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Conditioned Inhibition In An Operant Discrimination
As A Function Of Component Duration

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CONDITIONED INHIBITION IN AN OPERANT DISCRIMINATION AS A FUNCTION OF COMPONENT DURATION

By

ROBERT BENJAMIN YOUNG

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ABSTRACT

Conditioned Inhibition in an Operant Discrimination as A Function of Component Duration

by Robert Young

The effects of component duration on acquisition of a discrimination and inhibition were assessed using a between subjects design. Following five days of single stimulus training, four groups of pigeons were given discrimination training between a green key (S+) and a vertical line (S-). The durations of the S+ and S- components were either 15 or 120 seconds. These durations were combined factorially to produce the 4 groups of subjects. Each subject received 30 alternations between S+ and S- for 25 days of discrimination training. After discrimination training was completed, all subjects were given five days of single stimulus training on a new S+, a red key, and inhibition associated with S- was measured by superimposing the S- on the red key and the original S+.

The results showed that the groups with shorter S+ durations and longer S- durations produced higher response rates to S+ at the beginning of discrimination training. With extended training, however, these differences disappeared. Superimposing the S- on the S+ produced more suppression of responding in the groups trained with the short S+ than in the groups trained with the long S+. These differences, however, did not reach significance. No effect of S- duration could be found during inhibition testing.

ACKNOWLEDGEMENTS

I would like to acknowledge the guidance and assistance given me by my advisor, Dr. Mark Rilling. Both his conceptual advice and his editorial comments have been invaluable in the production of this thesis.

I would also like to acknowledge the contributions of my committee members, Drs. M. Ray Denny and James Zacks, and of Mr. Steven Gitterman who freely contributed his time to help produce the final copy of the paper.

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INTRODUCTION

A discrimination is formed when responses in the presence of one stimulus (S+) are reinforced and responses in the presence of another stimulus (S-) are extinguished. For dissimilar stimuli, acquistion is complete when responding continues to occur in the presence of the reinforced stimulus and no longer occurs in the presence of the extinguished stimulus. Pavlov (1927) argued that the reduction in responding to the extinguished stimulus occurred through an active process he called conditioned or differential inhibition. As evidence that the decrement in responding involved an active process, he reported that when the positive and negative stimuli were presented simultaneously in a compound, responding to the postive stimulus was reduced or inhibited. He also found that responding during the extinguished stimulus was increased or disinhibited by the presentation of a novel stimulus.

In their analyses of instrumental discrimination learning, Spence (1936, 1937) and Hull (1943) also used the concept of inhibition as a process which opposes excitation. However, Skinner (1938) explained discrimination learning without appealing to a concept of inhibition. He suggested that extinction is simply a reduction in the probability of a response, not the growth of a process which opposes the emission of a response. Discrimination learning was proposed to be a modified form of extinction in which responding is maintained in the presence of one stimulus through reinforcement while it is extinguished in the presence of another stimulus. According to Skinner, the stimulus associated with extinction merely loses excitatory strength gained through generalization and does not become inhibitory. The response suppression reported by Pavlov was explained by Skinner as an emotional byproduct of extinction which disrupted rather than suppressed responding.

During the 1950's the operant approach to animal learning blocked research into inhibitory phenomena. However, Guttman and Kalish (1956) obtained generalization gradients from individual subjects using operant methodology. These gradients showed that after intradimensional discrimination training between two stimuli sufficiently close together on the same dimension, the point of maximum responding in the gradient was no longer the stimulus associated with reinforcement (S+), but a stimulus further removed on the dimension from the stimulus associated with extinction (S-). This phenomenon is called "peak shift." Peak shifts were predicted by Spence (1937) in his theoretical paper on transposition. Spence's theory uses an interaction of generalized excitation and inhibition to predict the shape of post-discrimination gradients.

Jenkins and Harrison (1962), Schwartzbaum and Kellicut (1962) and Honig, Boneau, Burstein, and Pennypacker (1963) reported finding U-shaped inhibitory gradients around an S- after giving interdimensional discrimination training between two stimuli on orthogonal dimensions. These researchers argued that excitatory strength generalized equally well to all stimuli on the S- dimension, while inhibition generalized more strongly to those stimuli close to the

S- on the dimension. Thus, the most response strength was observed at the stimuli on the dimension most removed from the S-. The gradients seemed to confirm Spence's theory of inhibition, and researchers began to use the peak shift and inhibitory gradients as evidence for inhibition.

A "gradient test" of inhibition, however, involves a different set of assumptions about inhibition than those proposed by Pavlov (1927). A U-shaped inhibitory gradient only reflects a generalized reduction in responding which decreases in strength at greater distances from the original S-. Since Skinner (1938) argued that extinction as well as reinforcement could generalize, these gradients do not discriminate between "passive" extinctive processes and "active", suppressive, inhibitory processes. Brown and Jenkins (1967) recognized this problem, and suggested that different techniques could produce a more convincing demonstration of inhibition than generalization gradients. In a procedure similar to Pavlov's, Brown and Jenkins trained an operant discrimination in which the S- was a combination of the S+ and a second stimulus. They demonstrated that the superimposition of this second stimulus on a different S+ suppressed responding to that stimulus. They argued that the suppression of responding to the new S+ was evidence that the S- stimulus controlled a tendency not to respond rather than a mere reduction in excitation.

Hearst, Besley, and Farthing (1970) also expressed dissatisfaction with gradient tests of inhibition, and argued that they do not reflect the defining property of inhibition, a suppression of excitation. Hearst et al. suggested that the minimum of an inhibitory gradient could be neutral while stimuli further removed on the dimension are progressively more excitatory. They proposed that one or more tests be used to identify an inhibitory stimulus. The first of these tests involved a procedure similar to that used by Brown and Jenkins (1967). The S- is superimposed on the S+, and the amount of suppression produced relative to a neutral stimulus is measured. The second test was a resistance to reinforcement measure in which a CS- is paired with the reinforcer and the number of trials required to condition a new response to the former CS- is measured.

