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STIMULUS PREFERENCE IN RATS

By

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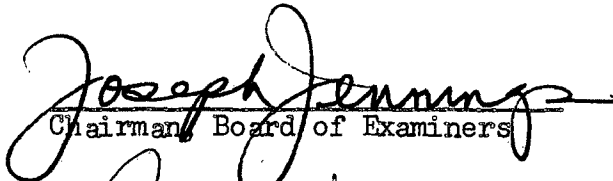
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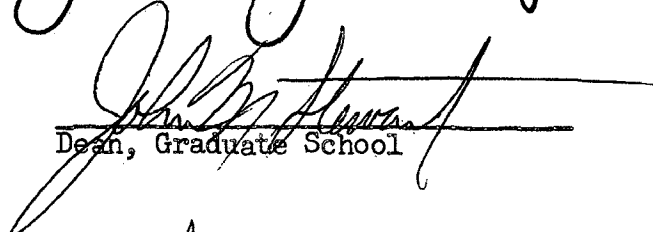
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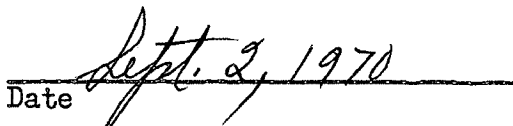
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## CHAPTER I

### INTRODUCTION AND STATEMENT OF PROBLEM

In order for psychologists to ascertain general principles of behavior that may be operating across species not only must a number of different species be carefully analyzed but the behavior of each species must be understood. Ratner (1969) outlines six stages of the comparative method that is aimed at the discovery of these general mechanisms of behavior. He suggested classification of behaviors and identification of variables within each class prior to the identification of general mechanisms. This can only be accomplished through extensive analysis of as many species as possible. Previous attempts to extract these generalities have had dubious results (Bitterman, 1969; Kimble, 1961) due to a paucity of information about the behavior of the species studied. One such species used as the model of behavior by psychologists is the laboratory rat, Rattus norvegicus. The extensive use of this species has been criticized by Lockhard (1968) and Driver and Corning (1968) who contend among other things that the psychologist fails to consider the sensory predispositions of the rat. They reported that most studies which are examinations of various theoretical positions employ situations in which rats are required to learn visual discriminations (Kimble, 1961; Lovejoy, 1968). Since psychologists have investigated the learning ability of the laboratory rat with the use of visual cues, this information must be considered only in relation to the evolved visual capacity of these rodents.

Reports on wild rats by Hediger (1950) and Barnett (1963) indicated that the parent stock of the laboratory rat was nocturnal or crepuscular and depended to a large extent on olfactory stimuli for orientation, maintenance and social behavior. Experimental work on the laboratory rat's use of olfaction has indicated that rats can make very subtle discriminations between different individuals of the same strain (Valenta and Rigby, 1968). Marr and Gardner (1965) reported that early olfactory experience in rats is an important variable in the establishment of effective social behavior in the adult rat. Reviews by Michel, et al. (1960) and Gleason and Reynierse (1969) have also indicated the importance of olfaction in the rat.

From the results of these studies on olfaction in the rat as well as the natural history data it seems quite obvious that an understanding of the rat's learning ability must take into account the rat's use of olfactory information. The methodology outlined by Ratner (1969) would require an analysis of the abilities of the rat under as many different sensory conditions as possible, especially conditions examining those sensory modalities strongly involved in important social behaviors. Since a great volume of data on visual learning in rats already exists, the data on olfactory learning could complement those results for a more effective comparative analysis. However, a comparison must first be made between olfactory and visual stimuli in order to determine the relative dominance of the two modalities in learning situations. This study therefore sought to determine if the rat would make use of one modality more than another when both are relevant as in discrimination problems.



Discrimination studies employing more than one set of relevant discriminable cues were begun by Pavlov (1927) using a classical conditioning paradigm. He trained dogs in a classical conditioning situation with a light and a tone followed by meat powder to the mouth and measured the amount of saliva produced. Upon testing the conditioned response to the individual stimuli, he found stronger conditioning to the visual cue than to the auditory. Pavlov labeled this phenomenon overshadowing, meaning an organism makes use of only one component of a compound in learning a conditioned response. More recent confirmations of this overshadowing effect in classical conditioning have been reported by Baker (1968). Pavlov (1927) as well as later theorists (Lawrence, 1949 ; Lovejoy, 1968) reported that organisms enter a learning situation with a hierarchy of stimulus dimensions. Cues in the dimension higher in this hierarchy will be attended to more often and therefore are more readily learned than cues in a dimension lower in the hierarchy.

Most work with rats on the problem of attention and discrimination has been done with multiple visual cues (Mackintosh, 1965). Results of these studies also indicate that rats will utilize one cue to the exclusion of the other. Babb (1957) while finding this to be the case reported that learning about the less distinct cue was taking place but to a lesser extent than about the more distinct cue. He determined cue distinctiveness by comparing acquisition rates when the component cues were dealt with separately. Recent confirmation of this method of determining the relative distinctiveness of cues was done by Birkiner (1969), who concluded that the stimulus component of a compound that

has the greatest control over responding can be predicted from independent determinations of the rate of learning by the separate stimuli. The studies of Pavlov (1927) and Mackintosh (1965) never matched the cues used in the compound stimulus for distinctiveness to see whether the overshadowing phenomenon was not a methodological artifact. Within a theoretical model such as the one proposed by Lovejoy (1968) one would expect that if the component cues of a compound stimulus were matched for distinctiveness, then an equivalent amount of learning would occur for both cues when tested separately. Lovejoy's model assumes that the rat attends to only one stimulus dimension on each trial. Lovejoy states that organisms are controlled by stimuli within the most distinct stimulus dimensions in the animal's stimulus dimension hierarchy. His model further states that animals learn by remembering which cue controlled his behavior on the previous trial. Reward variables serve to make the relevant dimension more distinctive and increase the probability of attention to that dimension, and if the animal forgets the controller, he must resample and will choose again the more distinctive dimension with higher probability than the less distinct. From this model it would be predicted that compound cue situations would be learned faster than single cue situations with the components of the compound presented separately. This would be the case since the probability of selecting a relevant dimension with compound cues would be the sum of the probabilities of attending to the components separately.

