroceptive discriminative stimuli were obtained from rats in the go-no go discrimination group, while essentially flat gradients were obtained from rats in the conditional discrimination group. The importance of this information for planning an integrated series of experiments investigating the functional similarity of interoceptive stimuli and exteroceptive stimuli is discussed.

Discrimination and Generalization Using Time
as a Discriminative Stimulus

The notion that animals are in some way able to mark the passage of time rather accurately and to discriminate between different temporal intervals has influenced a broad range of research areas (Anger, 1956, 1963; Baum, 1973; Church, Getty & Lerner, 1976; Dews, 1962; Reynolds, 1966; Sams & Tolman, 1925; Sheffield, 1949, 1950; Skinner, 1938; Wilson & Keller, 1953). Much of what has been considered evidence for temporal discrimination (TD) has come from the extensive literature on the parametric investigations of schedules of reinforcement; in particular FI schedules (Dews, 1962, 1965a, 1965b, 1966a, 1966b, 1969, 1970; Ferster & Skinner, 1957; Harzem, 1969; Jenkins, 1970; Morgan, 1970; Morse, 1966; Segal, 1962; Shull & Brownstein, 1975; Church & Roberts, Note 1) and DRL schedules (Frank & Staddon, 1974; Ferster & Skinner, 1957; Harzem, 1969; Hodos, Ross & Brady, 1962; Kelleher, Fry & Cook, 1959; Kramer & Rilling, 1970; Laties, Weiss & Weiss, 1969; Morse, 1966; Reynolds, 1964a, 1964b, 1966; Wilson & Keller, 1953). However, it has been suggested that performance on these schedules is a function of a number of variables in combination and so does not always yield unequivocal support for the animal's ability to discriminate between temporal intervals (Catania, 1970; Kramer & Rilling, 1970; Morse, 1966; Perikel, Richelle & Maurissen, 1974; Reynolds, 1966; Skinner, 1938; Staddon, 1965; Stubbs, 1968).

Recent contributions to the literature on TD include studies more directly investigating the limits of the animal's capacity to make TDs (Catania, 1970; Church, Getty & Lerner, 1976; Kinchla, 1970; Perikel, Richelle & Maurissen, 1974; Platt, Kuch & Bitgood, 1973; Reynolds & Catania, 1962; Staddon, 1972; Stubbs, 1968, 1976; Vandell & Ferraro, 1972; Church, Note 2). However, while it is true that TD in animals has received extensive attention, little effort has been made to integrate this literature. A significant obstacle to the integration of the findings of these investigations is the number of different procedures used to study TD.

Go-no go discrimination

Five investigations of TD have employed a go-no go discrimination paradigm. Woodrow (1928) reinforced Rhesus monkeys for reaching for food after an interval of 4.5 seconds (bounded on either end by the activation of an electromagnetic sound hammer) and punished them for reaching for the food after an interval of 1.5 seconds. One monkey reached a criterion of 10% errors after 2640 trials while the other reached it after 3600 trials. Reynolds and Catania (1962) varied the duration of a visual stimulus (dark key periods) between 3 and 30 seconds in 3 second steps, reinforcing pigeons' key pecks after 3 second durations only. Twelve presentations of each of ten durations were made in each daily session. The number of daily sessions needed for the animals to acquire the discrimination was not reported. Graphs of the median number of key pecks at each duration (averaged over the last five sessions) showed what appeared to be a linear decrease in the number of key pecks as the duration of the stimulus increased. Catania (1970) reports additional data obtained from these pigeons, with the same procedure. Stimulus durations ranged from 5 to 50 seconds in 5 second increments and from 20 to 200 seconds in 20 second increments. These graphs look extremely similar to those reported by Reynolds and Catania (1962). However, these data are the result of months of training on this discrimination, so that the data are not necessarily comparable to that obtained with naive subjects.

<u>Response duration discrimination</u>. Vandell and Ferraro (1972) used a go-no go discrimination task, but the discriminative stimuli were response durations of differing lengths; e.g., lever presses lasting 4.0 seconds (or 2.4 seconds for some rats) or 0.0 seconds (a normal lever press). Presses of either duration resulted in the retraction of the lever on which they were made and the insertion of another. Presses on the second lever were reinforced after a long duration press on the first lever and nonreinforced after a short duration press on the first lever. Each daily session continued for 189 trials (of which 2/3 required short presses and 1/3 required long presses). Graphs of response discrimination ratio (R^{Δ} rate/ R^{D} rate) during the last four of seven training sessions indicate that this discrimination was acquired. The relevance of the procedure for studying TD is somewhat questionable, since it is not clear whether rats were making a discrimination between different values of interoceptive temporal stimuli or interoceptive proprioceptive stimuli or a combination of these. While the nature of interoceptive stimuli temporal stimuli has not been specified, the previously discussed

discriminations each clearly involved a discrimination along the temporal dimension. In contrast, in Vandell and Ferraro's study the rat does not necessarily need to attend to the temporal dimension, since there are obvious differences in the response-produced proprioceptive (kinesthetic, cutaneous, etc.) stimuli occasioned by the two responses.

A more complex version of the go-no go discrimination paradigm used by Bowen and Strickert (1966) provides information about the rat's ability to use interoceptive temporal stimuli as one component of a compound discriminative stimulus. In a straight alley apparatus, rats can learn to run differentially on reinforced and nonreinforced trials if the goal event on trial n-1 predicts the outcome of trial n (Capaldi, 1967). Bowen and Strickert correlated the length of the intertrial interval (ITI) with the relationship between the goal event of trial n-1 and the goal event of trial n. That is, if the ITI was 5 minutes, the goal event on trial n would be the same as that on trial n-1; if the ITI was 15 seconds, the goal event on trial n would be the opposite of that on trial n-1. Mean log running times on nonreinforced vs reinforced trials were analyzed. They were significantly different after 120 trials. An additional 120 trials did not improve the discrimination.

Although each of these studies lend support to the notion that animals can learn to discriminate between temporal intervals, these investigations differ in the species of animal used as subjects, the mode used to present the temporal interval, the length of the temporal interval, the number of temporal intervals presented, the complexity of the discriminative response required, the complexity of the discriminative task, the dependent measure employed, and the setting of the task. Thus comparisons between the investigations yield little information other than that the phenomenon exists to some extent in a variety of situations.

Conditional discrimination: early investigations

Early investigations of TD required rats to choose between two or more paths to a baited goal box which differed only in the amount of delay imposed halfway down the path (Anderson, 1932; Sams & Tolman, 1925). That animals quickly learned to choose the path with the shorter delay was attributed to their ability to make a TD. However, Cowles and Finan (1941) and Heron (1949) proposed that the choice of the shorter delay might be a function of a delay of reinforcement gradient; i.e., the choice of the temporally shorter path was conditioned more strongly. To rule out this explanation, each of these experimenters presented the delay interval immediately after the rat left the start box and prior to his choosing a path to the goal. Thus, the rat had to learn a conditional discrimination -- for instance, if the delay interval is long, turning right is reinforced; if the delay interval is short, turning left is reinforced. Sams and Tolman (1925) required rats to choose between delays of 1 and 6 minutes, in a simultaneous two choice rectangular maze. Rats needed between 15 and 40 trials to reach a criterion of 100% choices of the shorter delay. This is not surprising since these durations are easily discriminable. One of the groups run by Anderson (1932) was required to choose between delays of 10 and 30 seconds (in a Grice-type apparatus). This group of rats achieved a criterion of 80% choices of the 10 second path after 200 trials. In contrast to this data, Cowles and Finan (1941) found that rats achieved a criterion of 75% correct choices only after 600 trials on a conditional discrimination (in a Y-shaped maze) using the same delays (10 vs 30 seconds). Thus, it appears that the conditional discrimination task is a more difficult task. Heron (1949) used a procedure very similar to that of Cowles and Finan (in a +-shaped maze) with a larger discrepancy between the two delays, 5 vs 45 seconds, however. Heron's rats achieved a criterion of 90% correct within 43-356 trials. These early investigations would seem to indicate that the objective discriminability between two temporal intervals is reflected in the ease of discrimination, as is true when exteroceptive stimuli are used as discriminative stimuli.

Conditional discrimination: psychophysical methods

The most recent contributions to the literature on TD have also employed conditional discriminations. However, the recent trend is to view the conditional discrimination as a psychophysical choice situation. Thus, data from these experiments have been examined for the extent to which they are comparable to the psychophysical judgments of sensory stimuli by animals and of temporal stimuli by humans. Catania (1970) reports a study in which a squirrel monkey was presented five different auditory stimulus durations: after a 1 second duration, responses on one lever were reinforced, but not on the other lever; after a 4 second duration, these contingencies were reversed; and after the intermediate durations of 2, 2.5, and 3 seconds, responses to either lever produced the ITI. A graph of the percent of responses on the left lever (averaged over the last five sessions) showed an apparently linear decrease in responding as the stimulus duration increased. Catania shows that these data are approximately linear in their logarithmic coordinates and suggests that these data are best described by a power function where short durations are overestimated, long durations are underestimated and an indifference interval is found at intermediate durations.

This power function is congruent with Anderson's (1932) finding that Weber's law (equal relative differences are equally discriminable) holds for choices between delay intervals, with Dews' (1969, 1970) description of performance on FI schedules, (cf. Harzem, 1969; Jenkins, 1970; LaBarbera & Church, 1974; Morgan, 1970; Shull & Brownstein, 1975; Church, Note 2) and the finding that temporal intervals are typically bisected at the geometric mean rather than the arithmetic mean (Harzem, 1969; Herrnstein, 1964).