The problems inherent in using inhibitory gradients as a measure of inhibition were highlighted in a study by Davis (1971). Davis trained a discrimination between a green key that served as S+ and a vertical line S-, and then obtained generalization gradients by superimposing different line angles on the S+. The response rates of all subjects showed suppressed responding to the S+. However, only one animal produced a U-shaped inhibitory gradient around S-. This study suggests that the presence of inhibition may not always be reflected by generalization gradients.

The measures proposed by Hearst et al. (1970) have an additional advantage in that comparisions are possible between the amount of suppression produced by an S- or the number of trials required for conditioning. Although these measures have successfully been used by researchers in Pavlovian conditioning to compare the amount of inhibition produced by different conditioning procedures (c. f. Wagner and Rescorla, 1972), they have more frequently been used in operant conditioning literature as an adjunct to generalization gradients. They have been used to show that the gradients actually reflect an inhibitory stimulus rather than as a measure of the amount of inhibition produced by differenct procedures. Consequently, little is known about the determinants of inhibition in operant discrimination learning.

The present study measured the suppression of conditioned responding by an S- as a function of the duration of the stimulus components used in discrimination training. The duration of the S+ and the S- was either 15 or 120 seconds. Thus four groups were produced by this procedure: One with a 15 second S+ and a 15 second S-, one with a 120 second S+ and 120 second S- one with a 15 second S+ and 120 second S-, and one with a 120 second S+ and a 15 second S-. The number of alternations between S+ and S- was held constant, so that the amount of experience with reinforcement and extinction depended upon the duration of the component.

Several investigators have suggested that increased experience with inhibitory stimuli reduces inhibition. Beiderman (1968) trained birds on two concurrent discriminations. In these discriminations the S+ and S- were present at the same time. Pecks to the S+ key produced food; whereas, pecks to the S- key produced a time out. One of the S+, S- pairs occurred twice as frequently as the other, and the two types of trials alternated randomly. On test trials the birds were given a choice between the two S+ stimuli or the two S- stimuli. The subjects chose most frequently the S- with which they had had the most experience during discrimination training, and the S+ with which they had had the least experience.

Beiderman suggested that increased experience with an S- may reduce its inhibitory strength, and related the phenomenon shown in his study to the overlearning reversal effect.

Terrace (1966) presented data showing that with increased discrimination training inhibitory gradients became flatter and behavioral contrast decreased. Terrace argued that the inhibitory properties of the S- had been reduced by the extended training period. Hearst (1969), however, obtained gradients after longer periods of training than used by Terrace, but found no tendency for the gradients to flatten or for behavioral contrast to decrease.

Terrace (1966), Hearst (1969), and Biederman (1968) manipulated exposure to discriminative stimuli by increasing the number of stimulus presentations rather than by manipulating the duration of each presentation. Only two investigators have manipulated the duration of extinction predicted by an S-, and then measured inhibition. Both of these investigators used a classical conditioning paradigm.

Weisman and Litner (1971) presented a CS preceeding a shock-free interval superimposed on a free operant avoidance schedule. The shock-free interval was either one minute or five minutes long. Although shocks occasionally occurred during the CS, animals inhibited avoidance responding during the CS which predicted the five minute shock-free interval, but not during the CS which predicted the shorter extinction period. Presumably, the CS preceeding the longer interval had produced more inhibition, and thus a greater suppression of the avoidance response.

Hearst and Franklin (1977) used a similar design in which free food was presented to pigeons, but a CS predicted a period of no food delivery. Hearst and Franklin used withdrawl from the key area when the CS was presented as a measure of inhibition. They found no effect of the timeout period predicted by the CS on either the amount of withdrawl from the key, or on the shape of generalization gradients around the S-. The gradients did differ, however, in that the gradient around the S- associated with the longest S- period also produced the greatest number of keypecking responses. Hearst and Franklin argued that the duration of the food-free interval associated with a CS is not a powerful determinant of inhibition.

Kamil and Davenport (1966) investigated the effect of component duration on the acquisition of a discrimination. These investigators trained discriminations in which the S+ and S- alternated at different rates. They found that increasing the rate of alternation to a rate over six times per minute precluded the formation of the discrimination in rats. It is unclear, however, whether these results were due to a lack of inhibition, or whether the subjects were simply unable to discriminate the contingency changes when the rate of alternation greatly exceeded the rate of reinforcement.

Several investigators have investigated the effect of component duration on a second product of discrimination learning, behavioral contrast. Behavioral contrast occurs when a decrease in the incentive conditions of one component results in an increase in response rate in the other component. Studies which have manipulated component duration report that the amount of behavioral contrast produced by a change in incentive is at least partially determined by the duration of the components of the discrimination. Taus and Hearst (1971) and Wilton and Clemens (1971) have shown that increasing the duration of an S- while the S+ duration is held constant also increases the amount of behavioral contrast produced. Two of the control groups run by Kodera and Rilling (1975) made an analogous comparison in which the duration of the S- was held constant at 60 seconds while the duration of the S+ was either three minutes or 60 seconds. The group with the longer S+ showed no behavioral contrast, while the group with the 60 second S+ produced a large increase in rate to the unchanged component. The design of the present study permitted the effect of both S+ and S- duration on the acquisition of the discrimination to be observed. A replication of the results of Wilton and Clemens, Taus and Hearst, and Kodera and Rilling was expected. The groups with the longer S- durations and shorter S+ durations should show higher response rates in the presence of S+ during the acquisition of the discrimilation.

The effect of component duration on inhibition is less easy to predict. Since component duration has not been systematically studied, it is unclear whether it affects behavior as an incentive variable, as an amount of training variable, or in an unique, independent way. Weisman and Litner (1971) and Hearst and Franklin (1977) clearly assumed that the duration of a UCS free interval predicted by a CS should be an incentive variable. This assumption seemed to have been confirmed in the Weisman and Litner study using an aversive reinforcer, but not in the analogous Hearst and Franklin study which used an appetetive UCS.

The effect S+ duration should have on inhibition is even less clear. If the duration of S+ is an incentive variable, and increased exposure and thus increased reinforcement in the prescense of S+ increases incentive, longer S+ durations should increase the amount of inhibition produced by an S-. Rilling (1977) suggested that increases in S+ incentive relative to S- increases the probability of peak shift. Beiderman (1968), however, showed that animals preferred S+ stimuli with which they had had less experience. The present study was designed to eliminate some of these questions.

