A Study of Stimulus Control Functions Following Discrimination Training Using a DRL Schedule of Reinforcement

Kathleen M. Krafft

Follow this and additional works at: https://scholarworks.wmich.edu/masters_theses

Part of the Experimental Analysis of Behavior Commons

Recommended Citation
A STUDY OF STIMULUS CONTROL FUNCTIONS
FOLLOWING DISCRIMINATION TRAINING
USING A DRL SCHEDULE OF REINFORCEMENT

by

Kathleen M. Krafft

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
Kalamazoo, Michigan
December, 1977
ACKNOWLEDGEMENTS

I would like to thank M. Kay Malott for her help in all aspects of this research; especially for her patience and professional guidance throughout the writing of this thesis. I would also like to thank David Lyon, Ph.D. and Paul Mountjoy, Ph.D. for their thought-provoking discussions and suggestions in the theoretical aspects of this research.

An expression of sincere gratitude goes to Meg and Mike Dorsey for their last minute technical assistance in the final preparation of this thesis. And last but not least, many thanks to my husband, Tom Fredericks, and my family; for without their love and support this research would have been less satisfying.

Kathleen M. Krafft
INFORMATION TO USERS

This material was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

1. The sign or “target” for pages apparently lacking from the document photographed is “Missing Page(s)”. If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.

2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.

3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in “sectioning” the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again — beginning below the first row and continuing on until complete.

4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from “photographs” if essential to the understanding of the dissertation. Silver prints of “photographs” may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.

5. PLEASE NOTE: Some pages may have indistinct print. Filmed as received.

Xerox University Microfilms
300 North Zeib Road
Ann Arbor, Michigan 48106
KRAFFT, Kathleen M., 1953-
A STUDY OF STIMULUS CONTROL FUNCTIONS
FOLLOWING DISCRIMINATION TRAINING USING A
DRL SCHEDULE OF REINFORCEMENT.

Western Michigan University, M.A., 1977
Psychology, experimental

University Microfilms International, Ann Arbor, Michigan 48106
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1</td>
</tr>
<tr>
<td>II</td>
<td>8</td>
</tr>
<tr>
<td>Subjects</td>
<td>8</td>
</tr>
<tr>
<td>Apparatus</td>
<td>8</td>
</tr>
<tr>
<td>Procedure</td>
<td>9</td>
</tr>
<tr>
<td>DRL Training</td>
<td>9</td>
</tr>
<tr>
<td>Discrimination Training</td>
<td>12</td>
</tr>
<tr>
<td>Generalization Testing</td>
<td>15</td>
</tr>
<tr>
<td>III</td>
<td>17</td>
</tr>
<tr>
<td>IV</td>
<td>40</td>
</tr>
<tr>
<td>V</td>
<td>43</td>
</tr>
</tbody>
</table>
INTRODUCTION

Differential reinforcement of low rate (DRL) schedules, used prior to generalization testing, have typically resulted in generalization gradients (Hearst, Koresko and Poppen, 1964; Gray, 1976) which are less steep than gradients obtained following short variable interval (VI) schedules of reinforcement (Guttman and Kalish, 1956). Response patterns during a DRL schedule often include a collateral chain of behavior which precedes the reinforced response. This stereotypic behavior pattern may be maintained due to its adventitious temporal proximity with reinforcement (Zuriff, 1969). It is theorized that the collateral chain mediates the DRL interval requirement (Laties, Weiss, Clark and Reynolds, 1965; Laties, Weiss, and Weiss, 1969) and that this behavior is used by the organism as a stimulus controlling subsequent behavior (Ferster and Skinner, 1957). Hearst et. al. (1964) suggested two ways in which collateral chains may influence generalization gradients; (1) the subjects do not receive as much exposure to the exteroceptive stimulus, since much of the time is spent away from the key and (2) since key pecking is temporally linked with the preceeding collateral responses it may have become controlled by movement-produced stimuli (internal cues) derived from the collateral behavior so that the physical properties of the key do not gain control over key pecking.