Kinchla (1970) required pigeons to learn a conditional discrimination between auditory stimulus durations of 1 and 5 seconds. Pigeons were given 15 sessions (of 90 reinforcements each) on the 1 vs 5 second discrimination and 15 more on a 2 vs 5 second discrimination, then 30 sessions on a 3 vs 5 second discrimination and finally 10 sessions on a 4 vs 5 second discrimination. These durations were chosen because pigeons could maintain only a partial discrimination of 65% correct choices on the 4 vs 5 second discrimination. The data obtained from these discriminations were analyzed in terms of signal detection theory (Green & Swets, 1966). Discriminative performance became systematically poorer with the decrease in the discriminability of the discriminative stimuli. These data appear to be congruent wiht that of Woodrow (1928) and Heron (1949), who also progressively decreased the difference between the discriminative stimuli. Although the procedures and the data analysis are distinctly different, the initial discrimination employed by Woodrow (1928) was 1.5 vs 4.5 seconds, so these experiments should yield comparable conclusions. In Experiment 2, (Kinchla, 1970) naive pigeons were presented with changes in the "pay off functions" after the discrimination between 4 and 5 seconds had stabilized. Only weak sequential dependencies were found, supporting the notion that performance was the result of an independent trials process, rather than a sensitivity model.

Stubbs (1968) too, has made use of signal detection theory in his study of TD. In Experiment 1 of this study, pigeons acquired a conditional discrimination between a class of short durations, 1, 2, 3, 4, and 5 seconds and a class of long durations, 6, 7, 8, 9, and 10 seconds. This discrimination stabilized in approximately 90 daily sessions (each was 2.5 hours long or 40 reinforcements, on an FR 6 schedule). Graphs of the proportion of long responses (key pecks to the key designated as the correct key after long durations) showed a function that appeared to be a normal ogive when the stimulus durations were logarithmically scaled; i.e., the proportion of long response increased as the stimulus duration increased. These data support the earlier findings that discriminative responding is a function of relative time differences, not absolute, and that the obtained psychometric function cna best be described as a power function. In Experiment 2, half of the pigeons from the first experiment acquired a conditonal discrimination where the class of short durations was 2, 4, 6, 8, and 10 seconds, while the class of long durations was changed to 12, 14, 16, 18, and 20 seconds. As soon as performance stabilized on this discrimination, the class of short durations was changed to 4 through 20 seconds, while the long durations were changed to 24 through 40 seconds. As soon as this discrimination stabilized pigeons were switched back to the original discrimination of Experiment 1. Finally, the pigeons were presented with a discrimination task where the durations were equal logarithmic distances from the midpoint; i.e., the short durations were 1, 2, 3, 4, and 5 seconds and the long durations were 6, 8, 10, 15 and 30 seconds. Graphs of the first four discriminations closely resemble those from Experiment 1. A graph of the percentage of long response at each of the stimulus durations used in the final discrimination is clearly a normal ogive, indicating that discriminative performance is a function of relative, not absolute differences.

The other half of the pigeons from Experiment 1 were used in Experiment 3, where the "pay off functions" were manipulated, showing that the accuracy of the discrimination and the relative proportion of long responses could be controlled through contingency manipulations. The data obtained replicate those obtained in matching-to-sample research on color discriminations.

Stubbs (1976) extended his earlier work (Stubbs, 1968) showing that pigeons' discrimination of durations yield data congruent with that obtained from traditional and signal detection psychophysical procedures with exteroceptive sensory stimuli. Sevral different dependent measures indicate that when relative reinforcement rates for different choice reponses are varied, response bias varies, while sensitivity remains the same. This is in direct conflict with Kinchla's data (1970). Stubbs has supported a sensitivity model, while Kinchla has supported an independent trials process. The two most obvious differences between the studies are the differences in the type of discrimination tasks and the fact that Kinchla used naive pigeons, while Stubbs used pigeons that had had over a year's training on duration discriminations, including maintainence of discriminative responding under the influence of amphetimines.

The internal clock. A number of the recent psychophysical studies have had as their main objective an investigation of the properties of the internal clock with which rats are able to form TDs (Church, Getty & Lerner, 1976; Church & Roberts, Note 1; Church, Note 2; Church & Deluty, Note 3). Church, Getty and Lerner (1976) required rats to learn a conditional discrimination between auditory stimulus durations of .5 and 8 seconds. It should be noted that incorrect responses were followed by shock through the grid floor. After 4900 trials all three rats were making more than 90% choices of the correct lever. Data from the following test phase which involved varying the discriminability of the durations to determine a difference limen supported the predictions of a generalized Weber model more closely than they did a generalized Counter model. The significance of this study lies in its potential provision of a theoretical integration of the studies investigating whether animals' psychophysical judgments are made in absolute or relative units of time (Anderson, 1932; Catania, 1970; Dews, 1969, 1970; Ferraro & Grilly, 1970; Harzem, 1969; Herrnstein, 1964; Jenkins, 1970; LaBarbera and Church, 1974, Morgan, 1970; Platt, Kuch & Bitgood, 1973; Shull & Brownstein, 1975; Stubbs, 1968; Church & Deluty, Note 3).

Response duration discrimination. Although response duration discriminations are not necessarily an indication of TD per se, psychophysical investigations of response duration (Ferraro & Grilly, 1970; McMillan & Patton, 1965; Platt, Kuch & Bitgood, 1973; Vandell & Ferraro, 1972) are in support of the work by Catania (1970), Kinchla (1970) and Stubbs (1968, 1976). All of these studies have used rats and the differential reinforcement of bar press durations. These experiments have shown that response duration is a discriminable property of responding, that simple response duration discriminations are acquired in a length of time comparable to discriminations of stimulus durations (McMillan & Patton, 1965), that Weber's law is applicable to response duration discrimination and that Catania's (1970) power function forms a good fit to the data (Ferraro & Grilly, 1970; Platt, Kuch & Bitgood, 1973; note also that the graph presented by Vandell and Ferraro, 1972, is an ogive as is the function reported by Stubbs, 1968, Experiment 2, when durations were equal distance from the midpoint).

In summary, all of the studies where a conditional discrimination task has been employed, support the general conclusions that the ease of the discrimination task is a reflection of the objective discriminability of the durations, that Weber's law is applicable to TD, that the obtained psychometric function approximates a normal ogive and is best described by a power function, and that psychophysical procedures are easily adapted to the study of interoceptive stimuli (including temporal stimuli and response-produced stimuli, such as that occasioned by response duration discrimination).

A comparative study

Although, these general conclusions are easily drawn, there are significant procedural differences between the studies reviewed. It is not possible at this time to assess whether the differences in the results of these studies are a reflection of the procedures used or of the nature of TD. At least one study, has provided information that might help to alleviate the problems caused by the number of procedures used. Perikel, Richelle and Maurissen (1974) have attempted to show the common characteristics of go-no go and conditional discriminations. During pretraining, a perfect discrimination between .5 and 10 seconds was established where key pecks were reinforced after 10 seconds and nonreinforced after .5 seconds (i.e., a go- no go discrimination). Training began with two, 2 hour sessions with a 1 vs 10 second discrimination. Then the shorter stimulus duration was progressively increased in 1 second increments.

Pigeons were given four sessions with 2 vs 10 seconds, and then six sessions with each of the values 3-8 vs 10 seconds. Discriminative responding progressively decreased from 90% correct at the 1 second duration to 50% correct at the 8 second duration. In the second phase of the experiment, these pigeons were given 13, 2 hour sessions where pecks on one key were reinforced after a visual stimulus duration of .5 seconds and pecks on another key were reinforced after a visual stimulus duration of 10 seconds were reinforced (i.e., a conditional discrimination task). Training began with a 1 vs 10 second conditonal discrimination and was completed after the shorter interval had been progressively increased to 10 seconds in 1 second increments. The number of sessions given at each of the short durations was not reported. Discriminative responding progressively decreased from 90% at the 1 second duration to 75% at the 8 second duration to 50% at the 10 second suration. Thus, it would appear that the conditional discrimination is more easily acquired than the go-no go discrimination. However, these pigeons had had more than 110 hours of experience on duration discriminations before beginning the experimental training (including 26 hours on a conditional discrimination between .5 and 10 seconds, immediately prior to beginning experimental training). It is impossible to evaluate the effects of transfer of training or sheer practice, in this experiment, but it seems probable that one or both of these factors played some role in determining the increased accuracy of discriminative responding on the conditional discrimination. For this reason, this investigation is best viewed as providing preliminary information about the difference between the two discriminations. Although no psychophysical analysis was done on this data, it is clear that the data of both go-no go and conditional discriminations are equally amenable to analysis by psychophysical methods, since the data obtained here are quite comparable to that obtained by Kinchla (1970).

Temporal generalization

To this point, there has been little investigation of generalization along a temporal dimension following temporal discrimination training. Reynolds and Catania (1962) and Catania (1970) refer to their procedure as one which allows the simultaneous assessment of TD and temporal generalization (TG). That is, discrimination training consists of presenting from the beginning of training a number of stimulus durations, only one of which is reinforced. Thus, aplot of the number of responses at each duration should yield a TG gradient. Gradients obtained in this fashion show an essentially linear increase in responding as the duration becomes less discriminable from the reinforced duration. However, no data is reported concerning the change in the shape of the gradient over sessions. The gradient reported is that found after extensive experience with differential reinforcement across these durations. That is, it is easily conceivable that at the beginning of training the discrimination gradient would be flat and that it takes the shape reported only as behavior comes under stimulus control. Whereas in a generalization test that follows discrimination training, the animal shows a generalization gradient across stimulus durations which he has never experienced previously. Thus, the TG gradient obtained <u>following</u> discrimination training, is an objective indication of the animal's ability to discriminate one duration from another. It is not an expression of the artificial discrimination that is the result of procedures explicitly designed to induce stimulus control over behavior. Stubbs (1968) pretrained pigeons on a conditional discrimination between 1 and 10 seconds and then presented them with the novel stimulus durations of 2-9 seconds in one session (reinforcing one response after durations of 2-5 seconds and another response after durations of 6-9 seconds). The percentage of long responses was plotted across the stimulus durations for this session. This TG gradient shows an apparently linear increase in responding as the stimulus duration increases.

Vandell and Ferraro (1972) required rats to learn a conditional discrimination betwee two response durations. After this discrimination had stabilized, one out of every nine trials served as a generalization probe. No reinforcement was presented after a generalization probe trial. For rats for whom the reinforced response duration was 4.0 seconds, the generalization probes were .25, .50, 1.0, 2.0, and 8.0 seconds. For rats foe whom the reinforced response duration was 2.4 seconds, the generalization probes were .15, .30, .60. 1.20, and 4.8 seconds. A plot of the mean number of responsesat each of the stimulus durations tested approximated the normal ogive. From the evidence that exists, it would appear that TG gradients are comparable to the generalization gradients obtained with exteroceptive stimuli.