METHOD

Subjects

Twenty four experimentally naive white Carneaux pigeons were used. The subjects were individually housed in a constantly illuminated colony room with free access to water and grit.

Apparatus

All birds were trained in a two key Lehigh Valley Electronics operant conditioning chamber (LVE model 1519) which was controlled by electromechanical programming equipment located in an adjacent room. The left and center keys were covered, and only the right key was used. During the course of the experiment three stimuli were projected on this key through an Industrial Electronics Engineers in line projector. Two of the stimuli, a green light with a peak wavelength of 555nm and a red light with a peak wavelength of 606nm, were produced through Kodak Wratten gelatin filters #99 and #72B respectively. The third stimulus was a 1/4 inch wide white vertical line which bisected a dark surround.

Reinforcement consisted of 2.5 seconds of access to University Mix grain. During reinforcement presentations the hopper was illuminated by a white light. The chamber was illuminated throughout each session by a 2.25 W. houselight. A ventilating fan provided partial masking of external noise.

Procedure

All birds were first autoshaped using a procedure developed by Brown and Jenkins (1968). The CS+ was a green keylight with a peak wavelength of 555 nm. During autopshaping the interstimulus interval was six seconds, and the intertrial interval was programmed using a constant probability variable interval 30 second schedule developed by Catania and Reynolds (1968).

On the first day after the autoshaped keypeck was consistently established, the S+ was constantly presented and reinforcement was made contingent upon pecking. The first 15 keypecks were continuously reinforced, and the next 30 reinforcements were programmed on a constant probability 15 second variable interval schedule. Thereafter all reinforcements were programmed on a constant probability VI 30 second schedule. Each animal recieved five days of single stimulus training on the VI 30 sec. schedule for 15 minutes each day.

Following the fifth day of single stimulus training, discrimination training was begun. During S+ trials reinforcement continued to be available on the VI 30 second schedule. No reinforcement was available on S- trials. S+ and S- trials alternated, and each animal received 30 S+ and S- trials each day. The S- stimulus during discrimination training was a white vertical line bisecting a dark key. The animals were randomly assigned to four groups. For group 15-15 the duration of both S+ and S- was 15 seconds. Group 15-120 had a 15 second S+ and a 120 second S-. Group 120-15 had a 120 second S+ and a 15 second S-, and for group 120-120 the duration of both S+ and S- was 120 seconds.

Following the last day of discrimination training, each animal again received four days of nondifferential training on the VI 30 second schedule. The stimulus, however, was a red keylight with a peak wavelength of 606 nm. Each training session lasted for 30 minutes.

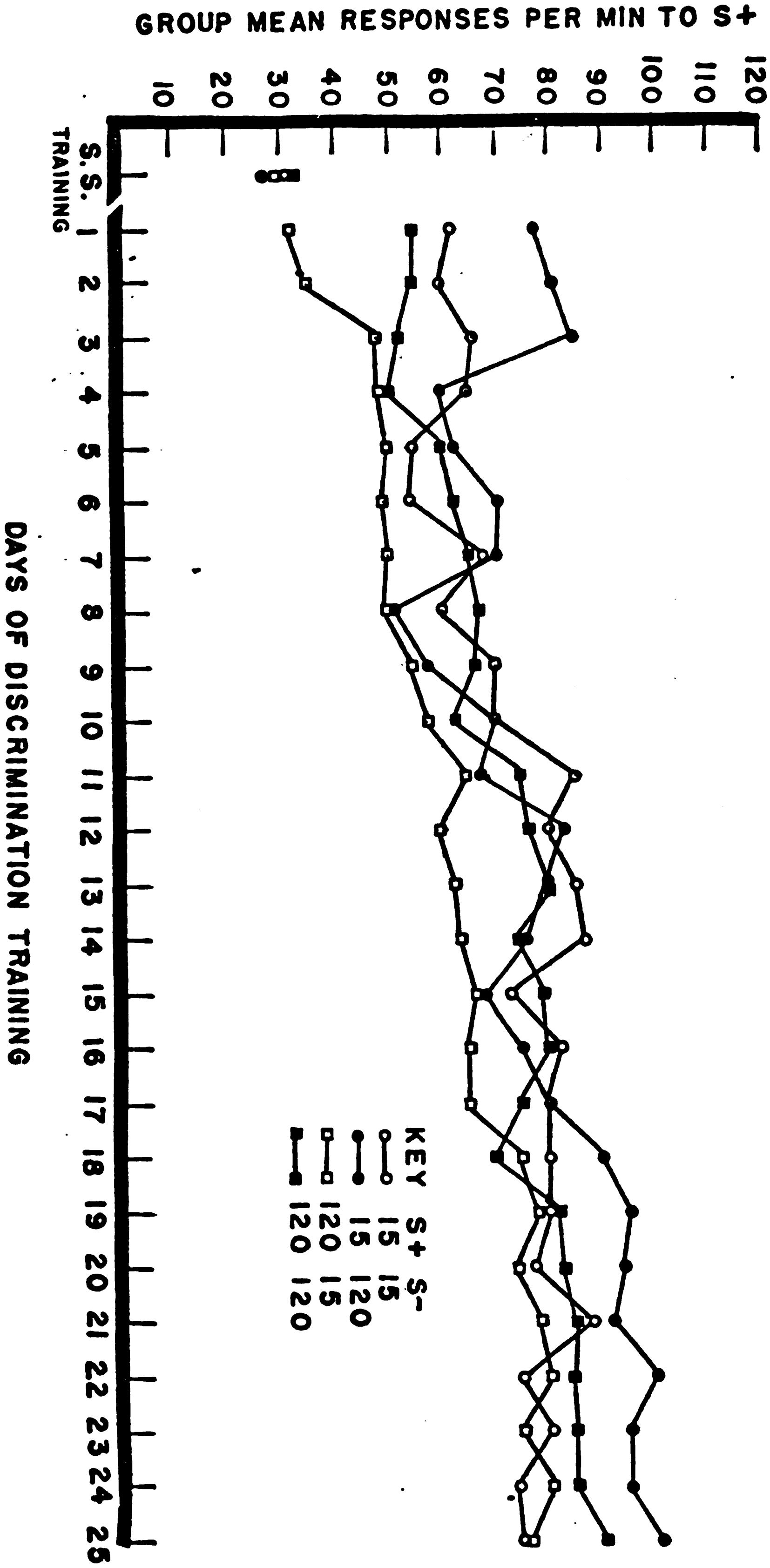
Inhibition testing started after the last day of the second phase of nondifferential training. Inhibition testing started with a nine minute warmup on the VI 30 second schedule with the red key. Following the warmup each of three stimuli were presented three times for 45 seconds each time. The three test stimuli were the S-, the red light, and the S- superimposed on the red light. Following the first nine test stimulus presentations, the animals were reexposed to single stimulus training with the red light for an additional 4.5 minutes. This was followed by nine more test stimulus presentations, another 4.5 minutes of nondifferential reinforcement, and a final nine test stimulus presentations.

