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# The Acquisition of Stimulus Control

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THE ACQUISITION OF STIMULUS CONTROL

by

Roger C. Lubeck

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

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Roger Clarke Lubeck

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The present research represents an examination of the acquisition of stimulus control in a multiple discrimination training procedure. In a multiple discrimination, the presentation of the S+ (a stimulus in the presence of which reinforcement is available for a response) is interspersed with the presentation of multiple S-s (stimuli in the presence of which no reinforcement is available for a response). Although there are several investigations which have used this multiple discrimination procedure in the examination of successive discrimination gradients (Pierrel, 1958; Boneaux and Cole, 1962; Blough, 1969; Schuster and Gross, 1969), no examination has been made of the acquisition of stimulus control under this procedure.

The evaluation of the acquisition of stimulus control using a multiple discrimination training procedure requires several methodological considerations which may in part explain the lack of research in the area. First it is necessary that any measure of the acquisition of stimulus control (discriminability) be determined concurrently in the S+ and S-s. From which it follows that there can be no differential strengthening of responses in the presence of any of the discriminative stimuli prior to the implementation of discrimination training. An experimental history of differential strengthening may set limitations on the dependent variable which would not permit a proper examination of the acquisition of stimulus control. Further to guard against uncontrolled stimulus bias (Thomas, 1972) from affecting initial measures of discriminability, it would be advantageous to implement discrimination training with a known baseline in the presence of the discriminative stimuli. Preferably a stable minimal baseline, established without

differential reinforcement for responses along the S+ and S- stimulus dimension.

If the measure of stimulus control is to be response rate, and the acquisition of rate of response is to be determined concurrently in the S+ and S-s without prior differential strengthening, one final consideration is necessary, the schedule of reinforcement for responses in the presence of the S+. Because of the necessity of no differential strengthening prior to discrimination training, a continuous reinforcement schedule would seem indicated. However, because response rate is the critical measure of stimulus control, and a CRF schedule of reinforcement in effect in the S+ may not permit equal comparisons of response rate in the S+ and the S-s (Frick, 1948) it is necessary to select a schedule of reinforcement which would allow equal intervals of comparison for response rates in the S+ and the S-s, without the difficulty of frequently delivered reinforcers. Ideally, a variable or random interval schedule of reinforcement would be selected, however, the use of a variable interval schedule may require the strengthening of response on some prior schedule (i.e. CRF), because without a procedure to establish an initial level of response in the presence of the S+, prior to the introduction of the variable interval contingency, the variable interval schedule may not be effective.

What is necessary is a procedure to establish a known baseline of response in the discriminative stimuli, preferably, one which is equal and minimal, and to do so without differential strengthening.

A method to establish such a baseline without differential strengthening would be to present the discrimination stimuli super-



imposed upon a stimulus from an orthonogal dimension in the presence of which there was a history of reinforcement. Using this procedure the generalized responding in the presence of the discrimination stimuli superimposed upon the orthonogal S+ would equally undergo extinction; discrimination training can therefore be implemented whenever the appropriate S+ and S- baseline is obtained. Therefore, the acquisition of stimulus control in a multiple discrimination procedure can be evaluated with a known baseline in the S+ and the S-s which is established without the use of differential strengthening in the presence of any of the discrimination stimuli.

## METHOD

### Subjects

Six experimentally naive, barren-hen White Carneaux pigeons, of unknown age, were maintained at 70% of their free-feeding weights. Purina Pigeon Grains were used to maintain daily weights and functioned as the reinforcer. Water and Grit were available at all times in the home cage.

### Apparatus

Two Lehigh Valley pigeon test chambers, with single response key intelligence panels were used. The response key was a 10 mm. (thick) transparent Plexiglas paddle located behind a 25 mm. diameter hole in the left hand portion of the intelligence panel. Each response to the Plexiglas paddle resulted in a .5 sec programmed blackout. The blackout was obtained by capaciting the output of the BRS oneshot 103. The .5 sec interval was checked with an Aristo Import Co., Inc. stopwatch. Stimuli were illuminated behind the response key via an industrial Electronic Engineers one-plane readouts (series #10), with G. E. #47 lamps. Two types of stimuli were available: a 576 mm. (yellow) stimulus and any of seven line orientations superimposed on the yellow stimulus. The White 25 X 2 mm. line varied in fifteen degree increments, 90° through 0°. White noise was continuously presented through a speaker in the intelligence panel, while a fan provided ventilation and additional masking noise. The houselight was off.