Proposal

The literature reviewed gives strong support to the notion that animals can form TDs. Moreover, it appears that the only distinction between TD and other sensory discriminations is the ease with which one is able to point to the receptor organ. It is clear that interoceptive stimuli are being used as discriminative stimuli in TD. The unspecifiability of the nature of the interoceptive stimuli is unimportant for the present purposes (for an elegant thoery of the internal clock, see Church, Note 2). The experiment presented here and those proposed as a result of it, were designed to assess the functional similarity of interoceptive discriminative stimuli and exteroceptive discriminative stimuli. A TD procedure was used precisely because TD is based on imprecisely specifiable interoceptive stimuli.

Before beginning a systematic investigation of the functional similarity of interoceptive stimuli and exteroceptive stimuli, it seemed appropriate to develop a single procedure conducive to the study of a wide range of phenomena relevant to TD and comparable to a wide range of procedures previously employed in the study of both TD and sensory discrimination. In this way, the results of previous research and the proposed research might be more easily integrated. For this reason, two types of discrimination tasks, a go-no go discrimination and a conditional discrimination were compared in a discrete-trials runway situation. These procedures are simply implemented, simply communicated, conceptually similar to those used previously, and yield the same dependent measures, probability and latency of response, as those used previously. Moreover, at the same time this study provides a comparison of the two discrimination tasks, it will also provide needed information about TG gradients obtained following TD.

Method

Subjects

Twenty, experimentally naive, male, albino rats of the Sprague-Dawley strain were purchased from the Holtzman Co., Madison, WI. They were approximately 60 days old upon arrival in the laboratory. They were housed two to a cage and given food and water ad libitum for 14 days.

Apparatus

A wooden Grice-type discrimination box (Grice, 1948) constructed at this institution, was employed in the study. This apparatus consisted of a Y-shaped black start-choice section which allowed simultaneous exposure to two of three parallel goal sections. The middle goal section was black and white striped and the two outer goal sections were gray. By sliding the start-choice section from side-to-side a gray goal section could be presented on either the left side or the right side of the striped goal section.

The rectangular start section measured 29.5 cm long, 15.5 cm wide, and 13 cm high (inside dimensions). The far end of this section was formed by a clear Plexiglas door which separated the start and choice sections. The start section had a hinged lid constructed of hardware cloth on a light wooden frame. The choice section formed a trapezoid whose sides projected at a 100° angle from the Plexiglas start door and were 15 cm long and 13 cm high. The top of this section was covered with hardware cloth. Two Plexiglas guillotine doors, each 9 cm wide and 16 cm high, separated the choice section from the two goal sections. Each rectangular goal section measured 46 cm long, 10.5 cm wide, and 13 cm high (inside dimensions). At the far end of each goal section, a shallow, round, metal, food cup (4 cm in diameter) was permanently mounted (6.5 cm off the floor). All three goal sections were covered by a single, hinged lid constructed of hardware cloth on a light wooden frame.

Latencies were recorded by two .01 second stop clocks (A.W. Haydon Co., Waterbury, CT, model number K15140). The first clock was started by a microswitch activated by sliding the start door up. When the rat broke a photoelectric beam (equipment obtained from a local distributor of Tandy Corp. products) located 6 cm into the goal section, the first clock stopped (start-choice latency) and the second clock started. The breaking of a second photoelectric beam located 30.5 cm from the first photoelectric beam (9.5 cm from the end of the runway) stopped the second clock (goal latency).

A one second stop clock (GraLab Universal Timer, model number 172, supplied by the Lafayette Instrument Co., Lafayette, IN) was used to time the start section confinement duration. The tone was generated by a transitorized tone oscillator (6-28 volt Sonic Alert) which was run by a timer constructed at this institution. The timer could be set for durations ranging from .1 seconds to 99.9 seconds. The tone generator was taped speaker down on the table adjacent to the start-choice section.

A rack of 12 wooden cages with wooden hinged lids and hardware cloth floors, each measuring approximately 10 cm wide, 21 cm long, and 15 cm high, (inside dimensions) mounted on a movable cart, was used to transport the rats from their home cages to the experimental room and to house the rats during the intertrial interval.

Design

There were two experimental conditions in the experiment. A conditional (if-then) discrimination and a go-no go discrimination. Rats in the conditional discrimination condition would be reinforced for running into the left-striped (LS) goal section if a tone of one duration were sounded and into the right-gray (RG) goal section if a tone of the other duration were sounded. Having two redundant cues should maximize the discriminability of the two alternatives. Rats in the go-no go discrimination condition would be reinforced for running after a tone of one duration was sounded and nonreinforced after a tone of the other duration.

Rats in Group IF-L were reinforced in the LS goal section after a 30 second tone and were reinforced in the RG goal section after a 3 second tone. Rats in Group IF-R were reinforced in the RG goal section after a 30 second tone and were reinforced in the LS goal section after a 3 second tone. Groups GO-L and GO-R were reinforced after a 3 second tone and not reinforced after a 30 second tone. Group GO-L always ran into the LS goal section and Group GO-R always ran into the RG goal section. In this way the factor of running LS versus RG was counter-balanced across all conditions.

There were five differrent sequences of 3 and 30 second trials used each day and three different orders of these sequences were used across days (see Table 1). In this way no rat could predict the nature

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Insert Table 1 about here

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of the trial he was about to get, based on the trial experienced by the rat before him, nor could he come to learn a given schedule over the course of discrimination training, since it was not repeated daily.

Procedure

On Day 1 of the experiment each rat was randomly assigned to one of four groups and his tail marked. Rats were housed individually and fed a 12 g ration of Purina Lab Chow (PLC). Rats continued to have access to water ad libitum through the course of the experiment. On the following seven days the rats were individually handled for approximately two minutes each day immediately prior to being fed. During the first four days of this period, the rats were fed 12 g of PLC daily. During the next three days, the rats were fed 3.5 g of Startena (Purina Hog Starter) and 8.5 g of PLC.

During the course of the experiment rats were allowed a maximum time of 15 seconds in the apparatus. Sections not entered in that time were assigned a latency of 15 seconds. Rats were then placed in the goal section directly in front of the food cup. The goal section was baited with two 1 cm pellets of Startena (approximately 300 mg) on reinforced trials. Rats were confined in the goal section until they finished eating on reinforced trials and for 30 seconds on nonreinforced trials.

Pretraining. Pretraining began on Day 9. All rats were given two running trials in the apparatus with the goal sections baited. Each rat received one trial with the 30 second tone and one with the 3 second tone. After all rats were run, each rat was given 3.5 g of Startena and 8.5 g of PLC. On Day 10 this procedure was repeated with the exception that the rats were given 12 g of PLC after running. Through the remainder of the experiment, rats were given 12-15 g of PLC daily immediately following their last running trial. On the following two days each rat received four trials per day. These trials followed the schedules that would be used for the first four trials of the first and second days, respectively, of discrimination training (see Table 1). On the final day of pretraining each rat was given six trials. These trials were given according to the schedules that would be used for the first six trials on the third day of discrimination training (see Table 1).

During pretraining and the following discrimination phase, rats were run in two squads of ten rats each. Rats within a squad were run in rotation, with all rats receiving their first trial before any rat received his second trial. The order of rats within a squad randomized. Squad one was composed of two rats from Group GO-L, three from Group GO-R, three from Group IF-L, and two from Group IF-R. Squad two was composed of three rats from Group GO-L, two from Group GO-R, two from Group IF-L, and three from Group IF-R. The intertrial interval was approximately 8-10 minutes.

Discrimination-Phase I. Discrimination training began on Day 14. Rats received eight trials per day for 25 days. For rats assigned to the conditional discrimination groups, the first four trials each day were forced trials (only the door to the reinforced goal section was open). Two of the trials were preceded by a 30 second tone and two were preceded by a 3 second tone, so that rats had equal experience with turning right and turning left. The next four trials for this group were free choice trials (both doors were open). Thus, rats in this group received at worst a 50% reinforcement schedule. Again, two of the free trials were preceded by a 30 second tone and two by a 3 second tone. Rats assigned to the go-no go discrimination groups always received a 50% reinforcement schedule; i.e., four trials were preceded by a 30 second tone (nonreinforced trials) and four trials were preceded by a 3 second tone (reinforced trials).

At the beginning of each trial, the rat was detained in the start section from 5 to 20 seconds before the tone began to sound. Thus, total time spent in the start section varied from 8 to 50 seconds, and was not correlated with the correct choice on that trial. The length of confinement prior to the onset of the tone varied over trials within a day and for a given trial across days, according to a predetermined schedule (see Table 2). Because there were five confinement schedules and three

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Insert Table 2 about here

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tone sequence schedules, a given confinement schedule was paired with a given tone sequence schedule on 1 out of 5 days, adding to the unpredictability of the nature of the forthcoming trial.

Discrimination-Phase II. After 25 days of discrimination training, it was apparent that rats receiving go-no go discrimination training had mastered the discrimination, whereas rats receiving conditional discrimination training had not. For this reason Groups GO-L and GO-R began generalization testing the day following the end of Phase I discrimination training, while Groups IF-L and IF-R began a new phase of discrimination training which lasted ten days.

In this phase, a correction procedure was adopted. All eight trials each day were free choice trials. The first trial of each day was run according to the tone sequence schedule used in Phase I discrimination training, however, if the rat did not choose correctly, that same trial was run again until he did choose correctly. Only then was the second trial in the tone sequence schedule run. No forced trials were run during this phase. The confinement schedule was not changed (see Table 2). Rats were run in two squads of five, composed of two rats from one group and three rats from the other. Rats within a squad were run in rotation, so that the intertrial interval was approximately 4-6 minutes.