The stimuli in each block of test stimulus presentations were ordered in a latin square, with the additional restriction that no test stimulus ever immediately preceded itself. Thus the red light alone was never the first test stimulus in a block of testing. The second inhibition test was exactly the same as the first except that the green training stimulus replaced the red stimulus.

RESULTS

Figure 1 shows mean response rates of the four experimental groups during discrimination training and on the last day of single stimulus training. The response rates for the four groups were approximately equal at the end of single stimulus training, and a one-way analysis of variance found no significant differences between the groups at this stage of training, $F < 1$. Immediately after transfer to the discrimination, however, differences in response rates for the four groups developed. In general, birds with short S+ durations (the birds from groups 15-15 and 15-120) produced higher response rates than the birds with long S+ durations (the birds from groups 120-15 and 120-120). The birds transferred to discrimination training with long S- durations (groups 15-120 and 120-120) also responded at a higher rate than the birds which received training with short S- durations. A 2x2x3 factorial analysis of these data across the first three days of discrimination training showed a significant main effect for S+ duration, $F(1,20) = 5.65$, $p < .05$, but no significant main effect for S-

Figure 1. Group mean response rates produced in the presence of S+ during discrimination training and the last day of single stimulus training. The square symbols represent the groups which were trained with a 120 second S+ during discrimination training, and the circles represent the groups trained with a 15 second S+. The filled symbols represent the groups trained with a 120 second S- during discrimination training, and the open symbols represent the groups trained with a 15 second S-.

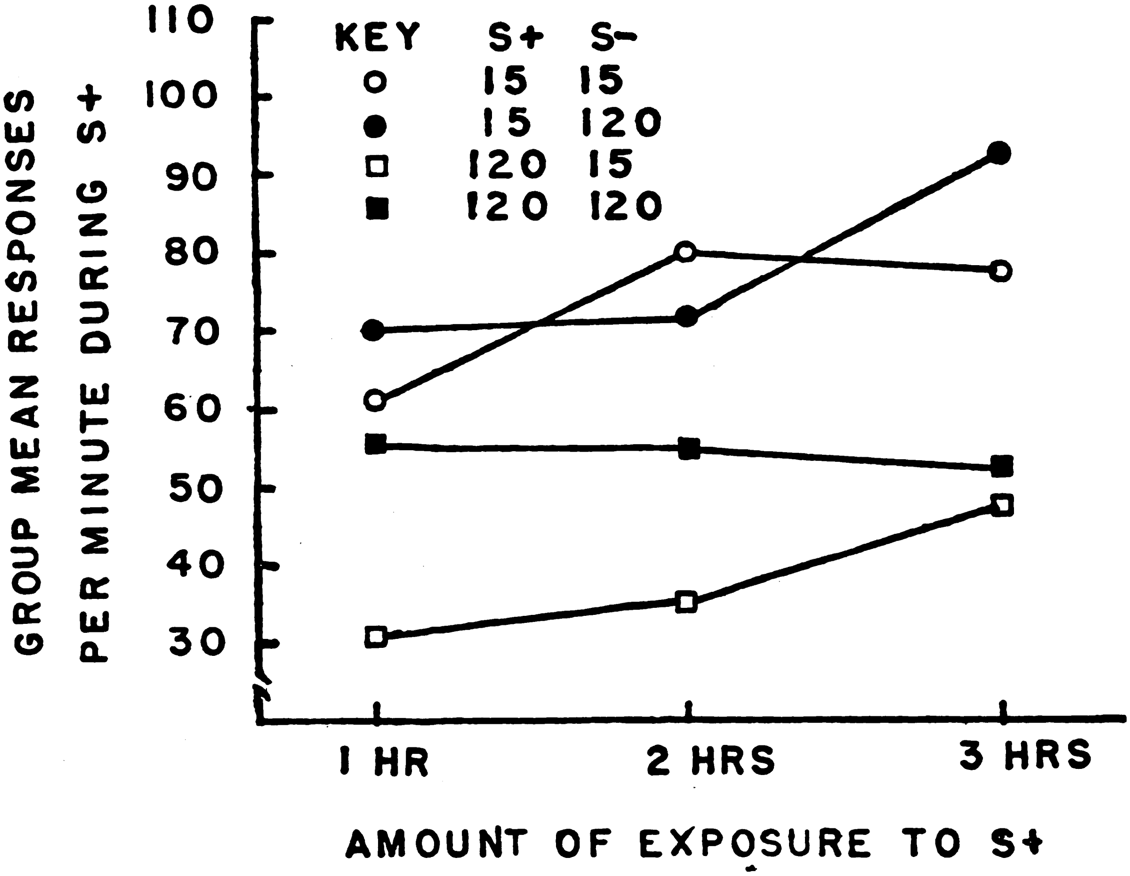

GROUP MEAN RESPONSES PER MIN TO S+
10
20
30
40
50
60
70
80
90
100
110
120
S.S. TRAINING
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
DAYS OF DISCRIMINATION TRAINING
KEY S+ S-
○ 15 15
● 15 120
□ 120 15
■ 120 120

duration, $F(1,20) = 2.64$, $p > .1$.