By applying the principles of this model to the problem of determining whether a visual or olfactory cue would be most effectively utilized by a rat in a simple discrimination situation, several

hypotheses were tested. On the basis of Lovejoy's (1968) model it was hypothesized that if odor cues are more important to the rat than brightness, then the rats trained with both odor and brightness cues relevant should perform better on a subsequent test with only the odor cue present than with only the brightness cue. Conversely, if brightness cues are more important than odor, then the rats tested with the brightness component should have higher test scores than those tested with the olfactory component. If both brightness and odor have about the same degree of distinctiveness then test scores for brightness and odor should be about the same. The acquisition rates of two groups of rats, one trained with only brightness relevant, the other with only odor relevant should indicate the relative distinctiveness of the stimuli and predict the test results of the groups trained with compound stimuli. That is, if trials to criterion for the brightness group are significantly lower than for the odor group, then rats trained with compound cues would be expected to have higher test scores for the brightness component than for the odor component and conversely.

## CHAPTER II

### METHOD

#### Subjects

Eighty male hooded rats of the Long-Evans strain were used. A total of 120 Ss were obtained from Simonsen Laboratories in groups of 30 over a five month period. This number was required since approximately one-third of the rats introduced to the apparatus would not enter the alleys.\* Male rats were used because the ovarian cycle may affect the olfactory sensitivity of rats (Elsberg, et al., 1935; LeMagnen, 1950). An analysis of this type with female rats represents a separate problem. While albino and pigmented rats seem to be equal in olfactory ability (Moulton and Eayrs, 1960; Briggs and Duncan, 1962; Jennings and Keefer, 1969), it seemed best to use a pigmented rat because of its better vision (Hermann, 1950). All Ss were between 90 and 100 days of age at the beginning of their training. This age range has been conventional throughout the literature (Sidowski and Lockhard, 1966) and there was no reason not to conform.

All rats were housed separately and maintained on an artificial 24 hour cycle of 12 hours of light then dark. The rats were subjected to this lighting schedule for 14 days prior to the beginning of experimentation so that their activity cycles would be stabilized. Lockhard (1966) suggested an illumination level of one foot-candle as standard

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\* An additional ten Ss were subsequently employed in a follow-up control group.

for work with rats since this value is well below the aversive threshold for both pigmented and albino rats. Therefore, the illumination level in the colony was approximately one foot-candle at the front of the rats' cages during the 12 hour light period. Due to the location of the illumination source there was a gradient from 1.20 foot-candles at the top cages to 0.85 at the bottom cages. Approximately one foot-candle illumination was also maintained in the experimentation area, since Sidowski and Lockhard (1966) stated that rats transferred to a brighter area for experimentation will show a reduction in general activity and conversely rats transferred to a darker area will show increased activity. Additional control over the rats' activity during experimentation was hoped for by running the same subjects at the same time each day.

The rats were maintained on a 23 hour water deprivation schedule with food constantly available. Six days prior to the beginning of training the Ss were placed on this water deprivation schedule with all Ss receiving one hour of water per day. After a shipment of rats arrived, they were handled for five minutes per day to reduce their fear of the experimenter. This was begun 7 days prior to the beginning of training.

### Apparatus

The apparatus was the one used by Jennings and Keefer (1969) with a modification to permit the use of brightness as well as olfactory stimuli (see Appendix A for a detailed description of the apparatus). All surfaces in one set of alleys were unpainted black plastic, while all walls and the floor of the center alley in the other apparatus were

painted with a white latex paint. The floor of one of the remaining alleys of this apparatus was painted black with the same type of paint so that any textural cues that might be associated with the paint could be partialled out. An additional set of alleys was subsequently constructed, having the same dimensions as the others and painted white with latex paint.

The olfactory stimuli used were pure extracts of orange and wintergreen manufactured by McCormack foods and marketed under the brand name of Schilling. These two odorants had been used by Jennings and Keefer (1969) and in a pilot study by this experimenter. All indications were that these odors could be easily detected by rats. There was no noticeable preference or aversion for either of these odors. Each odorant was kept in its own sealable plastic container along with the particular odorant. These plastic containers were stored in a room adjacent to the one in which the Ss were run so that the rats could have no experience with the odors prior to training.

### Design

The 80 Ss were divided into 40 control and 40 experimental Ss. The experimental Ss were supplied with two pair of stimuli; black and white alleys and extracts of orange and wintergreen. The 40 experimental Ss were divided into four groups of 10 Ss each so that all possible combinations of the above cues were rewarded. These Ss were trained to a criterion of two consecutive days of eight or more correct responses in ten trials. The probability of this criterion being reached through chance responding is .006.