Generalization. Two days of generalization testing were run for Groups GO-L and GO-R at the same time the first and second days of Phase II discrimination training for Groups IF-L and IF-R were being run. All rats in Groups IF-L and IF-R were run before any rats in Groups GO-L and GO-R were run on these days. Rats in groups GO-L and GO-R were run in two squads of five, composed of two rats from one group and three from the other. Rats within a squad were run in rotation, so that the intertrial interval was approximately 4-6 minutes. Eight trials were run each day. The first trial was preceded by a tone of 3 seconds duration and was reinforced. Each rat was then tested over the next seven trials with tones lasting 3, 6, 15, 18, 27, 30, or 40 seconds. None of these trials were reinforced. Each rat in the squad received a different schedule of tones and each rat received two different schedules on the two days of testing (see Table 3). The first and second confinement schedules (see Table 2)

Insert Table 3 about here

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were used on Days 1 and 2 of this phase respectively.

Generalization testing for Groups IF-L and IF-R began the day after the end of Phase II discrimination training. Their testing followed the format of genrealization testing for Groups GO-L and GO-R with the following exceptions: the first trial each day was forced and reinforced, the first trial was preceded by a 3 second tone on Day 1 of testing and a 30 second tone on Day 2, for all rats, and the following seven nonreinforced trials were free choice trials, and were run according to the schedule presented in Table 3.

Results

Discrimination-Phase I

Proportion correct choices. In Phase I of discrimination training, rats in the conditional discrimination groups were free to choose between the goal sections on the last four trials of each day. Each day, the number of trials on which a rat correctly chose the baited goal section was divided by the total number of trials (four) to yield proportion correct choices. A 2 (Groups) x 25 (Days) analysis of variance was performed on this dependent measure. None of the tests was significant, ($p > .10$) indicating that the groups were not disfferentially affected by the counterbalancing procedure, and that neither of the groups showed an increase in the proportion of correct choices over the course of discrimination training.

In order to straightforwardly compare performance on the two discrimination tasks, data from the go-no go discrimination groups were converted to a proportion correct choices format in the following manner: when a rat's total latency (the sum of start and goal latencies) equaled or exceeded 4.00 seconds, it was considered to be a "correct" choice for a nonreinforced trial and an "incorrect" choice for a reinforced trial. The converse, of course, was also true. Thus, each day the number of trials on which a rat "chose correctly" was divided by the total number of trials (eight) to yield proportion correct choices (a dependent measure conceptually similar to this was employed by Perikel, Richelle & Maurissen, 1974; Woodrow, 1928). A 2 (Groups) x 25 (Days) analysis of variance was performed on this dependent measure. The main effect of groups was not significant ($p > .10$) indicating that the groups were not differentially affected by the counterbalancing procedure. The main effect of Days was significant, F (24,192) = 8.13, $p < .001$, and did not interact significantly with the factor of Groups ($p > .10$) indicating that both groups showed the same increase in the proportion of correct choices over the course of discrimination training.

Since the dependent measure analyzed for the conditional discrimination groups is roughly comparable to the dependent measure analyzed for the go-no go discrimination groups a 2 (Type of Discrimination) x 25 (Days) analysis of variance was done comparing the groups. Counterbalancing was not included as a factor since it had been shown to have no effect. The Type of Discrimination main effect was significant, F (1,18) = 17.11, $p < .001$, and the Days main effect was significant, F (24,432) = 4.16, $p < .001$. However, their interaction was also significant, F (24,432) = 3.09, $p < .001$, indicating that the two groups acquired the discrimination at differential rates (see Figure 1).

Insert Figure 1 about here

<u>Goal speed</u>. The typically employed dependent measure for assessing the extent to which rats in a go-no go discrimination group learn the discrimination is a speed measure. In this experiment start, goal and total (start + goal) latencies were recorded and converted to speeds (1/latency). The start speed was highly variable and appeared to reflect a decision-making time. The goal speed, however, is approximately the time it takes to run the length of the goal section, once the rat has completely entered the goal section. For this reason it seemed that analyzing goal speeds was more appropriate in this case than analyzing either start or total speeds. Each day each rat's mean goal speed over the reinforced trials (4 trial block) was calculated along with his mean goal speed over the nonreinforced trials (4 trial block). A 2 (Groups) x 2 (Type of Trial) x 25 (Days) analysis of variance was performed on this dependent measure. The main effect of Groups was not significant, ($p > .10$) nor did the Groups factor interact significantly with any other factor, ($p > .10$) indicating that the groups were not differentially affected by the counterbalancing procedure. The main effect of Type of Trial was significant, F (1,18) = 64.96, $p < .001$, and the main effect of Days was significant, F (24,192) = 6.26, $p < .001$. However, these two factors interacted significantly, F (24, 192) = 12.83, $p < .001$, indicating that over days the differences between nonreinforced and reinforced trials diverged; i.e., rats ran more and more slowly on nonreinforced trials with each day of discrimination training (see Figure 2).

Insert Figure 2 about here

In a further effort to compare the different types of discrimination, start, goal, and total (start + goal) latencies on the first four (forced) trials of each day were recorded and converted to speeds (1/latency) for the conditional groups. Goal speeds of the conditional discrimination groups were analyzed, in order to compare the performance of these groups to that of the go-no go discrimination groups. Each day each rat's mean goal speed on the two trials on which he was forced into the LS goal section was calculated. (Rats in the IF-L group received a 30 second tone on these trials, while the rats in the IF-R group received a 3 second tone on these trials.) In addition, each rat's mean goal speed on the two trials on which he was forced into the RG goal section was calculated. (Rats in the IF-L group received a 3 second tone on these trials, while rats in the IF-R group received a 30 second tone on these trials.) These data were analyzed via a 2 (Groups) x 2 (Direction of Trial) x 25 (Days) analysis of variance. The main effect of Groups was not significant, ($p > .10$) nor did the factor interact significantly with any other factor, ($p \geq .09$) indicating that the groups were not differentially affected by the counterbalancing procedure. The main effect of Direction of Trial was significant, F (1,8) = 30.25, $p < .001$. This factor did not, however, significantly interact with any other factor, ($p \geq .09$)

indicating that throughout the course of Phase I discrimination training, rats in both the groups ran faster in the RG goal section than they did in the LS goal section (regardless of whether it was correlated with a 3 or a 30 second tone). The main effect of Days was significant, $\underline{F}$ (24,192) = 5.73, $\underline{p}<.001$, and it did not interact significantly with any other factor, ($\underline{p}\geq.09$) indicating that both groups acquired the running response over trials.

Since the dependent measure employed in the two analyses just discussed and the analyses themselves were roughly comparable, an overall analysis was done to see how these groups compared on running speed in the goal section. It should be pointed out before presenting this analysis that the factors have been rather arbitrarily chosen and that only superficial comparisons should be made between these groups on this dependent measure. A 2 (Groups) x 2 (Type of Trial) x 25 (Days) analysis of variance was performed on goal speeds. The factor of counterbalancing was not included as a factor, since it had not been shown to have any effect in the previous analyses. The factor of Type of Trial has been arbitrarily imposed on the data in factorial combination with the other factors: for the go-no go discrimination group the levels of this factor are non-reinforced trials (N trials) and reinforced trials (R trials); for the conditional discrimination group the levels of this factor are left and right forced trials.

The main effect of Groups was significant, $\underline{F}$ (1,18) = 14.18, $\underline{p}<.002$, indicating that collapsed over the other factors, the conditional discrimination group ran faster than the go-no go discrimination group (cf. Figure 2); this difference is exaggerated, of course, by the low speeds on N trials for the go-no go discrimination group. The main effect of Type of Trial was significant, *F* (1,18) = 86.81, *p*<.001, supporting the earlier findings that rats in the go-no go discrimination group ran faster on R trials than on N trials and that rats in the conditional discrimination group ran faster on RG trials than on LS trials (cf. Figure 2). The Days main effect was significant, also, *F* (24,432) = 4.47, *p*<.001, but remains largely uninterpretable due to its significant interaction with other factors. The factor of Type of Trial significantly interacted with Groups, *F* (1,18) = 16.33, *p*=.001. Individual comparisons on these interaction means done via Tukey's method showed that the difference between the means of the N trials and the R trials of the go-no go discrimination group (1.34-1.99) was greater than the difference between the means of the LS trials and the RG trials of the conditional discrimination group, (2.22-2.41) although both differences were significant, *q* (4,18) = 13.41, *p*<.01 and q (4,18) = 5.29, *p*<.01, respectively. That both differences were significant is in support of the findings of the previous analyses. The Days x Groups interaction was significant, *F* (24,432) = 7.03, *p*<.001, however, this is not particularly meaningful, given the nature of the study and the significant Type of Trials x Days x Groups interaction, *F* (24,432) = 5.06, *p*<.001. It can be seen from Figure 2, that while the speeds on N and R trials diverged over days for the go-no go discrimination group, the difference between RG and LS trials remained relatively constant over days for the conditional discrimination group.

Discrimination-Phase II

In Phase II of discrimination training, a correction procedure was used. Data from the correction trials which followed errors, were not used in the calculation of the dependent measure. The dependent measure, proportion correct choices, was obtained by dividing the number of times the rat chose correctly on trials presented according to the pre-established schedule, by the total number of trials that were presented according to the pre-established schedule (which varied with individual rats and was only occasionally equal to the total number of trials run each day, a constant eight). A 2 (Groups) x 10 (Days) analysis of variance was performed on this dependent measure. The Groups main effect was significant, $\underline{F}$ (1,8) = 35.26, $\underline{p} < .001$, and it did not significantly interact with Days, ($\underline{p} > .10$) indicating that the difference between these groups remained relatively constant over this phase. The Days main effect was not significant, ($\underline{p} > .10$) indicating that neither of the groups showed any increase in the proportion of correct choices over days of training (see Figure 3).

Insert Figure 3 about here

The performance of each group on the last day of Phase II discrimination training was compared to the chance performance level of 50%. Group IF-L performed significantly better than chance, $\underline{t}$ (4) = 2.43, $\underline{p}<.05$, while Group IF-R did not ($\underline{p}>.10$). Thus it appears that when the 30 second tone is correlated with turning right into the gray goal section rather than turning left into the striped goal section the difficulty of the discrimination is affected.

Generalization.