After the third day of discrimination training these differences in response rate disappeared, with the response rate of group 15-120 decreasing while the response rate of group 120-15 increased. Average response rate over the first 24 days of discrimination training was still highest for group 15-120, followed respectively by groups 15-15, 120-15, and 120-120, but a 2x2x3 factorial analysis of variance performed on these data in blocks of eight days showed no significant main effect for either the duration of S+, $F < 1$, or the duration of S-, $F < 1$. None of the interactions were significant, and the only significant main effect indicated that responses increased across blocks of days, $F(2,40) = 10.40$, $p < .01$.

On each day of discrimination training the birds with the short S+ (groups 15-15 and 15-120) received 7 1/2 minutes of exposure to S+, while the groups with the long S+ received 60 minutes of exposure to S+. The groups with the long S+, therefore, received approximately eight times the amount of daily reinforcement received by the groups trained with the short S+. Figure 2 shows the response rate for each group when the groups were equalized for the amount of exposure to S+. Thus, the first hour of exposure to S+ reflects the first day of training for groups 120-15 and 120-120, but the first eight days of training for groups 15-15 and 15-120. These data indicate higher response rates for the birds trained with the shorter S+. The effect of S- depended upon the level of S+ duration; there was very little difference between the response rates produced by groups 15-15 and 15-120, but group 120-120 produced a higher response rate than group 120-15. A 2x

Figure 2. Group mean response rates to S+ during discrimination training presented for the first, second, and third hour of exposure to S+. For the groups with the 15 second S+, eight days of training were required to produce one hour of exposure to S+. The groups with the 120 second S+ received one hour of exposure to S+ on each day of training. The square symbols represent the groups which were trained with a 120 second S+, and the circles represent the groups trained with a 15 second S+. The filled symbols represent the groups trained with a 120 second S-, and the open symbols represent the groups trained with a 15 second S-.

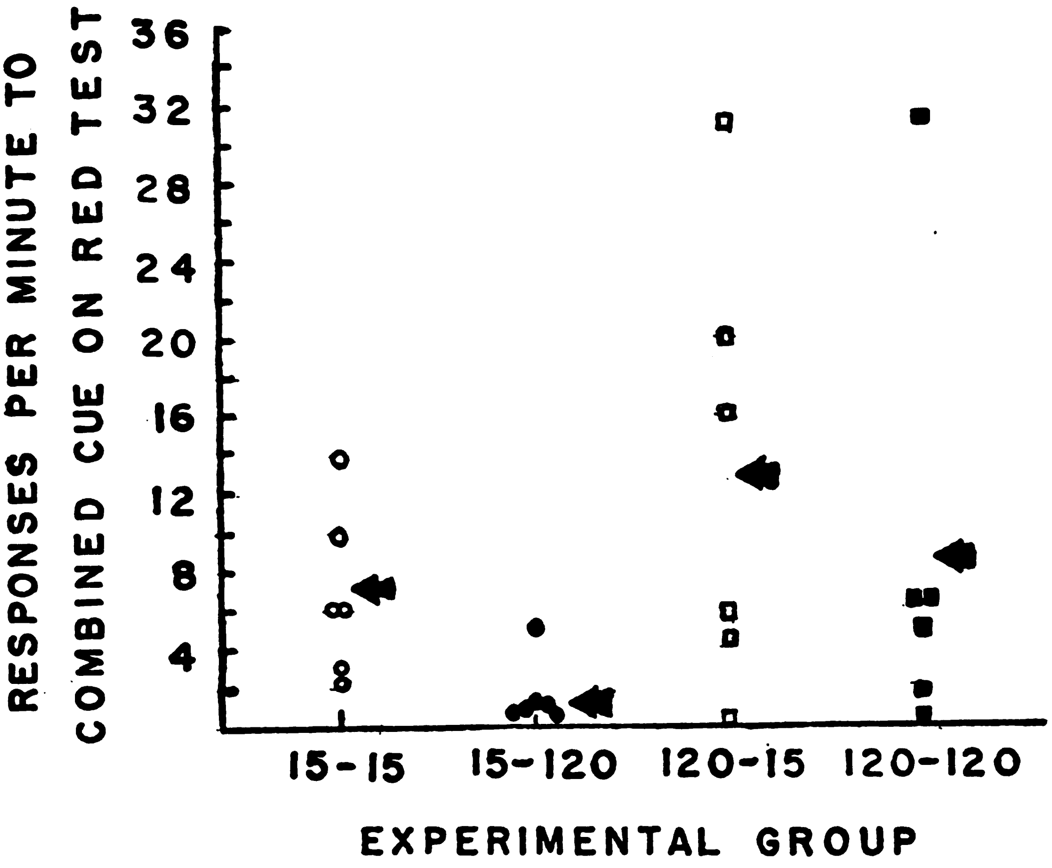

GROUP MEAN RESPONSES PER MINUTE DURING S+
110
100
90
80
70
60
50
40
30
KEY S+ S-
○ 15 15
● 15 120
□ 120 15
■ 120 120
1 HR
2 HRS
3 HRS
AMOUNT OF EXPOSURE TO S+

3x3 factorial analysis of variance performed on these data showed a significant main effect for the duration of S+, $F(1,20) = 4.6$, $p < .05$, but no significant main effect was found for the duration of S-, $F < 1$. Despite the differential effect of S- at the different S+ values shown in figure 2, the S+ x S- interaction was not significant.

Two tests for inhibition were performed after the completion of the 25 days of discrimination training. In the first test, the S- was superimposed on a newly trained S+, a red key. In the second test the S- was superimposed on the original S+, the green key. Figure 3 shows the response rate produced by each bird in each experimental group in the presence of the red key - line angle combination. Solid arrows were also used in this figure to indicate the average response rate for each experimental group. The lowest average response rate to this combination was produced in group 15-120, followed by group 15-15, group 120-120, and finally by group 120-15. Generally, the birds trained with a 15 second S- showed more inhibition than those trained with a 120 second S+, and fewer responses were emitted by the birds trained with a 120 second S- than those trained with a 15 second S-. The difference in the group averages, however, seemed to have been produced by a gradually increased range of response rates rather than by a shift in the response rates of all the birds. Each of the experimental groups had several birds with very low response rates to the combined cue, but the groups differed in the number of birds which produced high reponse rates.