The internal cues hypothesis has been further developed and extended to account for relatively flat gradients obtained after
training on long VI schedules of reinforcement (Hearst, 1965; 1969). A short VI schedule of reinforcement is typically used prior to generalization testing. If the value of the VI schedule affects the slope of the gradient, inferences regarding the type of stimuli that control behavior may be made. Hearst et al. (1964) used mean intervals of a variable interval schedule of 1/2, 1, 2, 3 and 4 min schedules of reinforcement prior to generalization testing along the line-orientation stimulus dimension. The gradients were compared with the results from a group of subjects trained on a DRL 6 sec schedule of reinforcement. The generalization gradients following DRL training resulted in relatively flat gradients, which seldom had their peak at the training stimulus. The gradients following VI training demonstrated an inverse relationship between gradient slope and the mean VI interval. The gradients following VI 4 min training closely resembled the DRL gradients. The authors suggested that the frequency of reinforcement indirectly affected the slope of the generalization gradient through its direct effect on the rate and pattern of responding. Informal observations indicated that "mediating" response chains developed on the DRL and long VI schedules which reduced the amount of exposure to the external stimulus. They attributed the relatively flat gradients following training on DRL and long VI schedules to the control exerted by proprioceptive and other internal stimuli.

A similar comparison between variable ratio (VR) and VI schedules of reinforcement investigated the hypothesis that internal and external cues compete for the control of operant behavior (Thomas and
Switalski, 1966). The authors proposed that the proprioceptive feedback from rapid bursts of responding during VR schedules might provide a discriminative cue for additional responding which may reduce control obtained by the external stimuli. To test this hypothesis, the VI reinforcement contingency was yoked to the VR schedule contingency; such that when a reinforcement was delivered on the VR schedule, reinforcement was made available for the next response made by the yoked subject in the VI contingency. The initial generalization gradients, obtained under an extinction schedule, resulted in flatter slopes for the VR subjects than for the VI subjects. The authors hypothesized that the discriminative cue for rapid responding under the VI schedule should diminish with time, under extinction conditions, during generalization testing since response rate is expected to decrease. The reduced control by the proprioceptive stimuli should lead to an increase in the steepness of the gradient. To investigate this hypothesis, further generalization testing in extinction was provided. The resulting gradients demonstrated a reduction of response rate and increased the steepness of the slopes. The gradients were similar in shape to those after VI training. The authors concluded that the "mediating" behavior, consisting of rapid responding under the control of proprioceptive stimuli, affected the slope of the resulting gradient. They suggested that once the control by the proprioceptive stimuli was weakened, because of their lower frequency, the external stimuli gained more control over responding, as demonstrated by the resulting gradients. The results of this study show that even when the amount of exposure to the external stimulus might

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
have been the same, subjects on the VR schedule produced gradients which were flatter than the gradients following VI training. An internal cues hypothesis seems to be supported although collateral behaviors were not necessarily involved.

The measurement of stimulus control via generalization gradients is usually displayed as changes in response rate (absolute or relative) as a function of variations along a stimulus dimension (Hearst and Koresko, 1968; Hearst et. al., 1964; Migler, 1964; Terrace, 1963; Haber and Kalish, 1963). This practice assumes that the rate measure reflects a homogeneous response class with all members of the class controlled by similar features of the external stimuli. Blough (1963) observed that, within individual subjects, some responses seem to be under the control of the exteroceptive stimuli and some not. A steady state generalization testing procedure was used (Malott, Malott and Glenn, 1973; Blough, 1969; Gray, 1976) in which reinforcement was available for responding to one stimulus on a DRL 3.5 sec schedule and a tandem VI 2 min DRL 7 sec schedule in the presence of all other stimuli. The frequency of IRTs was recorded as a function of changes in the stimulus dimension. This showed an equal distribution of responses with .1 sec IRTs across all stimulus values, and a high frequency of longer IRTs (2-4 sec) only at the training stimulus. A similar analysis was performed on data from another subject trained on a VI 4 min schedule of reinforcement prior to generalization testing. The .4 sec IRT class occurred with equal frequencies across all test stimuli, while the frequency of longer IRTs (1-4 sec) was concentrated around the training stimulus. Blough hypothesized that
responses with short IRTs, which contribute to the response rate measure on DRL schedules, are almost entirely controlled by prior responses; but the probability of their occurrence does not vary with changes in the exteroceptive stimulus conditions. Responses with long IRTs demonstrated control by the properties of the external stimulus. Blough's interpretation suggests that the response rate measure, used in determining generalization gradients, is dependent on factors other than the exteroceptive stimulus and these include the external and internal stimuli produced by ongoing behavior. Responses with short IRTs do not appear to be controlled by the external stimulus yet they are added into the rate measure. This implies that the relatively flat generalization gradients may reflect the averaging of several response categories, some of which are under stimulus control and some not rather than the absence of stimulus control (Blough, 1965).