Goal speed. A 2 (Groups) x 2 (Days) x 7 (Stimulus Duration) analysis of variance was performed on goal speeds of the go-no go discrimination group during the generalization test. Goal speeds on the first trial of each day were not included in this analysis. The main effect of Groups was marginally significant, $\underline{F}$ (1,8) = 4.43, $\underline{p}=.07$, indicating that the counterbalancing procedure might have had some affect upon speeds in this test, however, this was not considered to be a reliable phenomenon, and the Groups factor did not interact significantly with any other factor ($\underline{p}>.10$). The main effect of Stimulus Duration was significant, $\underline{F}$ (6,48) = 22.22, $\underline{p}<.001$, (see Figure 4). Since this factor did not

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Insert Figure 4 about here

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interact significantly with Groups (or any other factor) individual comparisons were done via Dunn's method to determine whether or not the apparent decrease in goal speed as stimulus duration increased was significant. Therefore the mean goal speed when the stimulus duration was 3 seconds was compared to the mean goal speed at each of the other six durations: 6, 15, 18, 27, 30, and 40 seconds. Goal speeds at stimulus durations of 3 and 6 seconds were not significantly different, $p > .10$ (d (6,48) = .63). Goal speeds at each of the remaining stimulus durations were significantly different from goal speeds at the 3 second stimulus duration, $p < .01$ (3 and 15, d = 4.66; 3 and 18, d = 7.10; 3 and 27, d = 6.76; 3 and 30, d = 7.20; 3 and 40, d = 8.16). The Days main effect was significant, F (1,8) = 11.01, $p = .01$, but did not interact significantly with any other factor, indicating that there was extinction over the two days of training (means equal 1.11 and .75, respectively), but that the shape of the TG gradient was constant over days. Goal speed data for the conditonal discrimination groups would not be meaningful on the generalization test.

<u>Proportion running right</u>. In the generalization test there is no "correct choice" at the novel stimulus durations. However, to the extent that the rat has learned the appropriate discrimination, at those stimulus durations which closely approximate previously reinforced stimulus durations, the rat should be more likely to run in the direction that was previously reinforced. Thus at stimulus durations that approximate 3 seconds, rats in the IF-L group should run to the right, and at stimlus durations that approximate 30 seconds animals in the IF-L group should run to the left. The opposite would be true for rats in the IF-R group. For this reason, a record of the proportion of rats per group that run to the right at each stimulus duration (i.e., the number of rats running right divided by the total number of rats per group) should show a

function which decreases as the stimulus duration increases for the IF-L group and increases as the stimulus duration increases for the IF-R group. That is, the IF-L group, if it has learned the discrimination, should yield a generalization gradient very similar in shape to that found with goal speeds for the go-no go discrimination group, while the IF-R group should yield its mirror image. This dependent measure is similar to that employed by Catania (1970), Church (note 2), Church and Deluty (Note 3) and Stubbs (1968, 1976).

A 2 (Groups) x 2 (Days) x 7 (Stimulus Duration) analysis of variance was performed on proportion running right data. None of the tests was significant, ($p \geq .07$) indicating that rats in both groups chose the different goal sections unsystematically, without regard to the duration of the stimulus. The gradients obtained using this dependent measure for the two conditional discrimination groups over the two days of generalization testing are shown in Figure 5. This result is not

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Insert Figure 5 about here

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surprising given the poor discrimination exhibited by these groups in training. Moreover, the IF-L group which appeared to be performing better than chance in Phase II of discrimination training does show a gradient that grossly approximates the form predicted (see Figure 5).

<u>Proportion short latencies</u>. For the purpose of assessing the meaningfulness of the proportion correct choices data employed in Phase I

of discrimination training with the go-no go discrimination groups, an analogous dependent measure was obtained in the generalization test. At those stimulus durations which closely approximate the reinforced stimulus durations from the discrimination training, rats in the go-no go discrimination groups should have short latencies. The converse is also true; at those stimulus durations which closely approximate the nonreinforced stimulus durations, rats should have long latencies. Thus a record of the proportion of rats per group which had short latencies (i.e., the number of rats with short latencies divided by the total number of rats per group) should show a generalization gradient comparable to the generalization gradient found with goal speeds for these groups. This dependent measure is similar to that employed by Catania (1976), Church (Note 2), Church and Deluty (Note 3) and Stubbs (1968, 1976).

A 2 (Groups) x 2 (Days) x 7 (Stimulus Duration) analysis of variance was performed on proportion short latencies, where a short latency was defined as a total latency shorter than 4.00 seconds. The Groups main effect was significant, $F\ (1,8) = 6.52$, $p=.03$, indicating that the counterbalancing procedure had some effect. Moreover, the Groups x Stimulus Duration interaction was marginally significant, $F\ (6,48) = 2.07$, $p=.07$. However, this latter result was not taken to be relaiable and the significant Stimulus Duration main effect was interpreted straightforwardly, $F\ (6,48) = 28.79$, $p<.001$, (see Figure 6).

Insert Figure 6 about here

Individual comparisons were done via Dunn's method to determine whether or not the apparent decrease in the proportion of short latencies as stimulus duration increased was significant. That is, the mean proportion of short latencies at the 3 second duration was compared to the mean proportion of short latencies at each of the other six stimulus durations: 6, 15, 18, 27, 30, and 40 seconds. Means were not significantly different at durations of 3 and 6 seconds, $p > .10$ (d (6,48) = 1.09). Means at each of the remaining durations were significantly different from the mean at the 3 second duration, $p < .01$ (15, d = 3.82; 18, d = 7.64; 27, d = 7.64; 30, d = 8.73; 40, d = 9.28). The Days main effect was significant, F (1,8) = 5.73, $p = .04$, but did not interact significantly with any other factor, indicating that there was extinction over the two days of training (means equal .54 and .36, respectively), but that the shape of the generalization gradient did not change over days.

Discussion

It is clear from the proportion correct choices data that the go-no go discrimination group mastered the discrimination over the course of Phase I discrimination training, while the conditional discrimination group did not. The goal speed measure plainly shows the extent to which the go-no go discrimination group was able to predict the outcome of the forthcoming trial. It was not expected that gathering goal speed data on the conditional discrimination group would yield any information on these rats' ability to master the discrimination task, but it should allow for a comparison of the demand charactersistics of the two tasks. The finding that rats in the conditional discrimination group tended to run faster than those in the go-no go discrimination group can be attributed to the fact that the conditional discrimination group received a 100% reinforcement schedule on these trials, while the go-no go discrimination group received a 50% reinforcement schedule. It also appears that saliency differences between gray and striped alleys affects running speed when a within-subjects comparison is made, but not when a between-groups comparison is made.

It was expected that Phase II discrimination would increase the level of discrimination performance in the conditional discrimination groups. This correction procedure did serve to exaggerate the differences between the groups within the first few trials, but no further change was seen over the ten days of training. There is no obvious factor to which the stable, but substandard performance of these groups can be attributed. While it did appear that Group IF-L had acquired the discrimination, the level of performance was not as high as desired. Kinchla (1970) reports a similar stable partial discrimination. Of course, it is highly probable that had enough trials been run, the rats' performance on the conditional discrimination task would have come to match the rats' performance on the go-no go discrimination task. Of those experiments using conditional discriminations that reported the number of trials to reach a discrimination criterion, none required less than 450 trials, while several required more than 3000 trials. In contrast to these data, Bowen and Strickert (1966) report that rats acquired a complex go-no go discrimination in 120 trials. Although the work of Perikel, Richelle and Maurissen (1974) provides a comparison between the two types of discrimination tasks, the nature of their design precludes an assessment of this particular difference.

Because only two durations were presented during the course of the discrimination, the data presented are not particularly amenable to analysis with psychophysical methods. However, it was not the function of this experiment to add to the literature on the use of psychophysical methods in investigating TD (Kinchla, 1970; Stubbs, 1968, 1976). Nevertheless, both conditional and go-no go discrimination tasks, used appropriately, can be analyzed as psychophysical choice situations (Perikel, Richelle & Maurissen, 1974; Church & Deluty, Note 2).

The difference between these groups in terms of the level of mastery of the discrimination is clearly reflected in the generalization gradients. The go-no go discrimination groups show an unequivocal decrease in both the speed and proportion measures as the stimulus durations approximate the nonreinforced stimulus durations used in training. The IF-L group which gave some indication of discriminative performance show a trend towards a similar gradient, while the IF-R group which showed no indication of discriminative performance shows an essentially flat gradient.

Given the paucity of TG data accrued in the course of the study of TD, it seems inappropriate to draw any general conclusions as to whether the TG gradients are best fitted by linear functions or power functions or other functions. It should suffice to say at this point that they are gradients which in many respects match those obtained after similar sensory discriminations.

The results of this experiment have yielded valuable information about the use of a procedure which is simple for the rat to learn, simple for the experimenter to implement, and yields multiple dependent measures. Moreover, the success of this experiment should be measured in terms of its ability to show that interoceptive temporal stimuli can function as discriminative stimuli in much the same manner as exteroceptive stimuli; i.e., to the extent that a given discrimination task is acquired, the expected generalization gradient will be obtained.

Given the success of this preliminary experiment, three experiments have been proposed which should provide information on four issues that should be investigated if TD is to be used to support the more general concept that interoceptive stimuli are functionally similar to extero-oceptive stimuli: (a) will animals continue to attend to time as the relevant dimension if TDs employ long durations (the typical duration used in TD studies is under 60 seconds, although extremely long FI schedules, 27 3/4 hours, Dews, 1970, have been employed successfully) (b) can TG gradients of different shapes be shown to be a function of

TD training (c) can stimulus control phenomena commonly found with sensory discriminations be shown to hold for TDs (for instance--peak shift) (d) can animals learn TDs where multiple S^Ds and S^Δs are employed.

All three of the proposed experiments would use a go-no go discrimination task in a straight alley apparatus. In Experiment 1, a discrimination group would receive 10 and 1 minute ITIs differentially correlated with N and R trials, respectively. A random control group would receive these ITIs in an unpredictive schedule. In a subsequent generalization test, rats would be tested at ITIs ranging between 1 and 10 minutes. The discrimination group should learn to respond differentially on N and R trials, while the random control group should run equally fast ona ll trials. The discrimination group should show a TG gradient with fastest speeds at the previously reinforced duration and slowest speeds at the previously nonreinforced duration. The random control group should show a flat TG gradient. In Experiment 2 a more difficult discrimination with longer ITIs would be used--for instance, 6 vs 12 minutes. The discrimination group would be divided into two groups, one receiving reinforcement after the 6 minute duration and nonreinforcement after the 12 minute duration, and the other having the opposite discrimination. A random control group would be run again. In a subsequent generalization test, durations between the durations used in discrimination training, and durations past either of those extermes would be presented. Discrimination groups in this experiment should show TG gradients that are mirror images of each other, while the random group shows a flat gradient.