All sessions were controlled by BRS, 100-series, digital switching circuitry. Responses, reinforcements, and time in each stimulus component were recorded with Sodeco electro-mechanical counters.

### Procedure

Sessions were conducted seven days a week. Sessions were administered concurrently to an A and C subject, for a maximum of 50 min. a day. Using standard operant conditioning procedures the two groups of subjects (A-1, A-2, A-3, C-1, C-2, C-3) were trained to eat from the food magazine and then shaped to peck the response key which was trans-illuminated with the yellow stimulus. Each response to the key resulted in a .5 sec stimulus off period. Because inter-response-times (IRT) of less than .5 sec have been shown to be under inadequate stimulus control (Blough, 1969) the .5 sec blackout procedure (Blough, 1969) was in effect to eliminate short IRTs. Responses during the blackout had no programmed effect and were not recorded.

Once responding was established, the first phase was begun during the next session. During the first session of the first phase, responses were placed on a continuous reinforcement schedule (CRF), with all reinforced responses resulting in 3 sec access to grain with the hopper light illuminated and the stimulus off. All CRF sessions terminated with the delivery of 50 reinforcers or when 50 min. elapsed, whichever occurred first.

During the first phase, the schedule of reinforcement was changed from CRF to a random interval (RI) schedule of reinforcement (cf. Farmer, 1963) following three consecutive sessions in which the rate of response

was 25 responses per min. or greater. The initial random interval schedule, RI 8 sec was increased to RI 16 sec and then to the terminal RI 32 sec schedule according to the three session criterion. For each RI schedule, the availability of reinforcement was sampled for the first response in each consecutive four sec interval of the session. The probability of reinforcement for the first response in each four sec interval was progressively decreased from 1/2 to 1/4 to 1/8 for RI 8, RI 16, RI 32 sec, respectively. For all RI training sessions, the S+ was the yellow stimulus.

For all sessions in which the RI schedule was in effect, once reinforcement became available, the availability of reinforcement for a response remained in effect until a response in the presence of the S+ occurred. Therefore, in subsequent training sessions in which stimuli were presented in which reinforcement was not available, the availability of reinforcement was still sampled and could become available and remain available until the first response in the presence of the S+. The probability of reinforcement for the first response upon entering an S+ was dependent upon the amount of time elapsed since the last reinforcement in the prior S+. Thereafter, the probability of reinforcement was uniform for each response in the S+.

In phase two, subjects were given discrimination training in which the yellow S+ was presented with seven line orientation stimuli, the S-s, those stimuli in the presence of which no reinforcement was available. Phase two discrimination training sessions consisted of five presentations of a fixed order of fifteen 30 sec stimulus components. Within each block of fifteen stimuli, the order of presentation

was four yellow S+ stimuli followed by a randomized block of eleven stimuli in which the seven S-s were interspersed with two additional presentations of the yellow S+ and two presentations of the yellow stimulus with no reinforcement available. Discrimination training was continued in phase two until a discrimination ratio, the response rate in the S-s divided by the response rate in the S+, appeared stable for a minimum of three days. The determination of stability was made upon visual inspection, however, the phase was not terminated, and phase three begun, until a minimum of 10 sessions had been administered in phase two.