A similar attempt to demonstrate the effects of averaging data was performed by Migler (1964). A DRL schedule of reinforcement was used in a two-key chamber during training prior to generalization testing along the click-frequency dimension. During training, a response on key A produced one of two training click frequencies. In the presence of one frequency, reinforcement was delivered if the response to key B was made 6 sec after a response to key A. If a response to key B did not occur within 21 sec of the key A response, the DRL contingency was re-initiated. A DRL 1 sec schedule of reinforcement was in effect during another frequency for the A-to-B response requirement. Steady state generalization tests were conducted using six novel click frequencies. The resulting gradient,
which plotted median A-to-B interresponse times for the click frequencies between the two training frequencies, showed intermediate A-to-B IRTs for the click frequencies between the two training stimuli. When the test data were re-evaluated in terms of the relative frequency of A-to-B times during each test stimulus, the results demonstrated that intermediate test frequencies did not generate intermediate A-to-B IRTs; rather, a bi-modal distribution with peaks at the two reinforced response classes was obtained. Migler concluded that the averaging of different behaviors was responsible for the shape of the initial gradient.

A recent study by Gray (1976) refined Blough's use of IRTs to analyze stimulus control functions. An IRT per opportunity analysis (Anger, 1956) was used to investigate generalization gradients obtained after training on a DRL 8 sec schedule of reinforcement, in the presence of a single wavelength stimulus. A relative frequency measure of responses for the resulting gradient demonstrated the usual flat curves for DRL schedules in three of the five subjects. The test data were re-evaluated in terms of IRT per opportunity (IRT/op) as a function of changes along the wavelength continuum for each of seven classes of IRTs ranging from 0 to 14 sec divided into one-sec bins. The IRT/op is a statistic which estimates the probability of a response occurring within a specified time interval. In calculating IRT/op, the number of opportunities to respond in a given interval (bin) is equal to the number of IRTs in that bin plus the number of longer IRTs. The number of IRTs in that bin is divided by the number of opportunities in that bin. This analysis demonstrated rather flat
but V-shaped stimulus generalization gradients for IRTs less than 8 sec and steep gradients with peaks at the training stimulus value for IRTs greater than 8 sec. The initial flat generalization gradients, obtained using a relative response measure, appear to lend support to the internal cues hypothesis which predicts minimal control of the external stimuli due to the control exerted by the temporal contingencies of the schedule. However, the IRT/op analysis showed that there was, in fact, differential control of the IRTs by the external stimuli thus supporting the analysis discussed above, resulting from Blough's data. The IRT/op analysis again indicates that the rate measure is not an appropriate measure of stimulus control for DRL contingencies.