In Experiment 3 one group would be reinforced for responding after ITIs of either 2 minutes or 20 minutes, and nonreinforced for responding after an ITI of 8 minutes. The other group would be reinforced for responding after an ITI of 8 minutes and nonreinforced after ITIs of 2 and 20 minutes. These groups should show symmetrical and rather sharp TG gradients around the 8 minute duration.

To the extent that these expectations are met, it will have been shown that interoceptive discriminative stimulu have a number of functional properties in common with exteroceptive stimuli. It seems clear that these findings would support both theoretical and atheoretical approaches to behavior which employ the notion that interoceptive stimuli should be treated as analogous to exteroceptive stimuli.

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Table 1

Tone Sequence Schedules

Discrimination Day

Subject	1 4 7 10 13 16 19 22 25 28 31 34	2 5 8 11 14 17 20 23 26 29 32 35	3 6 9 12 15 18 21 24 27 30 33
1	30 3 30 3 3 3 30 30	3 30 30 3 30 3 30 3	30 30 3 3 30 3 3 30
2	3 3 30 30 3 30 30 3	30 3 30 3 3 3 30 30	3 30 30 3 30 3 30 3
3	3 30 3 30 30 30 3 3	3 3 30 30 3 30 30 3	30 3 30 3 3 3 30 30
4	30 30 3 3 30 3 3 30	3 30 3 30 30 30 3 3	3 3 30 30 3 30 30 3
5	3 30 30 3 30 3 30 3	30 30 3 3 30 3 3 30	3 30 3 30 30 30 3 3
6	30 3 30 3 3 3 30 30	3 30 30 3 30 3 30 3	30 30 3 3 30 3 3 30
7	3 3 30 30 3 30 30 3	30 3 30 3 3 3 30 30	3 30 30 3 30 3 30 3
8	3 30 3 30 30 30 3 3	3 3 30 30 3 30 30 3	30 3 30 3 3 3 30 30
9	30 30 3 3 30 3 3 30	3 30 3 30 30 30 3 3	3 3 30 30 3 30 30 3
10	3 30 30 3 30 3 30 3	30 30 3 3 30 3 3 30	3 30 3 30 30 30 3 3

Table 2

Start Section Confinement Schedule

Discrimination Day	Schedule	Seconds
1 6 11 16 21 26 31	1	6 15 9 12 10 19 12 5
2 7 12 17 22 27 32	2	18 9 5 7 11 6 9 12
3 8 13 18 23 28 33	3	15 5 14 8 5 13 11 11
4 9 14 19 24 29 34	4	7 11 16 10 7 5 9 15
5 10 15 20 25 30 35	5	9 18 7 13 20 10 5 6

Table 3

Generalization Testing Schedules

Days	Subject	Seconds						
1	1	3	40	18	30	27	15	6
	2	6	27	30	40	3	18	15
	3	15	18	6	3	40	30	27
	4	30	6	3	15	18	27	40
	5	40	15	27	6	30	3	18
2	1	40	15	27	6	30	3	18
	2	3	40	18	30	27	15	6
	3	6	27	30	40	3	18	15
	4	15	18	6	3	40	30	27
	5	30	6	3	15	18	27	40

Figure Captions

Figure 1. Mean percent correct choices for the 25 days of discrimination training in Phase I (in two day blocks).

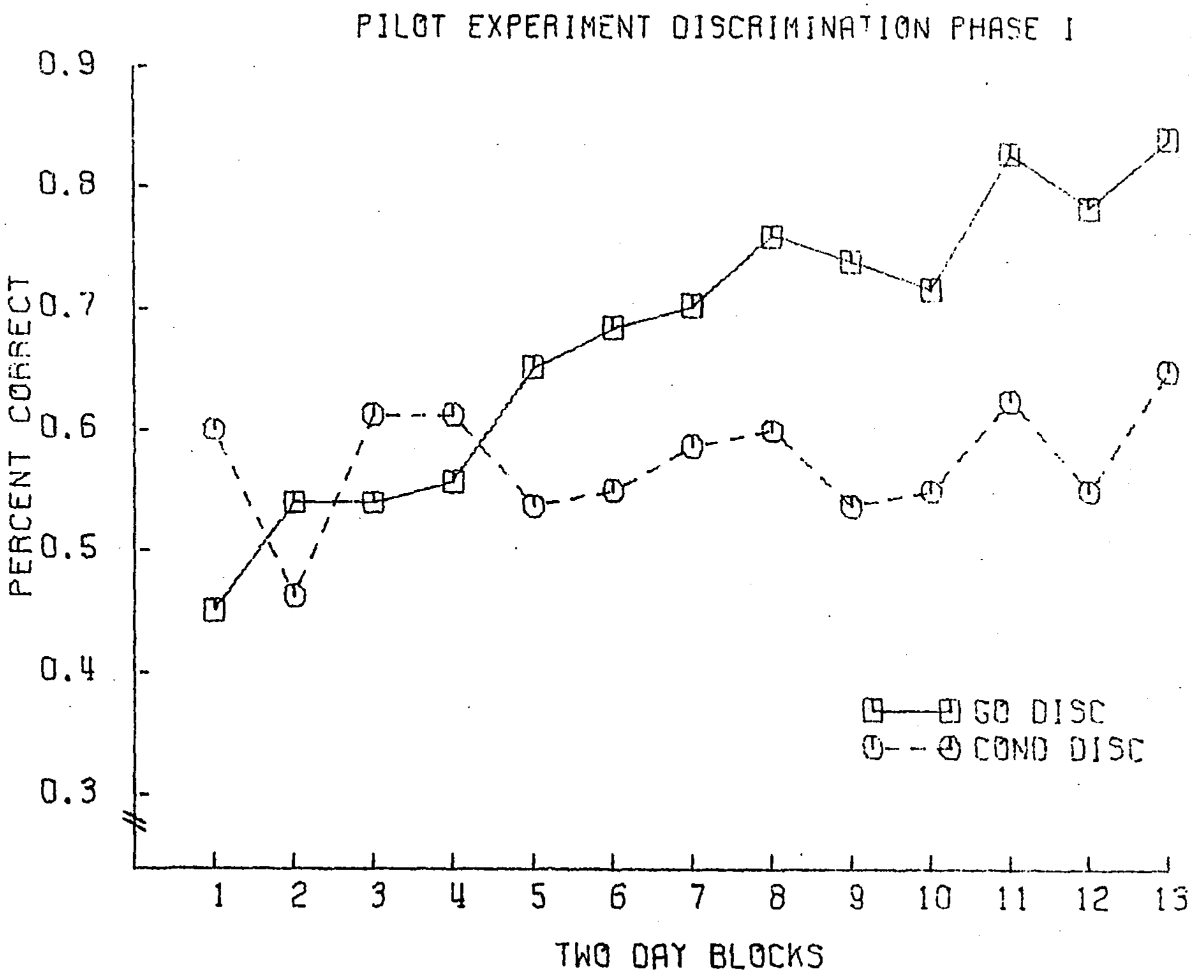
Figure 2. Mean goal speeds: on reinforced and nonreinforced trials for the go-no go discrimination group, and on right and left trials for the conditional discrimination group, for the 25 days of discrimination training in Phase I (in two day blocks).

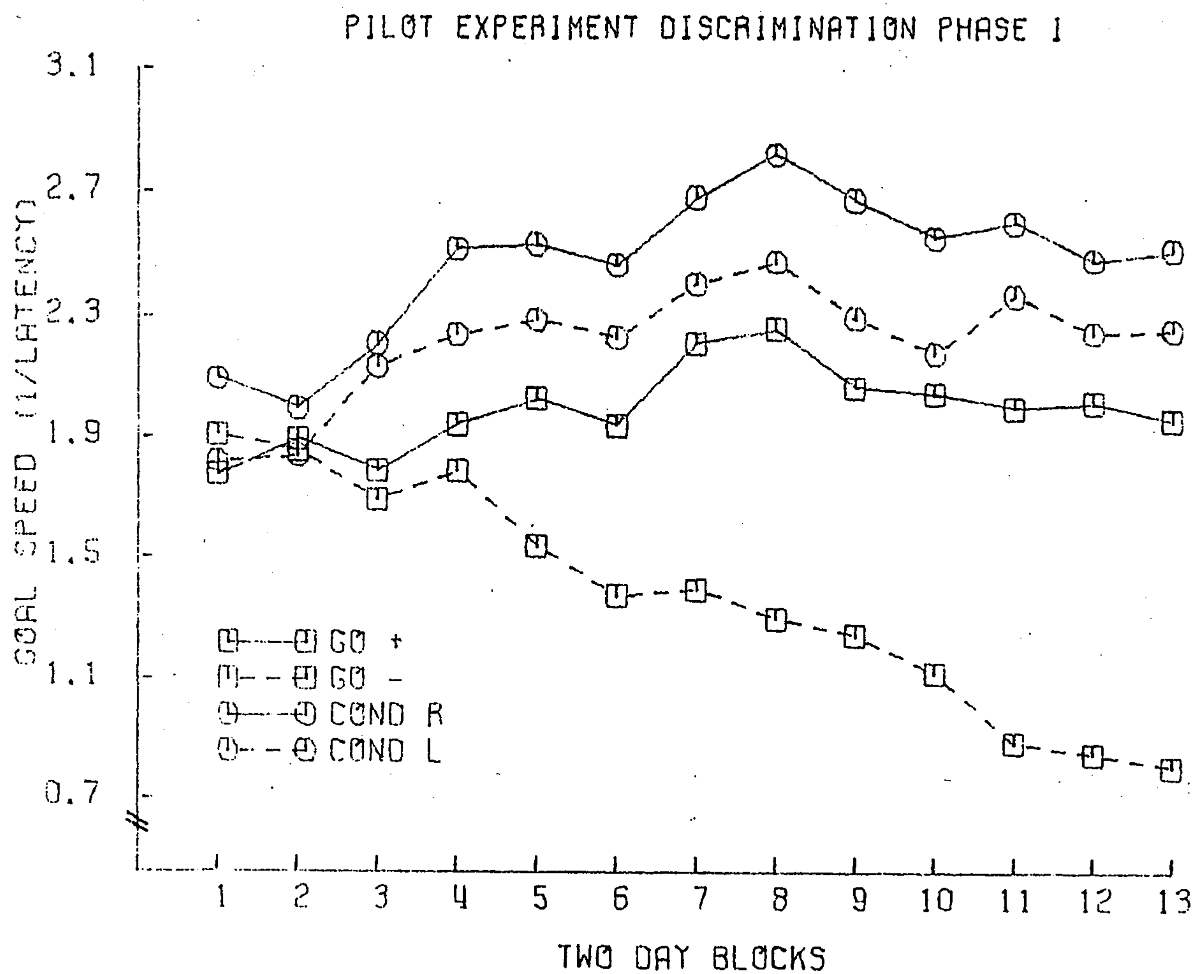
Figure 3. Mean percent correct choices for the ten days of discrimination training in Phase II.