In phase three, the discrimination procedure of phase two was altered such that one of the S-s, the 45° line orientation was changed to an S+ for each of the five daily presentations. For the first session, the first response to occur in the presence of the S+, 45° was reinforced; thereafter in that session, and all subsequent sessions, responses in the presence of the 45° line orientation were reinforced according to the RI 32 schedule of reinforcement. All sessions in phase three were identical to discrimination sessions in phase two with the exception of reinforcement for responses in the presence of the 45° line orientation. For all subjects, phase three discrimination sessions were terminated after a minimum of 40 sessions and upon the visual determination that response rates in the S-s were unchanging. For the A group (subjects A-1, A-2, and A-3) in phase three 54, 50, and 47 discrimination sessions were conducted respectively. For the C group (C-1, C-2, and C-3) 45, 56, and 44 discrimination sessions were conducted respectively.

## RESULTS AND DISCUSSION

For each subject, three measures are presented in Figure 1. In the first column, a measure of the relative rate of response is presented; this measure was calculated by dividing the total number of responses in the presence of the line orientation S+, 45° by the total number of responses obtained in the presence of all of the line stimuli. Each function represents the percentages for the last 10, baseline, sessions in phase two and the percentages for all discrimination sessions in phase three, the final phase. These functions show how the level of discrimination changes across daily discrimination training sessions. For each subject, the median percent of response at the S+ was obtained from the last eleven sessions of phase three. The arrangement of the subjects in Figure 1 was made on the basis of these medians, with the lowest percentage at the bottom and the highest percentages at the top of the figure.

The top left hand function is for the A-1. In the final 10 sessions of phase two, the data before the dashed vertical line, the percent of response at the S+ was zero for the last four sessions. This zero level was obtained because no responding occurred in the presence of 45°, however, responding still occurred in these sessions in the presence of the other line orientations. For the discrimination sessions there was a gradual increase in the median percent response at the S+ from the first eleven sessions to the final eleven sessions. This represented an increase from 26 to 45% response at the S+, 45° and was

the greatest percent steepening obtained by any subject.

In the second column, response rate functions are presented for four line orientation stimuli; the S+, 45° and three S-s, 90°, 75°, and 60°. Each function represents the running median response rate, in blocks of nine sessions. In a running median of nine sessions, the first data point represents the median response rate for the first nine discrimination sessions; the second data point represents the median response rate for sessions 2-10, the third, the median for sessions 3-11, and so on. The median response rate for nine discrimination sessions was selected because of the smoothing effect this measure had on the day to day variability in the response rate. The median response rates for the three additional line orientation are not presented here, however, the data presented may be considered representative for either side of 45°.

From the functions for A-1, in the second column, it can be observed that the median rate of response in S+ (shown in a darker line) progressively increased from an initial 25 responses per min. to a final 75 responses per min. In the S-s, there was only an initial increase in the median response rate in the 60° stimulus, followed by a gradual decrease. For the other two S-s, there was little change in the median response rates obtained. However, all the S-s response rates were above the phase two baseline of one response per min. (this baseline measure, shown as a horizontal dashed line, represents the median of the averaged rate of response in the presence of the line orientations). By the final 10 discrimination sessions there was a clear separation in the median S-s response rates, with the highest

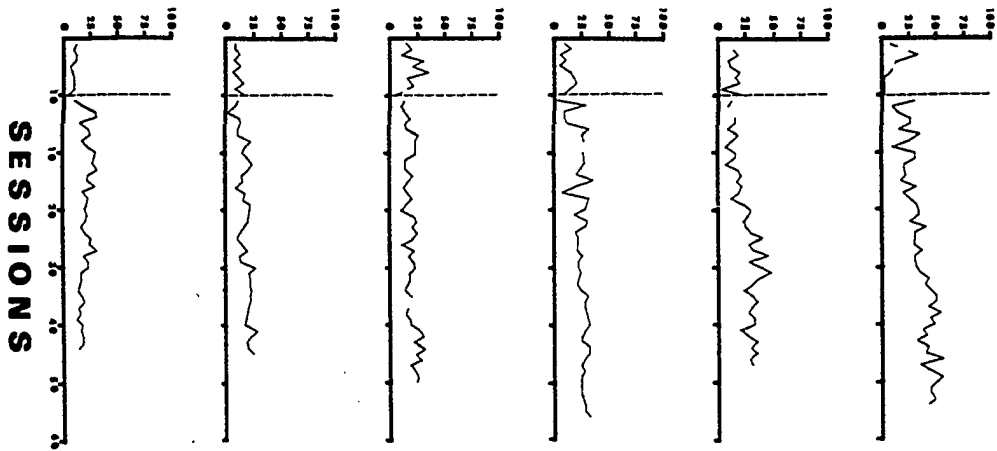
Figure 1. For each subject, in column one, the percentage that responses in the 45° S+, represent of the total number of responses obtained at all line orientation stimuli for the final 10 sessions of phase two and for all sessions of phase three.