The present experiment attempts to provide an extension of Gray's procedure. A successive discrimination procedure was used in which responses with five-to-six sec IRTs were reinforced in the presence of one stimulus (DRL 5 sec with a one sec limited hold) and all responding was extinguished in the presence of another stimulus. The successive discrimination procedure was used to investigate whether or not the peak shift phenomenon (Bloomfield, 1967; Hanson, 1959; Honig, Thomas and Guttman, 1959; Malott and Malott, 1970; Kalish, 1958), often observed in generalization gradients following discrimination training with a VI schedule, would occur. A steady-state generalization test was performed and an IRT/op analysis was used to investigate the stimulus control functions. This analysis was used to avoid the possible confounding of rate measures found in averaged data.
METHOD

Subjects

Six experimentally naive barren-hen White Carneaux pigeons were maintained at 80% of their free-feeding body weights. All subjects were individually housed with fresh water and grit continuously available. Purina Pigeon Grain was used for maintenance of weight and as the reinforcer. Each subject was weighed following the session and fed an appropriate amount of grain to maintain its weight.

Apparatus

Two Lehigh Valley Electronics pigeon chambers were used. Two transparent Plexiglas response keys were each located behind a 2.5 cm in diameter hole and were situated 7.0 cm on each side of the panel's midline, 23 cm from the chamber floor. The right key remained unilluminated and inoperative throughout the experiment. A minimum force of 20 gm was required to operate the response key which was transilluminated via an Industrial Electronic Engineers Inc. one-plane read-out stimulus projector (series 10) with line stimuli. The line stimuli were 2 mm wide, white and centered on a dark background at the following angles: 90 (vertical), 75, 60, 45, 30, 15, and 0 (horizontal) degrees (°). Access to the grain via a raised magazine was provided by a 5 x 6 cm opening centered on the intelligence panel 11 cm from the floor. A 7 1/2 watt GE houselight provided illumination in the chamber throughout each experimental session and was centered 2.5 cm
from the top of the panel. White noise was provided by a Grason-Stadler noise generator (Model 901B) and a Quam speaker located behind a 7.5 cm diameter opening, located 10.5 cm from the bottom and 5 cm from the right edge of the intelligence panel. A Digital Electronics Corporation PDP8-L computer was used for programming and recording of experimental events. The computer was located in a room separate from the animal chambers.

**Procedure**

Experimental sessions were conducted seven days a week for approximately one hour per day. The subjects were magazine trained and a pecking response on the left key illuminated with a 45° line angle was shaped by standard operant conditioning procedures (Holland and Skinner, 1961). After key pecking was established, each of the next 25 responses was reinforced with three sec access to grain. The response key was darkened during reinforcement.

**DRL Training.** All subjects were individually exposed to a DRL 5 sec schedule of reinforcement with a one sec limited hold for key pecking in the presence of the 45° line-angle stimulus. Figure 1 presents a state diagram (Snapper, Knapp and Kushner, 1970) of the basic schedule. The enumerated circles (states) represent the stimulus appearing on the response key; the labelled vectors represent instantaneous transitions between states and the temporal or response requirements which effect the transition are shown above the vectors.

A key-peck response in state 1 (S1) transfers control to state 2 (S2) and initiates a five sec timer. Every key-peck response occu-
Figure 1: State diagram for the DRL training phase.
ring in S2 restarts the five sec interval. After five sec has elapsed without a response, control is transferred to state 3 (S3), in which a response will produce three sec access to grain if it occurs within one sec of the transition to S3. If one sec elapses prior to the response, control is transferred to S1, where the response requirement is re-initiated. After responding had stabilized on this schedule, such that the subjects were able to maintain their 80% weight (approximately 100 reinforcements during the session) the discrimination training procedure was initiated.

**Discrimination Training.** Prior to the first session of discrimination training the subjects were randomly divided into three groups with two subjects in each. The reinforcement schedule in the presence of the 45° line-angle stimulus (S+) remained the same; however, each group was exposed to a stimulus in which no responses were reinforced (S-). The S- stimulus for Group 1 was a dark key, for Group 2, a 90° line and for Group 3, a 0° line. The programmed contingencies are shown in Fig. 2. In State Set 1 (S.S.1), the onset of the S+ or S- is randomly determined in S1. If S2 is determined State Set 2 (S.S.2) is concurrently in effect during S+. which programs reinforcement for responses with five-to-six sec IRTs as in Fig. 1. The reinforcement duration was reduced to 2 sec during discrimination training due to weight gains which occurred during DRL training. In S2 of S.S.1, the S+ remains on the key for 60 sec, after which the presentation of S+ or S- is again randomly determined. If S3 is determined, there is no opportunity for the reinforcement contingencies in S.S.2 to occur during the S- presentation. The S-
Figure 2: State diagram for the Discrimination training phase.
duration was 10 sec after which the next S+ or S- presentation was randomly determined. If the S+ was determined to follow an S- presentation, the key was darkened for three sec (S4) between stimulus presentations for subjects in Groups 2 and 3 to avoid the adventitious onset of the S+ following a response during the S-.