On reaching criterion, tests were used to determine the degree to which the Ss utilized the olfactory or visual components in making a discrimination. Each experimental S, trained with the compound cues, was tested with only one pair of cues. In an attempt to equate the degree of experience the Ss had with the discrimination the Ss were assigned to either the brightness pair or the olfactory pair in a counterbalanced manner (ABBA) as they reached criterion. That is, the first S to reach criterion in a training group was assigned to the visual pair while the next two were assigned to the olfactory pair and the fourth to the visual pair again. The test consisted of two days of 10 trials per day with only the visual or the olfactory components present. The four training groups were thus separated into eight testing groups as indicated in Table I.

TABLE I  
DISPOSITION OF EXPERIMENTAL SUBJECTS

Group	Training Stimuli	Testing Stimuli
A 10 <u>Ss</u>	Orange+ WGreen- White + Black -	Orange+ WGreen- 5 <u>Ss</u> White + Black - 5 <u>Ss</u>
B 10 <u>Ss</u>	Orange+ WGreen- Black + White -	Orange+ WGreen- 5 <u>Ss</u> Black + White - 5 <u>Ss</u>
C 10 <u>Ss</u>	WGreen+ Orange- White + Black -	WGreen+ Orange- 5 <u>Ss</u> White + Black - 5 <u>Ss</u>
D 10 <u>Ss</u>	WGreen+ Orange- Black + White -	WGreen+ Orange- 5 <u>Ss</u> Black + White - 5 <u>Ss</u>

The 40 control Ss were divided into four groups of 10 Ss each. Two of these groups were presented only the visual stimuli; one with

TABLE II  
DISPOSITION OF CONTROL SUBJECTS

Group	Training Stimuli	Testing Stimuli
E 10 <u>Ss</u>	Orange+ WGreen-	Orange+ WGreen- 5 <u>Ss</u> Black + White - 5 <u>Ss</u>
F 10 <u>Ss</u>	WGreen+ Orange-	WGreen+ Orange- 5 <u>Ss</u> White + Black - 5 <u>Ss</u>
G 10 <u>Ss</u>	White + Black -	White + Black - 5 <u>Ss</u> Orange+ WGreen- 5 <u>Ss</u>
H 10 <u>Ss</u>	Black + White -	Black + White - 5 <u>Ss</u> WGreen+ Orange- 5 <u>Ss</u>

the white alley rewarded, the other with the black alley rewarded. The other two groups were presented only the olfactory cues; one with orange rewarded, the other with wintergreen rewarded. After each S reached the criterion of eight or more correct responses out of ten for two consecutive days it was assigned to a test condition in the same counter-balanced manner as the experimental Ss. Half the Ss in each group continued training on the original problem while the other half of the group was tested using stimuli from the modality not used during training (see Table II). These test situations were employed for two successive days of ten trials per day.\* No control group was run to determine if the rat could detect the presence of water independent of other cues

\* An additional control group of 10 Ss was trained with an odor discrimination (orange+ wintergreen-) in a set of white alleys and given two test days in a brightness discrimination situation. Half of these Ss were tested with the white alley positive and half with the black alley positive.



because Jennings and Keefer (1969) tested for this and found no such ability.

### Procedure

As the 30 Ss in a training group were received into the laboratory they were arbitrarily assigned to one of the eight training conditions. Each of the Ss was run at the same time each day and after running each S received one hour of free access to water in the home cage.

Step-by-step the procedure for running each S was as follows:

1. Identifying information is entered at the top of a data sheet.
2. Apparatus is wiped clean.
3. Olfactory stimuli are put in place; gun cleaning pads are placed in sink strainers and four drops of odorant are placed on the pad.
4. Exhaust fans are started for all Ss, even those not receiving odors.
5. E obtains the appropriate S in its home cage. The home cage will serve as the retaining cage during the inter-trial-interval (ITI).
6. S in its home cage is placed on a chair about 18" below the apparatus table and the cage is covered.
7. The water cup in the correct choice alley is filled with one cc. of water.
8. S is placed in the start box for 15 seconds before the guillotine door is opened.

9. S is given five minutes to enter an alley, if no choice has been made within this time period the trial is terminated and S returned to the home cage for an ITI of 30 seconds. When the S has walked the length of its body into an alley the guillotine door is lowered and the S remains in the alley for 30 seconds.
10. After the completion of a trial the S is returned to the home cage for an ITI of 30 seconds. During this time the alley (reinforced) position is changed and the water cup refilled if necessary. The position of the reinforcement will be determined by the series recommended by Fellows (1967). This series minimizes the effect of position and alternation behavior in rats.
11. This procedure was repeated for 10 successive trials for each S that will then be returned to the colony and given water for one hour.

All Ss received 10 trials per 24 hours until the criterion of eight or more correct responses in two consecutive days was reached. This sets a criterion which has a probability of 0.006 of occurring by chance. When each experimental S in each of the four groups (see Table I) reached criterion in training it was assigned to a test condition in a counterbalanced manner (ABBA). The A condition means that the S was to be tested on the brightness component alone. For example, a rat trained to orange and white as positive stimuli and black and wintergreen as negative stimuli, under condition A was tested with white positive and black negative and without odors; under the B condition the S would be

tested with orange as the positive cue and wintergreen as the negative and without brightness differences. Two consecutive days of 10 test trials each were run. When a group of 30 Ss finished testing they were destroyed to make room for another group.