In the second column, for each subject, the running median rate of response for four line orientations, the S+, 45° and three S-s, 60°, 75°, and 90°. The medians are presented for all sessions of phase three. The dashed horizontal line represents the median of the averaged rate of response in the presence of the line orientations for the final nine sessions of phase two. The dashed vertical line indicates the final block of nine sessions.

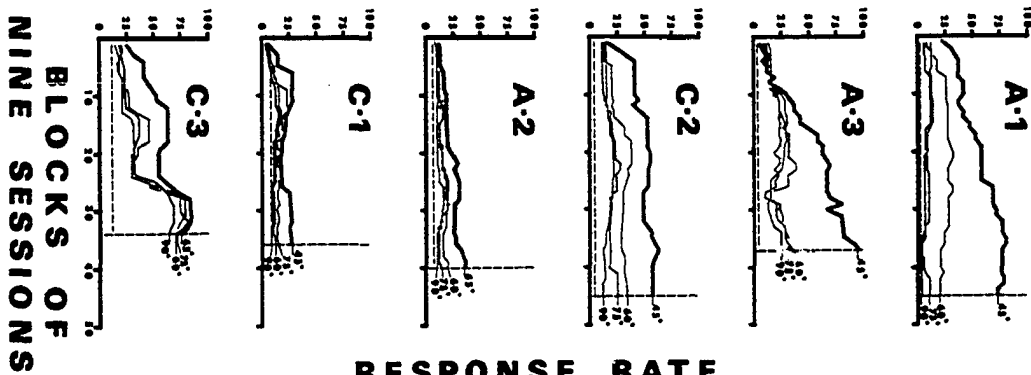
In the third column, for each subject, discrimination gradients are presented for three sessions in phase three. The square data points represent data for the first discrimination sessions. The two other gradients represent the flattest and the steepest sessions from the final eleven discriminations. The open circle data points represent the flattest session, while the closed data points represent the data for the steepest session. The S+ and S symbol represent the yellow only S+ and the yellow only S respectively.



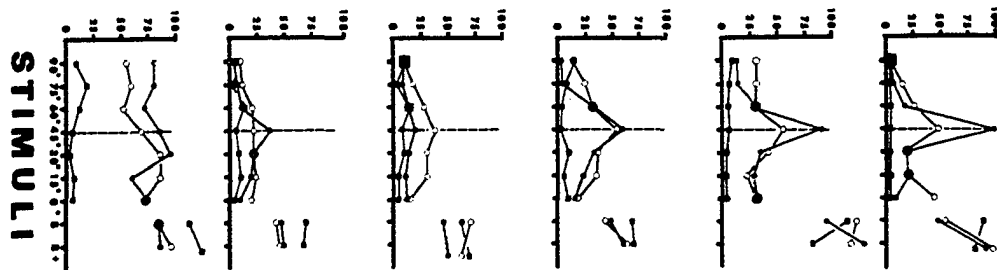
**PERCENT OF TOTAL AT S+**



**MEDIAN RESPONSE RATE**



**RESPONSE RATE**



**STIMULI**

**BLOCKS OF NINE SESSIONS**

**SESSIONS**

rate in the presence of the 60° stimulus and the lowest occurring at the 90° stimulus.