Data for one subject in Group 3 were eliminated during this phase, due to the subject's death.

The data recorded included the number of IRTs in each of nine one-sec bins from zero to nine sec with IRTs longer than nine sec being collected in a tenth bin, the number of reinforcements per session, and the number of responses to the dark key.

**Generalization Testing.** After two consecutive days in which the total number of responses in the S- was 10% or less of the total number of responses in the S+, the generalization test series occurred. During the first five min of the test, reinforcement and stimulus conditions were identical to the discrimination training procedure except that the S+ remained on during reinforcement and there was three sec access to grain.

Each of the seven line-orientation stimuli was presented 15 times, for 30 sec with a dark key separating the test stimuli for five sec. The order of the stimuli was determined randomly and was repetitious. The order of stimuli in test series 1 was 30, 45, 75, 0, 60, 15, and 90 and in test series 2 was 75, 60, 90, 15, 0, 45 and 30. One reinforcement was available for a five-to-six sec IRT occurring during each presentation of the S+.

Data recorded included the number of IRTs in the 10 IRT bins
(as above), the number of reinforcements in the test and the number of responses to the dark key.
RESULTS

This experiment deals with the stimulus control of responding following discrimination training on a stringent DRL schedule of reinforcement. The control of response patterns by the reinforcement contingencies during training is presented in Fig. 3. In this figure, the mean frequency of IRTs during S+ and S- presentations, for the five sessions immediately preceding the first generalization test is plotted as a function of IRT bins. The number assigned to each one-sec bin between zero and eight represents the lower limit of the IRT class (e.g., Bin 0 contains responses with IRTs between zero and one sec). Bin 9 contains all IRTs greater than or equal to nine sec. Subject 1 obtained a maximum at the reinforced response class (Bin 5), in the presence of the S+ with secondary maxima at the two extreme IRT bins. A maximum was obtained at Bin 0 in S+ for Subject 2 with a secondary maximum at Bin 5. Both Subjects 1 and 2 in Group 1 maintained a zero level of responding in the presence of the dark key (S-). Subject 3 obtained a maximum at Bin 4 with small secondary maxima at the two extreme bins, in S+. A maximum at Bin 5, in S+, was obtained by Subject 4 with a secondary maximum at Bin 0. Although Subject 3 did not obtain a maximum at the reinforced five-to-six sec IRT response class, the mean frequency obtained at Bin 5 was greater than that of Subject 4 which produced a maximum at Bin 5. For Group 2, zero level responding was maintained by Subject 3 in the presence of the vertical-line S-; while Subject 4 produced a
Figure 3: The mean frequency of IRTs during the S+ and S− for the five sessions immediately preceding the first generalization test as a function of the nine one-sec IRT bins. Bin 9 contains IRTs 9 sec or greater.
mean total frequency of 48.6 responses, with a maximum at Bin 0. The mean frequency of IRTs during S- for Subject 4 was subordinate to that of the S+ across all bins. Subject 5 produced maxima in S+ with similar mean frequencies at Bins 0 and 5 with a secondary maximum at Bin 9. A mean total frequency of 27.6 responses to the horizontal line (S-) was produced by Subject 5 in Group 3.