## CHAPTER III

### RESULTS

The mean trials to criterion for the experimental and control groups are indicated in Table III and Figure 1. The mean of the experimental groups was significantly below that of the control group ( $t = 2.10$ ,  $df. = 78$ ,  $p < .05$ ). This suggests that redundant information provided the experimental Ss resulted in a more discriminable situation. This would also tend to indicate that experimental Ss were using both sets of cues. Within the control groups there was a trend for rats run to black to reach criterion before those run to white, a trend noted in a previous study using brightness cues (Waller, 1968). A Mann-Whitney U test, however, indicated that the difference was not statistically significant ( $p > .07$ ).

After criterion was reached each rat was assigned to a two day test series as indicated in Tables I and II. These data were analyzed in two separate experimental designs, one for experimental Ss and one for control Ss. The test data from experimental Ss were analyzed in a partially nested design (Winer, 1962). This design had two factors, one visual with white and black reinforced cues nested under it and the other olfactory with orange and wintergreen reinforced cues nested under it. These four test conditions were then divided into day one and day two performance with total correct responses as the dependent variable.

The mean correct responses of the experimental group are indicated in Table IV. The analysis of variance is summarized in Table V and

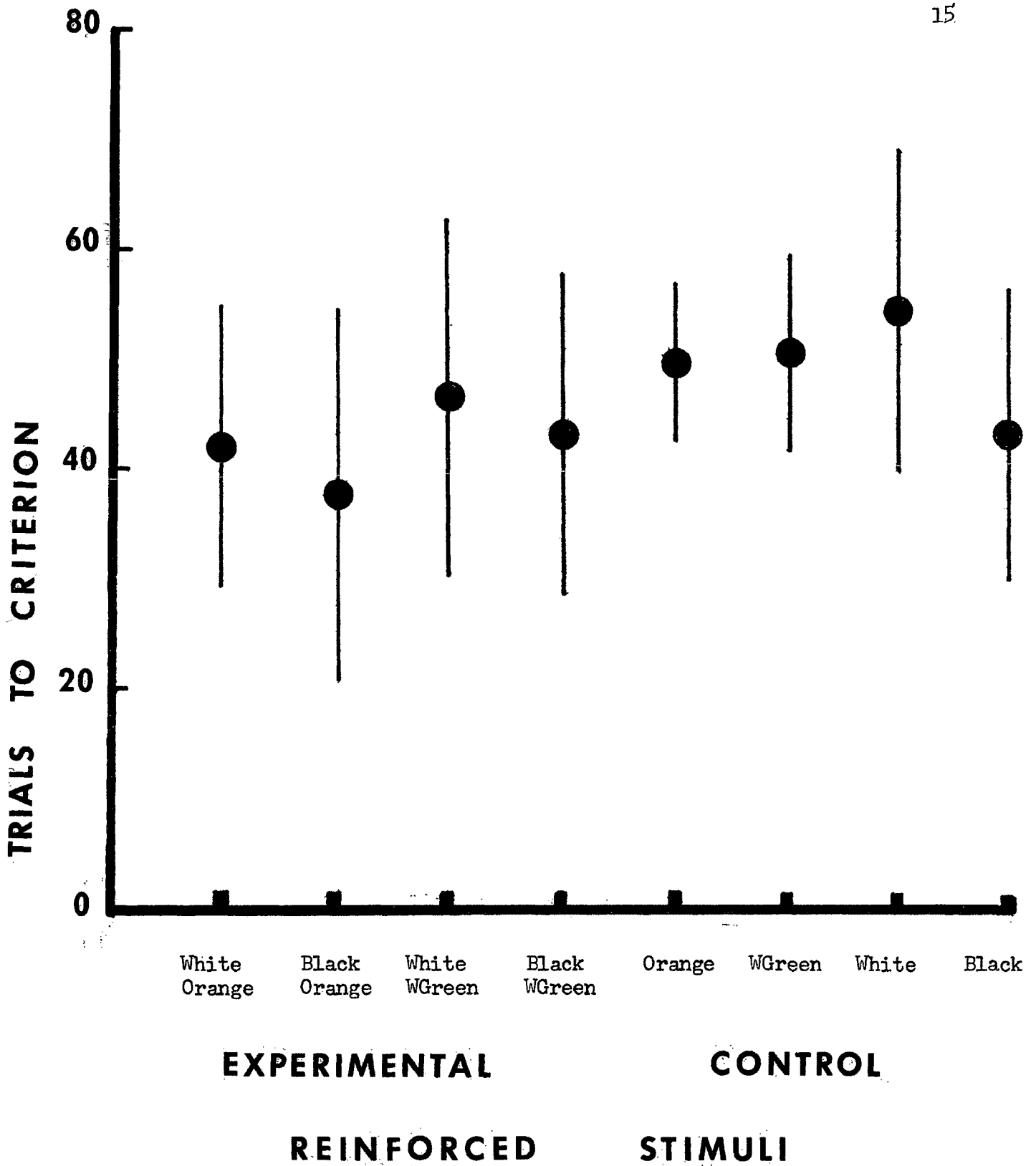


Figure 1. Trials to criterion for both experimental and control groups.  
Mean  $\pm$  1 S.D.