In the third column, for subject A-1, discrimination gradients for three sessions in the final discrimination phase are presented. The square data points represent the gradient obtained during the first discrimination session in phase three. It can be seen that near zero responses per min. were obtained in the presence of each of the line orientations. In the first session with reinforcement available in the 45° S+ there was no initial difference obtained between response rate in the presence of the yellow S and the yellow S+, with more responding in the presence of the yellow S stimulus. The two additional gradients represent the data for the flattest and steepest sessions of the final eleven discrimination of phase three. The data for the flattest session are presented as open circles and the steepest as closed circles. In both the flattest and steepest sessions presented, the maximum response rate occurred in the presence of the S+, 45°, although there was a considerable difference in response rate in the presence of the 45° S+ during these two sessions, there were only minimal differences in response rate in the presence of the S-s for these two sessions. It should be noted that a large difference (about 50 responses per min.) was obtained between responses in the presence of the yellow S and the yellow S+ for these sessions.

For subject A-3, the range in the percent response at the S+ was 4 to 20% for the final 10 sessions of phase two. For the first 18 discrimination sessions in phase three, there was no increase in the percent response at the S+ above the level obtained in the 10 sessions

in phase two. Following the 18 session there was a gradual increase in the median percent response obtained, with a total increase from the first eleven sessions of 13 to 31% by the final eleven discrimination sessions of phase three.

As shown in the second column, the median rate of response for the line orientation S+, 45° progressively increased from an initial rate of 6 responses per min. to final median of 95 responses per min. The median S-s rates initially increased until the 12 block of nine sessions, following which there was a gradual decrease and separation in the median response rates obtained. The final median response rate was highest in the presence of the 60° S-, while the lowest rate of response was obtained in the presence of the 90° stimulus.

As shown in the third column, the response rates for all line orientation stimuli in the first session were below 9 responses per min. In both the flattest and steepest sessions the maximum response rate occurred in the presence of the S+, 45°; the rates were 55 and 91 responses per min., respectively. The S-s response rates were near equal during both session at about 25 to 30 responses per min.

For subject C-2, an initial variability in the percent response at the S+ for the first 20 sessions of phase three was followed by a marked decrease in variability for the remaining 32 sessions. This decrease in the variability, however, did not represent any change in the slope of the discrimination gradients obtained. The median percent response in the presence of the S+ increased only one percent, from 26 to 27 percent.

In the second column, for subject C-2, an initial increase in the

median rate of response in the S+, from 17 to 42 responses per min. gradually increased to a final median of 61 responses per min. There was a gradual increase in the median S-s response rates, with consistent differentiation in the final sessions. The highest response rate was obtained in the 60° stimulus, while the lowest response rate was obtained in the presence of the 90° stimulus.

The discrimination gradients in the third column, for C-s, show that for both the steepest and the flattest sessions presented, the maximum rate of response was obtained for responses in the presence of the S+, 45°. In each case, the rate of response was greater than 50 responses per min. For the most part, the response rates in the presence of the S-s were equal, with the least responses occurring in the presence of the S- stimulus furthest from the S+. Responses in the presence of the yellow S and yellow S+ decreased from the baseline, of the first session, in both the flattest and the steepest sessions.

For the next subject, A-2, there was a range of 4 to 34% response at the S+ during the final 10 sessions prior to phase three. In phase three there was a gradual increase in the percent response at the S+ from 15% for the first eleven sessions to 25% by the final eleven sessions.

The median response rate in the presence of the S+ (in the second column) increased from an initial median response rate of 13 responses per min. to a final median response rate of 36 responses per min. The median S-s response rates each increased about 5 responses per min. across the third phase; all median response rates in the S-s were below 20 responses per min. By the 34 block of nine sessions there

were minimal differentiation in the S-s response rates, with the highest rate of response again occurring in the presence of the 60° stimulus and the lowest response rate occurring in the presence of the 90° stimulus.

For subject A-2, there were only minimal differences obtained from the first discrimination gradient to the flattest and steepest discrimination gradients of the final eleven sessions. As with subject C-2, there was a decrease in the response in the presence of the yellow S and the yellow S+ from the first session baseline to the two final gradients presented.

For subject C-1, the percentage of response at the S+ for the final 10 sessions in the second phase varied between 6 and 16 percent. There was an 8% increase (12 to 20%) in the median percentage from the first eleven sessions of phase three to the final eleven sessions.