Figure 4 presents a re-evaluation of the mean frequency of IRTs, in the presence of the S+ training stimulus, for the five days prior to the first generalization test in terms of an IRT/op function. The IRT/op measure was used because it attempts to equate the differences in the number of opportunities for long and short IRTs by calculating the number if IRTs in a bin per opportunity in that bin. The data from Bin 9 are not included due to the fact that they are meaningless in the transformation, since the IRT/op frequency of responses is equal to the number of opportunities for the highest bin number. The IRT/op value for this bin will always be one. Both subjects in Group 1 obtained a maximum at Bin 5 with secondary maxima at the two extreme bins. Subject 2 produced a greater IRT/op value than Subject 1 at Bin 5, which is in accord with the data presented in Fig. 3. Both subjects in Group 2 produced a maximum IRT/op value at Bin 5 with secondary maxima at Bins 0 and 8. The maximum for Subject 3 shifted from Bin 4 to Bin 5 in the transformation from mean frequency of responses (Fig. 3) to the IRT/op function. The maximum for Subject 5 shifted from Bin 5 to Bin 8 in the IRT/op function; while secondary maxima were produced at Bin 0 and Bin 5.

The percentage of total responses with five-to-six sec IRTs, in
Figure 4: The mean frequency of IRTs during the S= for the five sessions immediately preceeding the first generalization test as a function of one-sec IRT bins.
GROUP 3

GROUP 2

GROUP 1

ONE SEC IRT BINS

MEAN IRT/OP

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
the presence of the S+, for the five sessions immediately preceding the first generalization test and the two sessions immediately preceding each subsequent test is shown in Fig. 5. This figure was included to show the level of responding in S+ maintained during repeated testing compared with pre-testing data. Data for Subject 1 suggest a decreasing trend in the number of reinforced five-to-six sec IRTs during training sessions as testing progressed. The percentage of reinforced IRTs increased for Subject 2. Group 2 subjects maintained approximately the same percentage of reinforced responses on the two sessions following the first generalization test, compared to the five sessions prior to the initial test. On training sessions following the second generalization test, the percentage of reinforced IRTs for Subject 3 decreased; it also decreased slightly for Subject 4. Subject 5 produced relatively constant percentages of reinforced IRTs in the S+ throughout training sessions.

Figure 6 shows the discrimination index as a function of the training sessions prior to each generalization test. The discrimination index was calculated by dividing the total number of responses in the S+ by the total number of responses in the S+ and the S-. The possible values of the index range from zero through one, where values at or near zero indicate no discrimination (generalization) and values near or at one indicate perfect discrimination (no generalization). This figure indicates that all subjects maintained discriminative responding throughout the training sessions. Subjects 2 and 3 maintained a discriminative index at or near one while Subjects 1 and 5 maintained a value of .90 or greater. The discrimination index for
Figure 5: The percentage of total responses with five-to-six sec IRTs during S+ for the five sessions immediately preceding the first generalization test and two sessions preceding each subsequent test.
20% of total responses with 5- to 6-sec ITI's

GROUP 1

GROUP 2

GROUP 3

SESSIONS PRIOR TO TESTING
Figure 6: The discrimination index as a function of the five sessions immediately preceding the first generalization test, and two sessions preceding each subsequent test. The index was calculated by dividing the number of responses in the S+ by the number of responses in the S+ and S− in a session.
Subject 4 decreased approximately 10% on training sessions following the initial test.

Relative generalization gradients for the first test are shown in Fig. 7. Here the percentage of the total number of responses to each stimulus value (number of responses to stimulus x / total number of responses in the test), as a function of line orientation, is presented for individual subjects. The results for Subject 1 show a bi-modal curve with maxima on each side of the training stimulus. Subject 2 maintained a fairly constant percentage of responses across all stimuli, however a maximum was produced at the training stimulus. Subject 3's data show minimal differences in responding between the training stimulus and the two adjacent stimuli; however there were few responses made in the presence of stimuli on each end of the continuum for this subject. The gradient for Subject 4 is relatively flat compared to the gradient for Subject 3; however a maximum was obtained at the 45° training stimulus. The gradient for Subject 5 shows a relatively constant percentage of responses for stimuli to the right of the 30° stimulus, where the maximum was produced. A near zero percentage of responses was obtained in the presence of stimuli to the left of the maximum.