Figure 4 shows the individual and group mean response rates

Figure 3. Individual response rates emitted in the presence of the combined cue during the inhibition test which used the red key as an S+. The circles represent the response rates of the birds trained with a 15 second S+ during discrimination training, while the square symbols respresent the response rates of the birds trained with a 120 second S+. The open symbols represent the birds trained with a 15 second S-, and the filled symbols represent the birds trained with a 120 second S-. The arrows represent the mean response rate produced in the presence of the combined cue for each group.


RESPONSES PER MINUTE TO
COMBINED CUE ON RED TEST
36
32
28
24
20
16
12
8
4
15-15
15-120
120-15
120-120
EXPERIMENTAL GROUP

in the presence of the combined cue in the second test of inhibition. In this test the S- was superimposed on the original S+, a green key. The birds trained with the short S+ again showed fewer responses to the combined cue than the birds trained with the long S+. The effect of S-, however, was different than the effect it showed on the first test of inhibition. The groups trained with the long S- had higher average response rates than the groups trained with a short S-. A single analysis of variance was performed on the two tests of inhibition. The analysis showed only one main effect approaching significance, the effect of S+ duration, F (1,20) = 3.99, .1 > p > .05. No significant effect was found for the duration of S- or for the type of inhibition test used. Despite the reversal of the effect of S- between tests, the S- x test interaction was not significant.

During the inhibition test, response rates to either the red key or the green key alone were measured in extinction. Figure 5 shows the group mean response rates emitted in the presence of the S+ during testing. This figure shows that response rates to the S+ were higher for the groups trained with the 120 second S+ than for the groups which had the 15 second S+ during discrimination training. Separate analyses of variance were performed on the S+ response rate data of the two tests. These analyses showed that the main effect of S+ approached significance in the second inhibition test using the green key, F (1,20) = 3.03, .1 > p > .05, but not for the inhibition test with the red key, F < 1. The effect of S- was not significant in either test, F < 1. Since the only main effect approaching significance in the analysis of response rates to the

Figure 4. Individual response rates emitted in the presence of the combined cue during the inhibition test which used the green key as an S+. The circles represent the response rates of the birds trained with a 15 second S+ during discrimination training, while the square symbols represent the response rates of the birds trained with a 120 second S+. The open symbols represent the birds trained with a 15 second S-, and the filled symbols represent the birds trained with a 120 second S-. The arrows represent the mean response rate produced in the presence of the combined cue for each group.

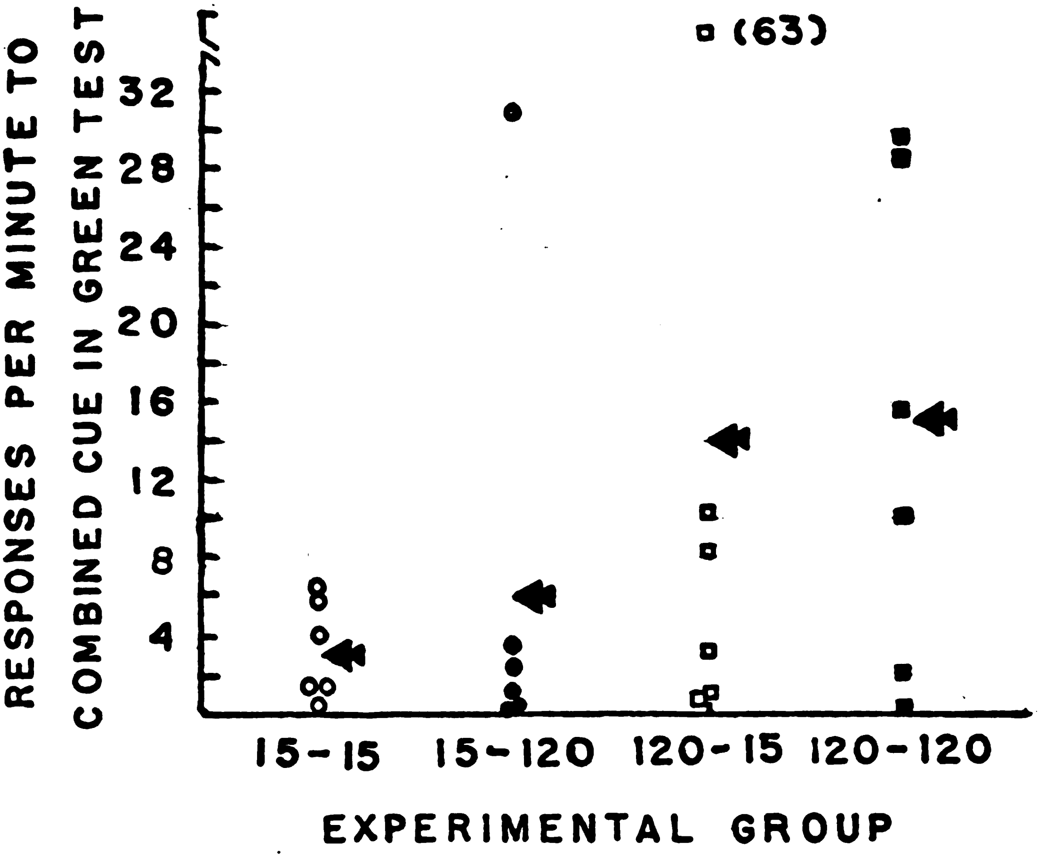
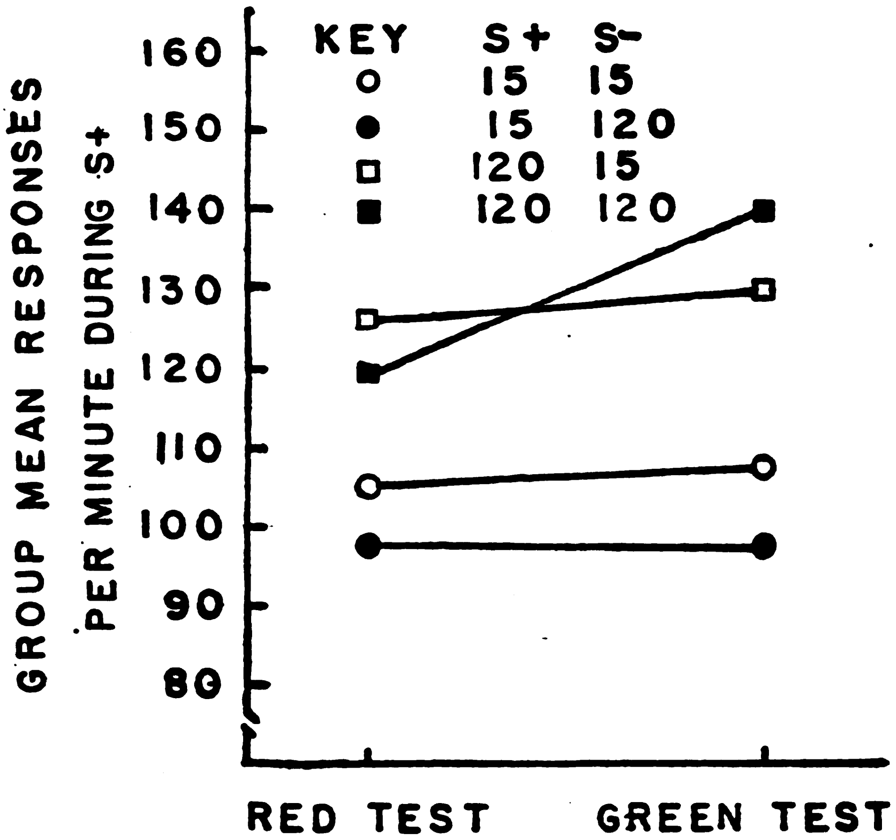