TABLE III  
 MEAN TRIALS TO CRITERION AND STANDARD DEVIATIONS  
 FOR EXPERIMENTAL AND CONTROL GROUPS

Reinforced Stimuli	Experimental				Control			
	Orange White	Orange Black	WGreen White	WGreen Black	Orange	WGreen	White	Black
Mean	42.0	38.0	45.0	43.0	48.0	49.0	55.0	43.0
Standard Deviation	13.2	17.5	17.8	14.9	9.2	11.0	16.5	13.4

TABLE IV  
 MEAN CORRECT RESPONSES DURING DAY 1 AND DAY 2  
 TEST TRIALS WITH EXPERIMENTAL SUBJECTS

Rewarded Cue	Visual Stimuli		Olfactory Stimuli		Mean
	Black	White	Orange	WGreen	
Day 1	7.9	7.5	8.1	7.5	7.7
Day 2	8.1	8.5	8.1	8.2	8.2
Mean	8.0	8.0	8.1	7.8	

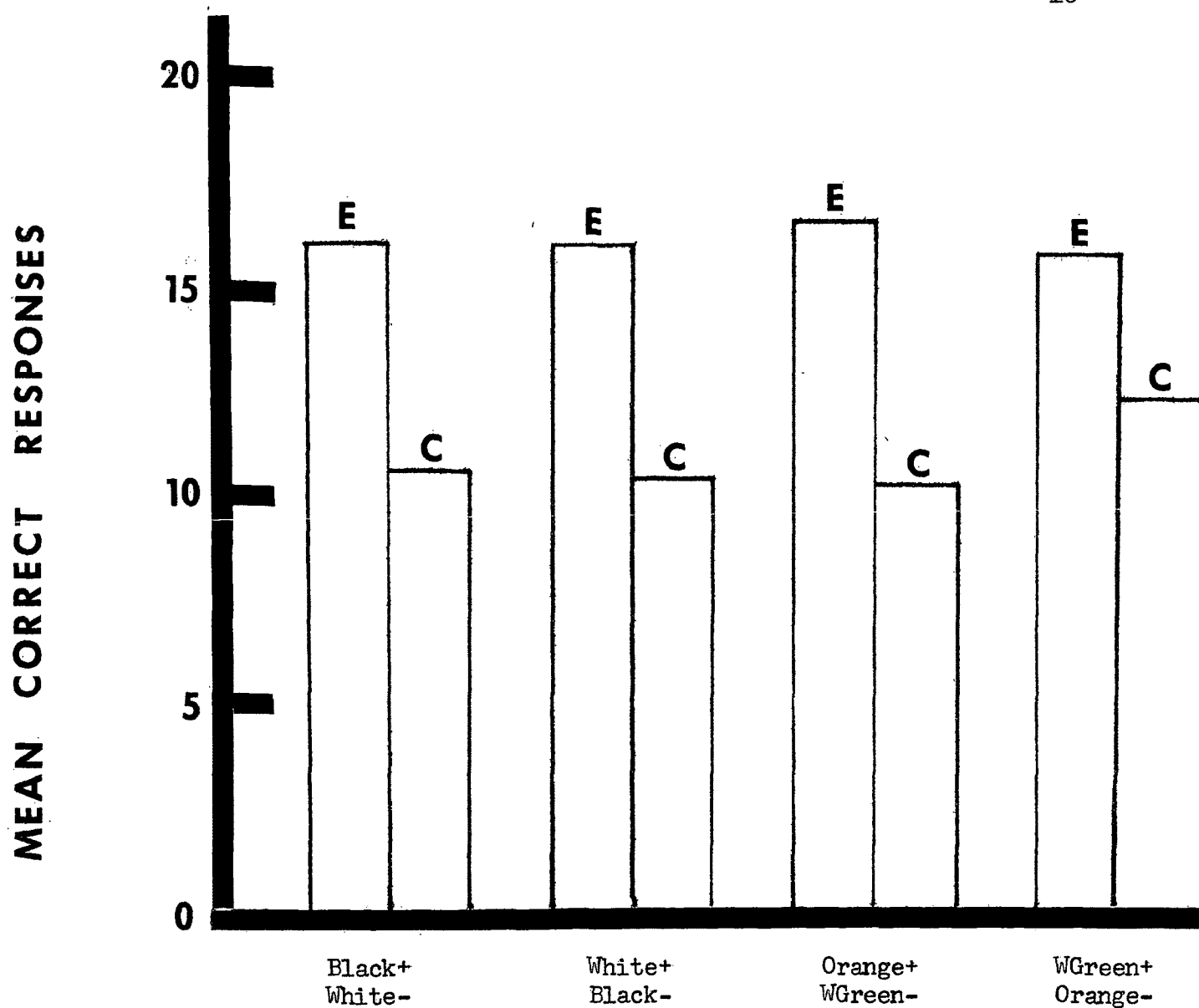
indicates no significant differences between test trials on the brightness and olfactory components. An inverse F ratio was significant ( $F^{-1} = 254$ ,  $df. = 72/1$ ,  $p < .05$ ) indicating a significant degree of equivalence between the test performance of the olfactory and visual modalities. This would suggest that the rats utilized the visual component to the same extent as they utilized the olfactory component in learning the discrimination. This result was reported in the trials to

TABLE V  
 SUMMARY OF EXPERIMENTAL SUBJECTS  
 TEST DATA ANALYSIS OF VARIANCE

Source	SS	df	MS	F	P
Sensory Modality	.01	1	.01	254*	.05
Stimuli within Modality	.6	2	.3	-	
Test Days	4.5	1	4.5	1.77	
Modality X Test Days	4.3	1	4.3	1.69	
Stimuli within Modality X Test Days	2.8	2	1.4	<1.0	
Error	182.7	72	2.54		

\* Inverse F ratio.

criterion analysis where it was found that the Ss supplied with cues from both modalities reached training criterion before those supplied with cues from a single modality. This analysis also indicated no significant differences between the stimuli nested under the modality factor as well as no effect between days of testing. In order to determine if this performance during testing represented a significant superiority over the responding of naive Ss, comparisons were made between control rats' performances on the first two days of training and the test performance of experimental Ss. These comparisons are indicated in Figure 2. For each stimulus situation the differences between experimental group test performances and control group training performance was significant (Mann-Whitney U,  $p < .01$ ) indicating significant retention of both the odor and visual discriminations during testing.