Figure 8 shows the generalization data from the first test transformed into IRTs/op as a joint function of line-orientation and IRT bins. The gradients shown in Fig. 8 suggest a division of responses, based on the overall frequency of IRTs in each bin and on the degree of stimulus control. Differentiation of these divisions is somewhat variable between subjects. The Bin 0 gradients for all subjects gen-
Figure 7: The percentage of total responses as a function of line orientation. The numbers to the right of the legend show the total number of responses made in the test.
GROUP 1
S1 • 663
S2 • 952

GROUP 2
S3 • 426
S4 • 390

GROUP 3
S5 • 742

% OF TOTAL RESPONSES

LINE ORIENTATION (°)
Figure 8: The IRT/op as a function of line orientation for each IRT bin in the first generalization test. Note in Bins 6 and 7 for Subject 3 and Bin 8 for Subject 5 there is a data point missing. There were no responses in those bins to calculate the IRT/op value.
eraly consist of a high frequency of IRTs with little stimulus control. For Subjects 2 and 5, the Bin 0 gradients appear relatively flat. Group 2 subjects produced minimum values in Bin 0 at $45^\circ$ and $30^\circ$, for Subjects 3 and 4 respectively. The Bin 0 gradient for Subject 1 shows a maximum at the $60^\circ$ stimulus with a secondary maximum at the $30^\circ$ stimulus.

The second category of IRTs is identified by a relatively low frequency of IRTs which lack strong evidence of stimulus control. For Subjects 1, 2 and 5 this category is represented in the Bin 1, 2, and 3 gradients, and for Subject 4 in the gradients for Bins 1 through 5. Subject 3's data do not show evidence of this category; rather, a low frequency of IRTs with maxima at or near the training stimulus occurs.

The final category of responses consists of gradients with a high frequency of IRTs with peaks at or near the training stimulus. This category occurs in the longer IRT bins for all subjects.

Figure 9 shows the percentage of IRTs in the presence of the $45^\circ$ training stimulus during the first generalization test as a function of IRT bins for each subject. The number in the upper right corner of each graph represents the total number of IRTs in the S+. All subjects produced maxima at Bin 0. Subject 1 produced secondary maximum at Bin 4 with decreasing values at longer IRT bins; while Subject 2 produced approximately equal percentages of IRTs in Bins 2 through 5. A bi-modal distribution of IRTs with secondary maxima at Bins 2 and 5 was produced by Subject 3. Subject 4 produced near zero percentages of IRTs in Bins 2 through 5 with a slight increase at longer IRT bins. Subject 5 produced a peak at Bin 5 with decreasing
Figure 9: The percentage of IRTs in S+ during the first generalization test as a function of IRT bins. The number in the upper right corner represents the total number of IRTs in the S+.
values on either side.

Figure 10 shows the IRT/op as a function of line orientation for each one-sec bin for subsequent generalization tests. The data from these tests were combined to obtain a mean IRT frequency distribution which was then converted to the IRT/op values shown in Fig. 10. The data for Subject 5 were obtained from only three of the four generalization tests following the initial test because the data from one test were lost due to computer failure. The division of responses based on the overall frequency of IRTs in each bin an on the degree of stimulus control is less evident here than for the initial generalization test. The Bin 0 gradients for Subjects 2 and 4 contain a high frequency of IRTs which remain relatively constant across all stimuli. Subjects 1, 3 and 5 produced maxima in Bin 0 at the 0° stimulus. The IRT/op function decreases to a minimum at the 75° stimulus for Subjects 1 and 3; while an approximately equal distribution of IRTs across the remaining stimuli was produced by Subject 5. The Bin 0 gradient for Subject 2 shows a maximum at the 15° stimulus after which the function decreases on either side. The development of gradients with a maximum or secondary maximum at or near the training stimulus appear in bins greater than zero for Subjects 1, 2 and 3. These gradients for Subjects 1 and 2 are composed of low frequencies of IRTs which increase with steepness as the bin number increases; while the gradients for Subject 3 appear relatively constant across IRT bins in terms of steepness and IRT frequency. Bin 1 through 5 gradients for Subject 4 remain at a low frequency with little evidence for stimulus control except at the longer IRT bin gradients where a maximum occurs at the
Figure 10: The IRT/op as a function of line orientation for each IRT bin. These data are composed of an IRT/op transformation of the mean frequency distributions for the generalization tests following the initial test.
training stimulus. The gradients for Subject 5 are composed of low frequencies of IRTs which increase gradually with bin size. A maximum occurs at the 30° stimulus in Bin 4 which continues to occur as a secondary maximum in subsequent gradients.
DISCUSSION