RESPONSES PER MINUTE TO
COMBINED CUE IN GREEN TEST
32
28
24
20
16
12
8
4
(63)
15-15
15-120
120-15
120-120
EXPERIMENTAL GROUP

Figure 5. Group mean response rates produced in the presence of the S+ stimulus when it was presented alone during the two inhibition tests. The data on the left represents response rate in the presence of the red S+ on the first inhibition test. The data on the right represents response rate to the green S+ on the second inhibition test. The square symbols represent the response rates of the groups trained with a 120 second S+ during discrimination training, and the circles represent the mean response rates of the groups trained with a 15 second S+. The filled symbols represent the mean response rates of the groups trained with a 120 second S-, and the open symbols represent the groups trained with a 15 second S-.


GROUP MEAN RESPONSES
PER MINUTE DURING S+
160
150
140
130
120
110
100
90
80
KEY S+ S−
○ 15 15
● 15 120
□ 120 15
■ 120 120
RED TEST
GREEN TEST

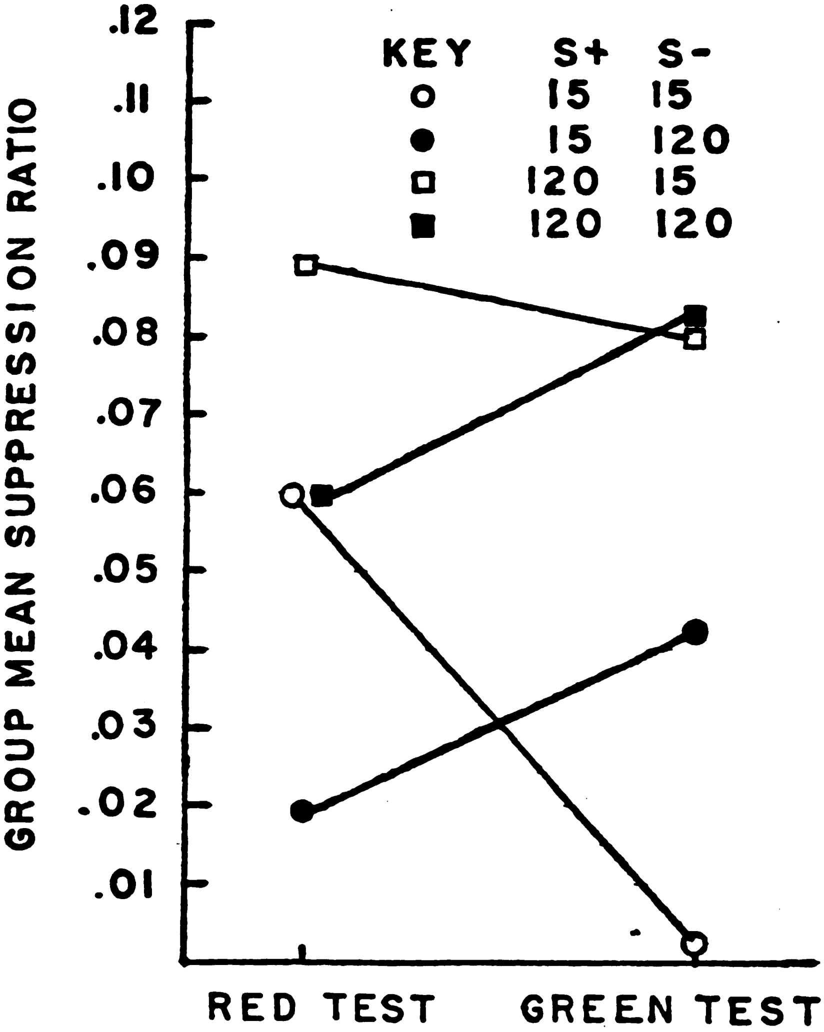
combined cue was also the duration of S+ during training, it was possible that the higher rates shown by the birds in the 120 second S+ groups may have been due to an overall higher tendency to respond.

To attempt to control for this problem, suppression ratios were calculated for these tests in which the total number of responses for each bird during the combined cue stimulus was divided by the number of responses emitted in the presence of the S+ alone. The resulting group mean suppression ratios for the two tests are shown in figure 6. These ratios show the same relationships between groups that were shown in figures 4 and 5. In the inhibition test using the red key, the group showing the most suppression was group 15-120 followed by groups 15-15, 120-120, and 120-15 respectively, In the inhibition test using the green key, group 15-15 showed the most suppression of responding to the combined cue, followed by groups 15-120, 120-120, and 120-15 respectively. An analysis of variance performed on these data showed a main effect for S+ which approached significance, $F(1,20) = 3.03$, $.1 > p > .05$. No significance was found for the effect of S-, or any of the interactions.