## RELEVANT STIMULI

Figure 2. Comparison of 20 test trials from experimental group (E) and first 20 training trials of the respective control group (C). All differences between experimental and control groups are significant (Mann-Whitney U,  $p < .01$ ).



Since it is apparent that both sets of cues were utilized to about the same degree in learning the discrimination, the Ss may have either learned the two discriminations independently (cf. Liu and Zeiler, 1968) or as a stimulus compound (Spence, 1936; Thomas, 1969). If they learned the discriminations independently there should be no decrement in performance from training to testing, whereas dependence upon the compound would result in a significant decrement in performance during testing since a portion of the stimulus complex was removed. To test this the criterion performance of experimental Ss was compared with their test performance. Since the criterion for learning was two consecutive days of eight or more correct responses out of ten, the total number of correct responses during these two criterion days was compared with the total correct responses during the two days of testing. These data, indicated in Figure 3, were analyzed in a 4 x 2 factorial design (Winer, 1962) and the results are summarized in Table VI. This analysis indicated significantly poorer performance during testing than during criterion responding ( $F = 19.68$ ,  $df. = 1.36$ ,  $p < .001$ ), thus indicating that there was a significant stimulus generalization decrement from the compound to the single cue situation. This again reaffirms the evidence that the Ss in this study were using both sets of cues in learning the discrimination.

The control group test data consisted of the two day performance of those Ss continued on the same discrimination problem presented during training and those Ss shifted to a new stimulus dimension. For the Ss continued on the same problem it was predicted that there would be no reduction in performance during testing. On the basis of previous



Figure 3. Comparison of criterion performance during training (C) and test performance (T) for the four groups of experimental Ss.

TABLE VI  
SUMMARY OF ANALYSIS OF VARIANCE OF EXPERIMENTAL  
SUBJECTS CRITERION AND TEST PERFORMANCE

Source	SS	df	MS	F
Between Subjects	199	39		
Stimulus groups	7	3	2.3	.43
Subjects within Groups	192	36	5.3	
Within Subjects	175	40		
Test vs. Criterion	61	1	61	19.68*
Stimulus Groups X Test vs. Criterion	3	3	1	.33
Test vs. Criterion X Subjects within Groups	111	36	3.1	

\*  $p < .01$ .

work on the acquired distinctiveness of stimuli (Lawrence, 1949) it was predicted that there would be a significant decrement in performance for those Ss faced with a new set of stimuli during testing. The control group test results are indicated in Figure 4. These data were analyzed in  $2 \times 4 \times 2$  factorial design (Winer, 1962) and the results are summarized in Table VII. The analysis of variance indicated a significant difference between the test groups ( $F = 6.12$ ,  $df. = 3/32$ ,  $p < .01$ ) as well as a significant superiority of the Ss continued on the same problem over Ss shifted to a problem in a new modality ( $F = 43.4$ ,  $df. = 1/32$ ,  $p < .001$ ). The interaction between training groups and test problems was also significant ( $F = 4.18$ ,  $df. = 3/32$ ,  $p < .05$ ).