The present experiment investigated stimulus control functions following a successive discrimination training procedure which provided reinforcement for responses with five-to-six sec IRTs. Figures 3 and 6 demonstrate the control over responding by the temporal contingencies of the reinforcement schedule as well as the control exerted by the discriminative stimuli during training sessions. The relative generalization gradients shown in Fig. 7 demonstrate some evidence of stimulus control for all subjects; however, they appear relatively flat compared to gradients typically following training on a VI schedule of reinforcement.

A common explanation of the reduced steepness in gradients following DRL training is the internal cues hypothesis which maintains that DRL responding is controlled by proprioceptive stimuli and that control by such stimuli reduces or prevents control by the external stimuli. However, it has been shown that the response rate measure may reflect the averaging of several response categories, some of which are and some of which are not under stimulus control, rather than the absence of such control. This does not necessarily eliminate an internal cues interpretation but it does show that other factors may be involved.

The results from the first generalization test were re-evaluated in terms of IRT/op, as shown in Fig. 8. In general, responses having different IRTs appear to be divided along two continua; (1) the overall frequency of responses and (2) the degree of stimulus control.

40
These data provide systematic replication of previous reports (Blough, 1963; 1969; Gray, 1976) of external stimulus control over responses with long IRTs and reduced or no stimulus control over responses with short IRTs. These results lend support to the notion that the response rate measure is composed of several response classes which are affected differently by the contingencies related to the external stimulus dimension.

The internal cues hypothesis is concerned with the ways in which internal stimuli, frequently assumed to consist of proprioceptive feedback from collateral chains, may influence generalization gradients. Reliable data on collateral behavior are difficult to obtain due to technical inadequacies; however direct observations by the experimenter, in the present case, may add some insight to this analysis. These observations revealed that subjects in Groups 1 and 2 developed a collateral chain of behaviors which mediated the DRL interval requirement. In general, during S+, the chain consisted of circling the perimeter of the chamber with periodic orientations of the beak in the direction of the key. During the S- presentations, wing flapping occurred periodically and the subjects usually positioned themselves in the middle of the chamber facing the intelligence panel until the key was darkened. Subject 5 exhibited some mediating behavior; however the topography was not consistent between or within sessions. One of Hearst's hypothesis was that collateral chains reduce the amount of exposure to the external stimulus since much of the time is spent away from the key. Although the subjects in the present experiment appeared to engage in collateral behavior, the result was not the
absence of stimulus control, at least for long IRTs, as predicted by Hearst's hypothesis. Hearst's internal cues hypothesis suggests that key-pecking responses may become controlled by proprioceptive stimuli derived from the collateral behavior, which reduces or eliminates stimulus control over key pecking. Again, Hearst's hypothesis is contradicted since stimulus control was shown for long IRTs where the most collateral behavior should occur; and very little stimulus control was shown for short IRTs, where the least collateral behavior should occur.

The present study also sought to investigate the occurrence or non-occurrence of the peak shift phenomenon. Hanson (1959) formulated several postulates concerning the position of the peak following discrimination training which include: (1) the maximum of a generalization gradient will be displaced away from the S- in relation to the S+ and (2) the magnitude of this displacement will increase as the difference between the S+ and the S- is reduced. The failure to obtain peak shift in the present experiment may have been due to the difference between the 45° training stimulus and the S- stimuli (0° and 90°). A smaller difference might have produced peak shifts.
REFERENCES