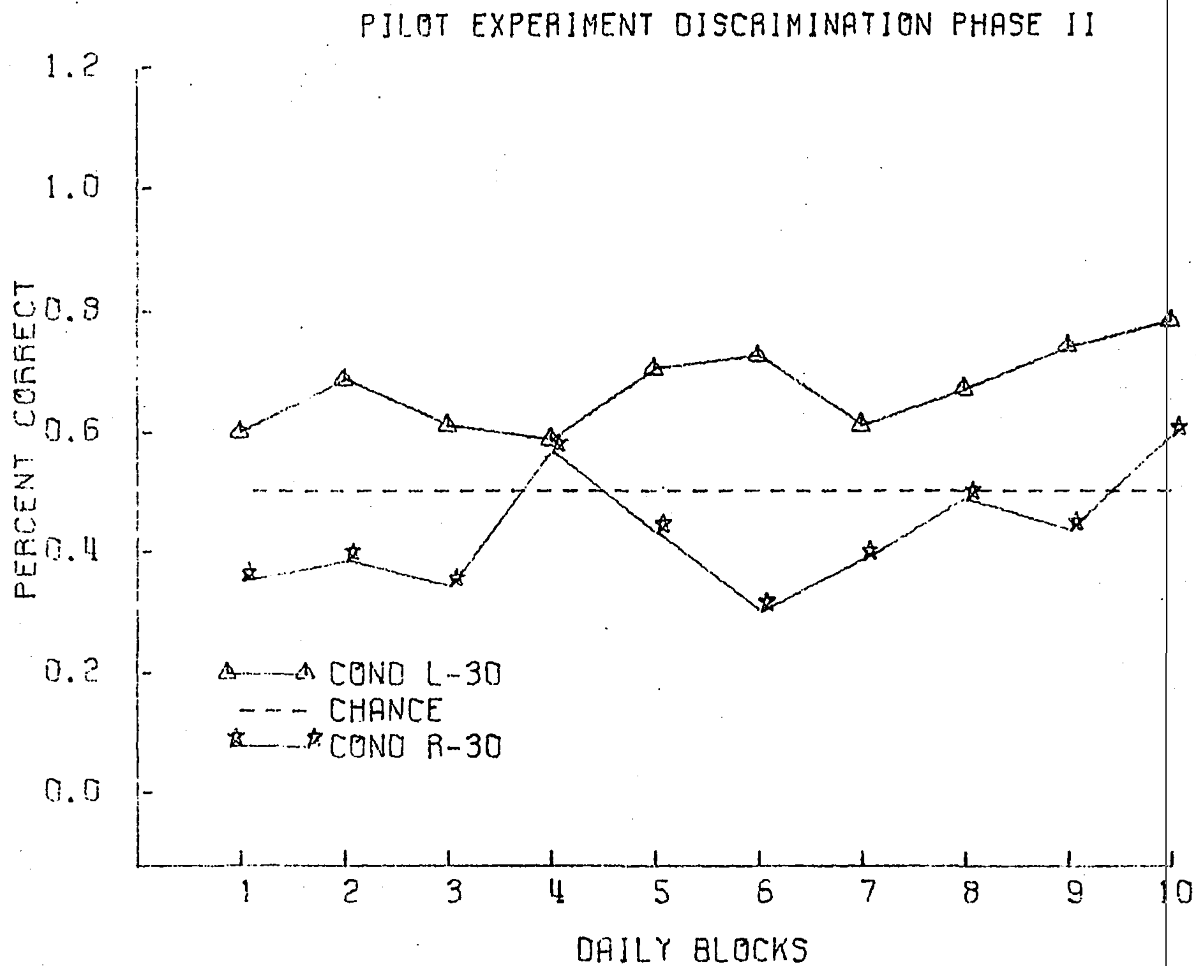
Figure 4. Mean goal speeds across seven test stimulus durations employed in generalization (Day 1).

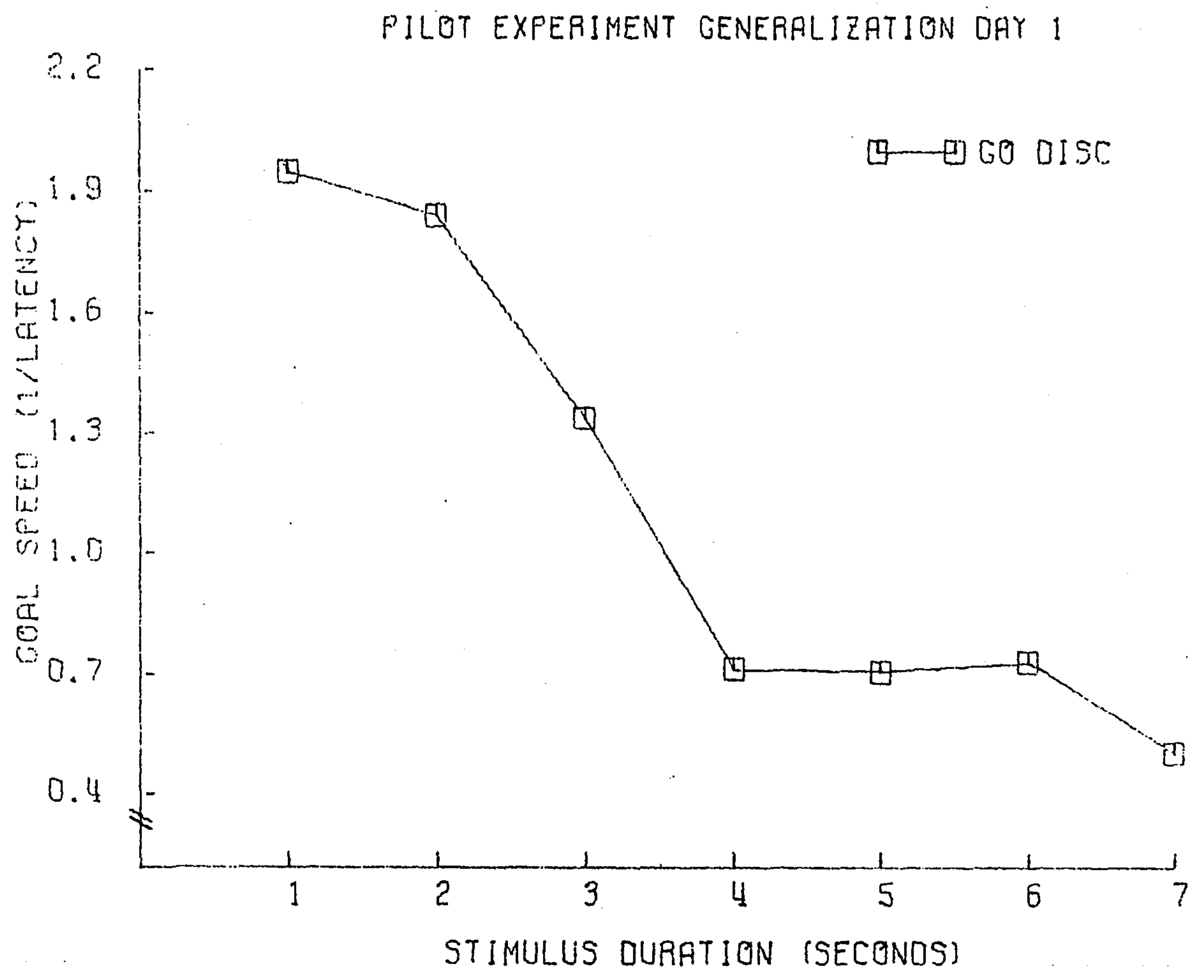
Figure 5. Mean percent running right across seven test stimulus durations employed in generalization (collapsed across Days 1 and 2).

Figure 6. Mean percent short latencies across seven test stimulus durations employed in generalization (collapsed across Days 1 and 2).