For C-1, as shown in the second column, the median rate of response in the S+ increased gradually from 6 responses per min. to a median of 27 responses per min. The median S-s response rates increased only minimally above the median baseline of 7 responses per min. There were stable median response rates in the S-s for the final 10 blocks of nine sessions and although there was differentiation of response rates obtained, unlike the prior four subjects, the highest response rate occurred in the presence of the 75° stimulus, while the lowest rate of response occurred in the presence of the 90° stimulus.

The three discrimination gradients for C-1 are shown in the third column. For both the flattest and the steepest sessions, there was an increase across all line orientation stimuli of 10 to 15 responses

per min. from the first discrimination session. Again a decrease was obtained from the first discrimination session to the two discrimination gradients presented.

In the bottom left hand column, for subject C-3 the daily percentages were all below 10% response at the S+ for the final 10 sessions of phase two. The percent response at the S+ initially increased to 24% in the first eleven sessions, following which there was a decrease in the percent obtained to a final median of 16% for the last eleven discrimination sessions.

From the functions in the second column, for subject C-3, there was an increase in the median response rate in the presence of the S+, 45°, from an initial 25 responses per min. to 75 responses per min. in the final blocks of nine sessions. The response rates in the presence of each of the S-s increased above the baseline of 10 responses per min. until the 17 block of nine sessions. After the 17 block of nine sessions, the differentiation in the median S-s response rates was lost and by the 24 block of nine sessions the S-s response rates increased until there was only minimal separation between the response rates in the S-s and the response rate in the presence of the S+. It was this increase in the median S-s response rates that accounts for the decrease in steepening shown in the final eleven sessions in the first column.

As shown in the third column, for C-3, the response rates in the presence of all the line orientation stimuli were below 20 responses per min. for the first discrimination session of phase three. For the two final gradients presented, the main characteristic of the gradients

is that there was little differentiation between the response rate in the S+ and the response rates in the presence of each of the S-s. It should be noted that the functions presented are not representative of earlier discrimination performance, as would be shown by data from the 13 to 17 block of nine sessions, but rather the gradients are representative of the breakdown in stimulus control seen in the final discrimination sessions.

For all of the subjects (for subject C-3 up to the 26 session) some degree of gradient steepening was obtained, as shown by the functions in column one. In each case, the median rate of response in the S+ and the S-s showed an increase in the S+ with only minimal increases in the S-s median response rates. The increases in the S+ obtained for each subject were all increases above any rate of response in an S-. The median response rate in the S-s typically increased initially, followed by a gradual decrease or leveling off in the median response rate. The leveling off of the S-s response rates was also characterized by a distinct differentiation of response rates in the S-s. This response rate differentiation for five of the six subjects (A-2, C-2, A-3, A-1, and C-3 up to the 26 session) was consistent with Frick's (1948) data that the rate of response in the S- is functionally related to the distance between the S+ and the S-, where the highest rate of response was obtained in the presence of the S- nearest in distance to the S+. The decrease and differentiation in response rates in the presence of the S-s, after an initial increase to the level of responding, without showing decreases to a zero level of response was also consistent with Frick's data. However, where

Frick's data indicate that the S-s response rates were initially equal, followed by decreases in the S-s response rates and differentiation in the S-s response rates with stabilization in response rates after about 60 min. in extinction, the present data are not in complete agreement. Response rates in the presence of the S-s increased gradually, followed by gradual decreases with limited indications of leveling off, or stabilization in the S-s response rates. For all subjects, however, there were separations in the S-s response rates.

The acquisition of stimulus control under a multiple discrimination procedure can, on the basis of the present data, be described as the progressive increase in the response rate in the presence of the S+ with minimal increases in the S-s response rates, followed by a gradual decrease or leveling off in the S- response rates. The decrease in the S-s response rates was followed in six out of six cases (for C-3 up to the 26 session only) by a differentiation of response rates. The differentiation of the S-s response rates was functionally related to the distance between the S+ and the S-s.



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