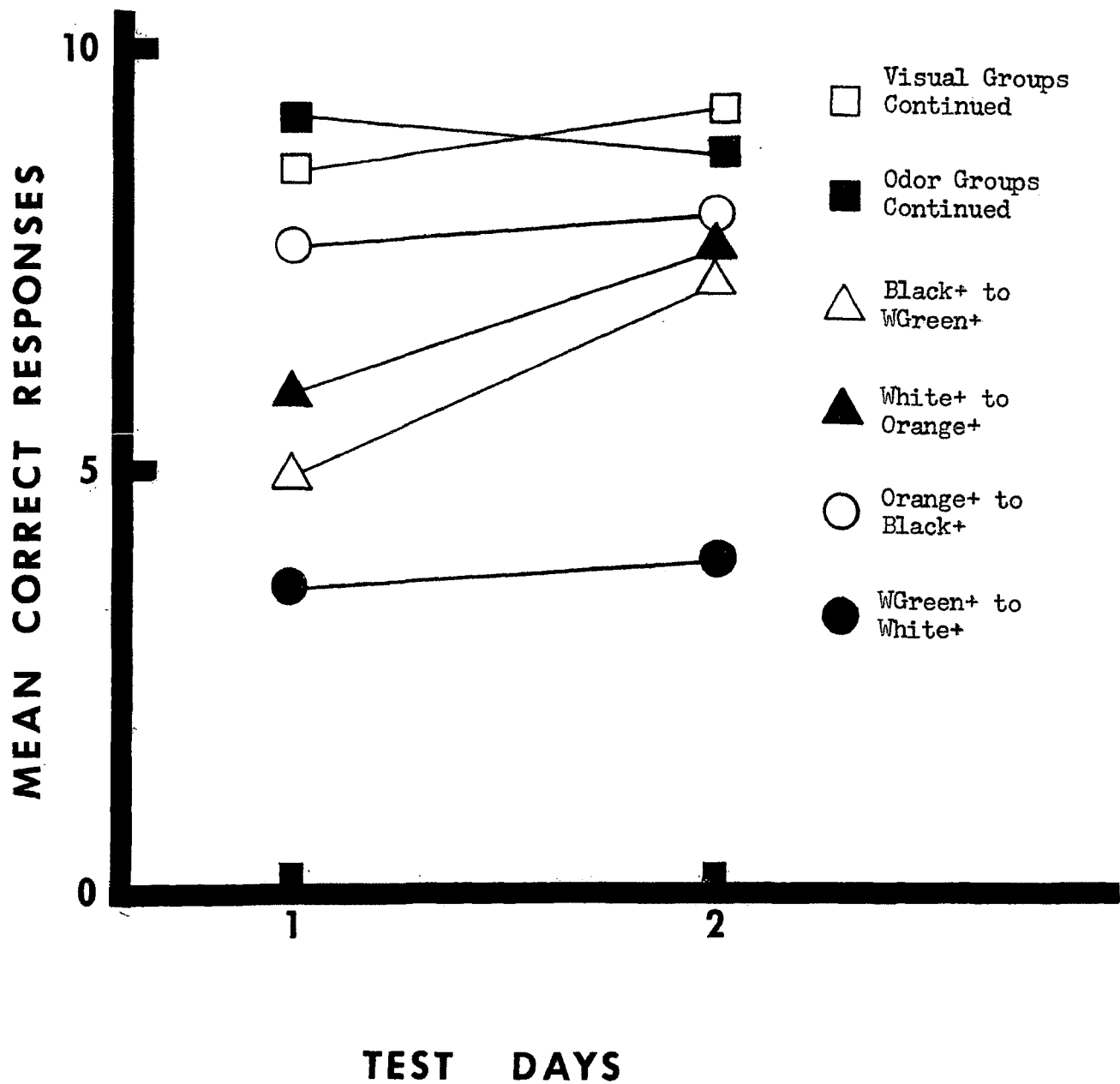


Figure 4. Performance of control Ss shifted to new problems and continued on original training problem during test days.

TABLE VII  
 SUMMARY OF ANALYSIS OF VARIANCE OF CONTROL  
 SUBJECTS TEST PERFORMANCE

Source	SS	df	MS	F
Between Subjects	352.0	39		
A Groups	60.5	3	20.2	6.12*
B Continued vs. Shifted	143.1	1	143.1	43.4**
A X B	41.4	3	13.8	4.18***
Error	107.0	32	3.3	
Within Subjects	71.5	40		
C Days	12.0	1	12.0	8.2*
A X C	7.3	3	2.4	1.64
B X C	3.6	1	3.6	2.47
A X B X C	2.0	3	.7	<1.0
Error	46.6	32	1.5	

\* p &lt; .01

\*\* p &lt; .001

\*\*\* p &lt; .05

The large difference between Ss tested with the same cues used in training and those tested with new cues in a different modality was expected and demonstrates the decremental effect of changing relevant stimulus cues. The remaining results are generally explainable in terms of two factors operating within the groups that were facing new stimuli during testing. Ss trained with odor cues in a totally black apparatus consistently preferred the black alley when subsequently presented a brightness discrimination problem. A Newman Keuls test of the mean

performance across days and conditions for the four groups supported this explanation in that the group trained with wintergreen rewarded performed significantly ( $p < .01$ ) below all but one of the other groups. From Figure 4 it is apparent that this was due primarily to the poor performance of the five Ss that were shifted to the brightness problem and rewarded for going to the white alley. The performance of these Ss may be contrasted with those trained with orange rewarded and tested with black rewarded who performed near criterion ( $\bar{X} = 7.8$ ) on the first day of testing and exceed criterion ( $\bar{X} = 8.2$ ) on the second day of testing. Significant differences between these two groups were obtained ( $Q = 10.2$ ,  $df. = 2/32$ ,  $p < .01$ ). This would suggest that training in the black apparatus resulted in some learning about the brightness dimension without the effect of differential reinforcement of that dimension. In order to determine whether this effect was due to the rats' preference for darker areas (Waller, 1968) or whether it was due to the training in an apparatus with black alleys, a second control group was run with an odor discrimination and white alleys. This group was trained with orange as the rewarded cue and wintergreen as the unrewarded cue in an apparatus having the same black start box but with white alleys instead of black. Half of the 10 Ss were then tested in a brightness discrimination problem with the white alley rewarded and half with the black alley rewarded. The results of these test trials are presented in Figure 5. The data were analyzed in a 2 x 2 factorial design (Winer, 1962) and are summarized in Table 8. The Ss tested with the white alley rewarded performed significantly better ( $F = 26.13$ ,  $df. = 1/8$ ,  $p < .01$ ) than those Ss tested with the black alley rewarded. These results