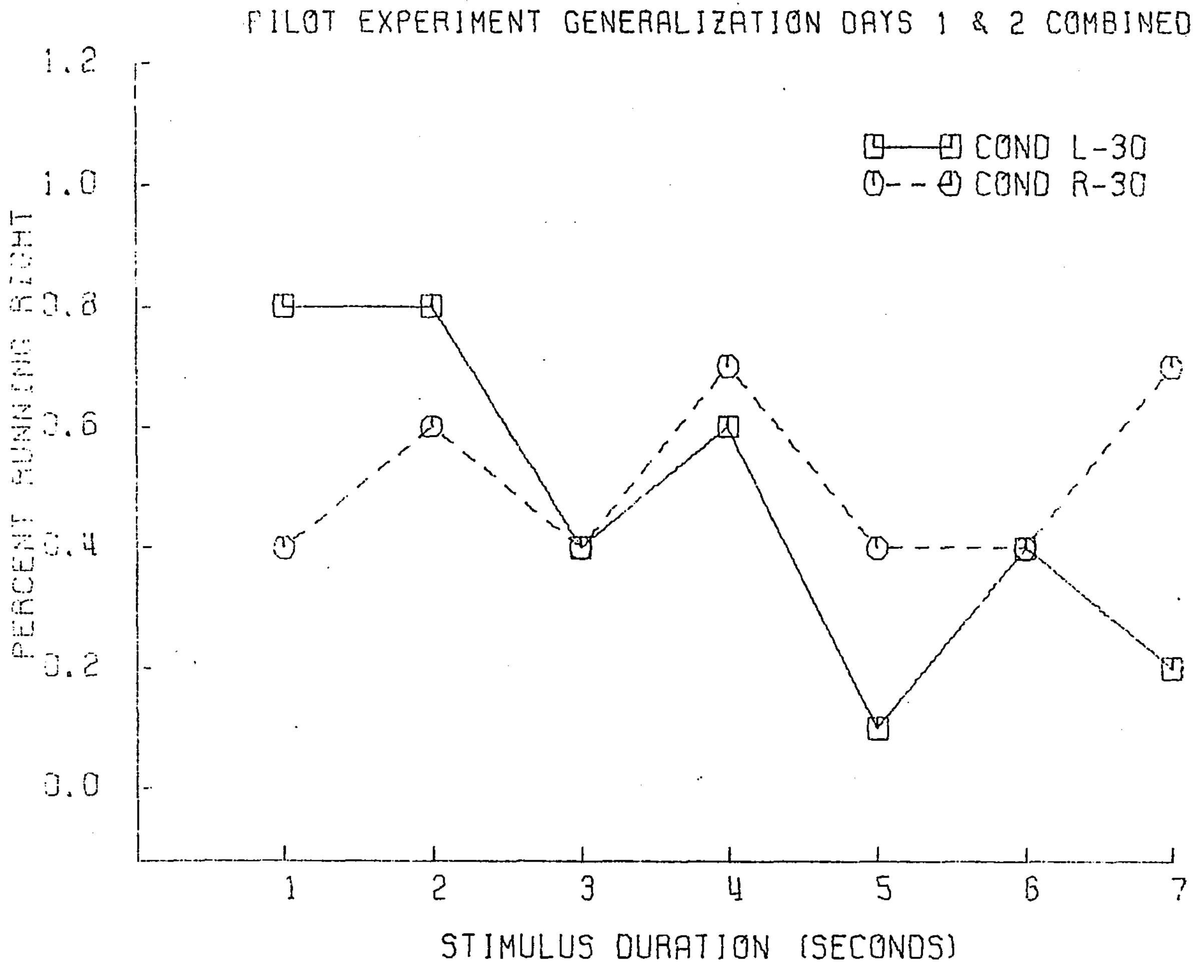

PILOT EXPERIMENT DISCRIMINATION PHASE I
0.9
0.8
0.7
0.6
0.5
0.4
0.3
PERCENT CORRECT
1
2
3
4
5
6
7
8
9
10
11
12
13
TWO DAY BLOCKS
GO DISC
COND DISC

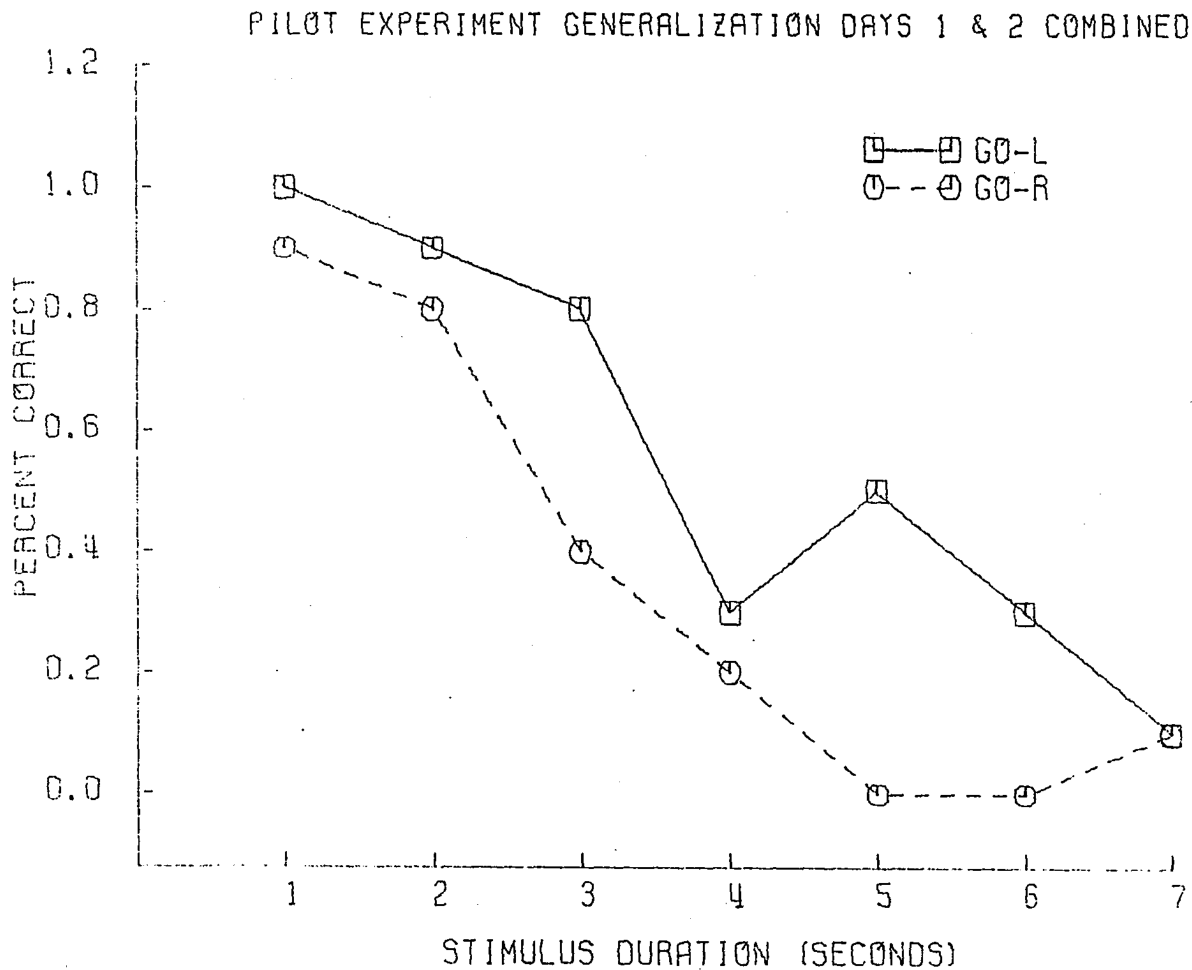

PILOT EXPERIMENT DISCRIMINATION PHASE I
GOAL SPEED (1/LATENCY)
3.1
2.7
2.3
1.9
1.5
1.1
0.7
1
2
3
4
5
6
7
8
9
10
11
12
13
TWO DAY BLOCKS
GO +
GO -
COND R
COND L


PILOT EXPERIMENT DISCRIMINATION PHASE II
PERCENT CORRECT
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
7
8
9
10
DAILY BLOCKS
COND L-30
CHANCE
COND R-30



PILOT EXPERIMENT GENERALIZATION DAY 1
GO DISC
GOAL SPEED (1/LATENCY)
2.2
1.9
1.6
1.3
1.0
0.7
0.4
1
2
3
4
5
6
7
STIMULUS DURATION (SECONDS)


PILOT EXPERIMENT GENERALIZATION DAYS 1 & 2 COMBINED
COND L-30
COND R-30
PERCENT RUNNING RIGHT
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
7
STIMULUS DURATION (SECONDS)


PILOT EXPERIMENT GENERALIZATION DAYS 1 & 2 COMBINED
GO-L
GO-R
PERCENT CORRECT
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
7
STIMULUS DURATION (SECONDS)

Appendix A

Statistical Tables

Table 1

Summary Table for Analysis of Variance

on Percent Correct Choices for Phase I

Source	MS	df	F	p
A (Groups)	1.55	1	17.11	.001
error	.09	18		
B (Days)	.11	24	4.16	.000
A X B	.08	24	3.09	.000
error	.03	432		

Table 2

Summary Table for Analysis of Variance on Goal Speeds of Go-No Go Discrimination Groups in Phase I

Source	MS	df	F	p
A (Groups)	1.14	1	.26	.628
error	4.39	8		
B (Trial Type)	53.73	1	64.96	.000
A x B	1.13	1	1.37	.275
error	.83	8		
C (Days)	.66	24	6.26	.000
A x C	.20	24	1.93	.008
error	.11	192		
B x C	1.01	24	12.83	.000
A x B x C	.08	24	1.00	.467
error	.08	192		

Table 3

Summary Table for Analysis of Variance

on Percent Correct Choices in Phase II

Source	MS	df	F	p
A (Groups)	1.49	1	35.26	.001
error	.04	8		
B (Days)	.04	9	.79	.631
A x B	.03	9	.51	.862
error	.05	72		

Table 4

Summary Table for Analysis of Variance on Percent Running Right of Go-No Go Discrimination Groups in Generalization

Source	MS	df	F	p
A (Groups)	1.61	1	6.52	.033
error	.25	8		
B (Durations)	2.42	6	28.79	.000
A X B	.17	6	2.07	.074
error	.08	48		
C (Days)	1.21	1	5.72	.042
A x C	.18	1	.85	.613
error	.21	8		
B x C	.04	6	.26	.952
A x B x C	.11	6	.71	.641
error	.16	48		

Table 5

Summary Table for Analysis of Variance on Percent Short Latencies of Conditional Discrimination Groups in Generalization

Source	MS	df	F	p
A (Groups)	.06	1	.30	.603
error	.21	8		
B (Durations)	.52	6	2.11	.068
A x B	.45	6	1.81	.117
error	.25	48		
C (Days)	.06	1	.45	.527
A x C	.58	1	4.05	.077
error	.14	8		
B x C	.21	6	.85	.537
A x B x C	.06	6	.25	.957
error	.25	48		

Appendix B

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temporal discrimination

Anger, 1956, 1963

Baum, 1973

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