DISCUSSION

Immediately after transfer to discrimination training, differences were produced in response rate that were consistent with the results of Kodera and Rilling (1976) and Taus and Hearst's (1970) investigations of behavioral contrast. These studies showed that birds transferred to discrimination training with 15 second S+

Figure 6. Group mean suppression ratios obtained during the two inhibition tests. The suppression ratio was calculated using the formula A / A + B. In this formula A equals the number of responses emitted in the presence of the combined cue, and B equals the number of responses emitted in the presence of the S+ during the inhbition test. The square symbols represent the mean suppression ratios of the groups trained with a 120 second S+, and the circles represent the suppression ratios of the groups trained with a 15 second S+. The open symbols represent the suppression ratios of the groups trained with a 15 second S-, and the filled symbols represent the groups trained with a 120 second S-.


GROUP MEAN SUPPRESSION RATIO
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
KEY S+ S-
○ 15 15
● 15 120
□ 120 15
■ 120 120
RED TEST
GREEN TEST

durations showed a significantly larger increase in response rate than birds transferred to discrimination training with 120 second S+ durations. Birds transferred to discrimination training with 120 second S- durations showed a larger increase in responding than birds transferred to discrimination training with 15 second S-, although these differences were not significant.

The birds failed to maintain these differences in response rate, however, after the third day of training. The major determinant of this phenomenon may have been the equalization of the number of alternations between S+ and S- in the present experiment. Kodera and Rilling (1976) compared response rates to a 3 minute and a 1 minute S+ after equal amounts of exposure to the S+ and found higher response rates in the presence of the 1 minute stumulus. Thus, in the Kodera and Rilling study, the groups with the 1 minute S+ had three times the alternations between S+ and S- as the three minute groups. The present study suggests that the number of alternations between S+ and S- is a more powerful influence on response rate than the amount of reinforcement in the presence of S+. When response rates were compared in the present study after an equal amount of exposure to S+, the groups with longer S+ durations and fewer alternations also showed lower response rates to S+. When alternations were equalized, however, these differences disappeared after the third day of training, so that the graph of daily response rates shows no consistent differences between groups. The data seem to suggest that birds given equal numbers of alternations between S+ and S- learn to respond to S+ equally well, independently of the amount of experience with S+ produced by each alternation.

Alternations between S+ and S- may have had this effect by training the birds to reinitiate responding at the end of S- periods. Early in training, the birds frequently showed delay in responding to the S+. Later in training, however, responding was immediately elicited by the S+. When the number of alternations between S+ and S- are not controlled, birds may be at different points in learning to respond with short latencies to the introduction of the S+. When response rates are averaged, this in turn may produce lower rates of responding in the birds trained with fewer alternations between S+ and S-.

Although Taus and Hearst (1970) reported that longer S- intervals produced more behavioral contrast, no significant effect of S- duration on response rate was ever discovered in the present study. Response rate differences at the very beginning and end of training, however, were consistent with the data reported by Taus and Hearst. The failure to find significant differences in the present study may have been due to the use of a different type of S- than that used by Taus and Hearst. Taus and Hearst used a blackout procedure in which the box was completely darkened during the S- period. This procedure may have produced larger effects on responding to S+ than the traditional discrimination procedure.

Several studies have shown that excitation is dependent upon rate of reinforcement in both the presence and absence of a cue. (c. f. Rescorla, 1968), and that inhibition shows a similar function; increases in the rate of reinforcement in the abscence of a cue, or decreases in the rate of reinforcement in the presence of a cue serve to increase inhibition (Wagner & Rescorla, 1972). It was hypothesized that the present study would show a similar phenomenon. An S- associated with a long absence of the opportunity to earn reinforcement should differ in inhibition from an S- associated with a short period of non-reinforcement. Secondly, this effect should be dependent upon the duration of S+ since this determines the overall amount of opportunity to obtain reinforcement.

The duration of the S+ had a more powerful effect on inhibition than the duration of S-. The groups with the longer S+ durations produced more responding to the combined cue than the groups with the shorter S+ duration. The groups with the longer S+ also show less suppression of responding relative to their rates to S+. lt seems unlikely that this phenomenon was caused by differences in the excitatory strength of S+. The S- was superimposed on two different cues in the inhibitory test. While the birds trained with different S+ durations differed in response rate to the original S+ in the test of inhibition, they did not differ in rate to the newly trained cue. Nevertheless, differences in response rate to the combined cue were found which were independent of the excitatory cue used in the test. Suppression ratios, which include response rate to S+ alone as a baseline against which the reduction in responding produced by the S- is measured, also showed differences in the level of suppression produced by different S+ durations, suggesting that differences in responding to the combined cue were due to differences in inhibition and not in the excitatory strength of S+.

No effect was found for the duration of S- in the inhibitory test. Hearst and Franklin (1977) have also recently published data suggesting that this is not a powerful variable in determining inhibition. Hearst and Franklin used a classical conditioning paradigm in which a CS of a fixed duration signalled UCS-free intervals of different durations. Movement away from the CS was measured during inhibitory conditioning. No difference was found in the amount of withdrawl produced by the different food-free intervals. Generalization gradients of key-pecking were then obtained around the CS's. The gradients differed in absolute number of responses emitted, but not in the slope of the gradient. Hearst and Franklin also concluded that the duration of the UCS-free period predicted by a CS- was not a powerful determinant of inhibition.

The present study showed little effect of the durations of an S- during a discrimination on either the number of responses emitted to the S- during discrimination training, or the amount of inhibition produced in later testing. The duration of S+ had a more powerful effect; with equal amounts of exposure to S+, lower response rates were emitted when this exposure was concentrated in long duration stimuli. This difference dissipated, however, when the number of S+ and S- alternations were equalized. The groups with the longer S+ durations also showed less inhibition around S-.

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