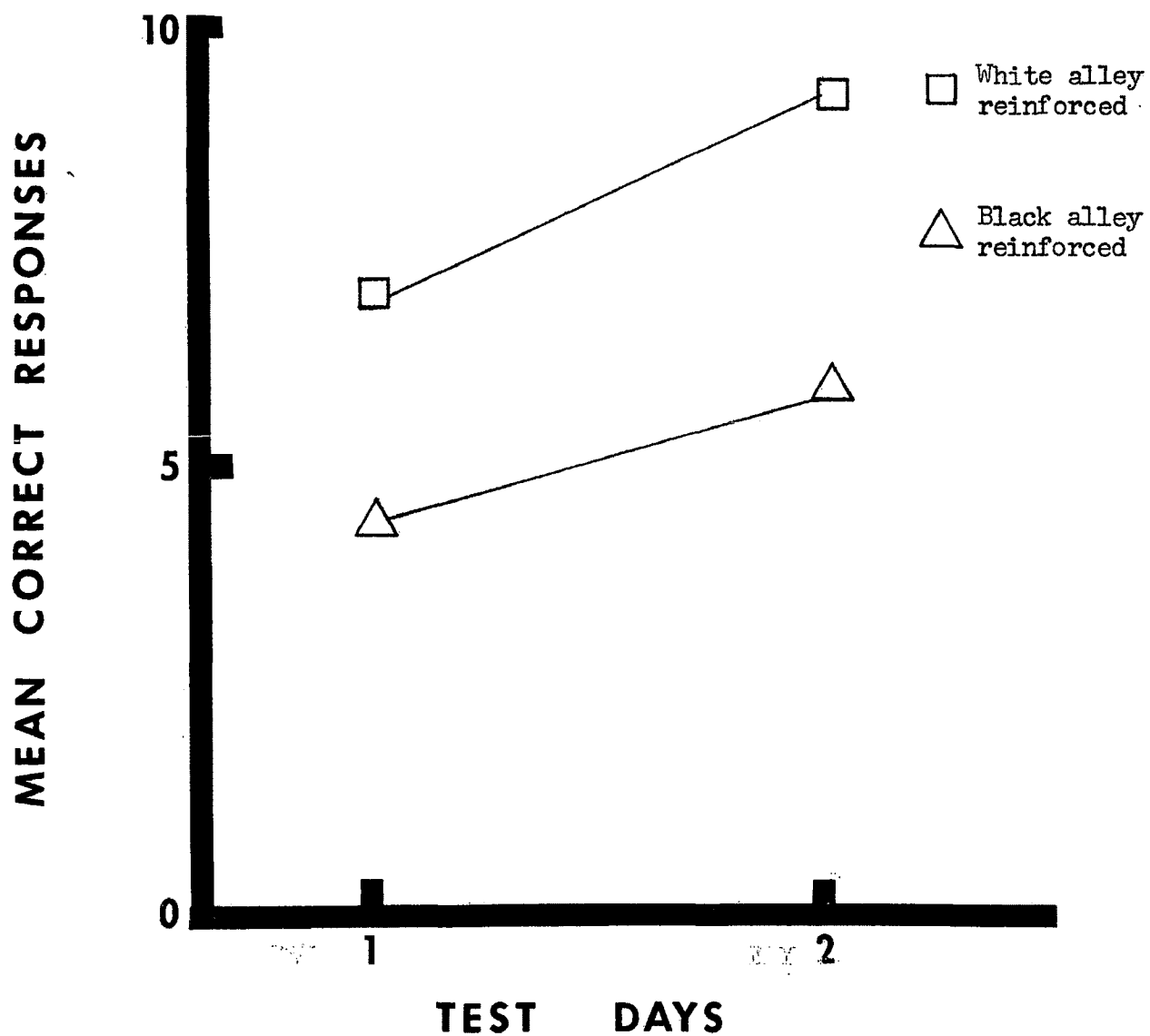


Figure 5. Test performance of control subjects trained with orange positive and wintergreen negative in an apparatus with white alleys and shifted to a brightness discrimination with either the white alley or the black alley reinforced.

TABLE VIII

SUMMARY OF ANALYSIS OF VARIANCE OF CONTROL SUBJECTS TRAINED  
WITH ODOR DISCRIMINATION IN A WHITE APPARATUS AND  
TESTED ON A BRIGHTNESS DISCRIMINATION

Source	SS	df	MS	F
Between Subjects	41.66	9		
A Black vs. White (Rewarded Stimulus)	31.88	1	31.88	26.13*
Subjects within Groups	9.78	8	1.22	
Within Subjects	20.53	10		
B Test Days	15.75	1	15.75	26.25*
A X B	.01	1	.01	<1.00
B X Subjects within Groups	4.77	8	.60	

\*  $p < .01$

confirm the contention that the large difference between Ss tested with white rewarded and black rewarded in the original control group was due to conditioning to the black alleys that were used during training. However, the latter control group trained in white alleys showed a significant ( $F = 26.25$ ,  $df. = 1/8$ ,  $p < .01$ ) improvement across test days which the original control group trained in the black apparatus did not show. In other words, Ss trained in a black apparatus tended to persist in responding to the black alley when presented a choice between black or white, irrespective of which alley contained the reinforcement. This pattern did not change over the two test days. In contrast, the Ss trained in the white alley initially preferred the white alley when given a choice between white and black alleys, but this preference was



beginning to break down by test day two to the extent that a significant test days effect was found (see Table VIII). This differential rate in the extinction of the conditioned preference for an alley of specific brightness may be due to the rats' general preference for darker areas.

Rats trained with brightness cues had no experience with odor cues and when presented those cues in a totally black apparatus, responded at chance level for the first test day but on the second test day they improved greatly. This improvement was sufficient to result in a significant test days effect for the within Ss analysis ( $F = 8.2$ ,  $df. = 1/32$ ),  $p < .01$ ). This result would also account for the significant interaction effect between groups and test problems. The rapid improvement from test day one to test day two suggests that the learning of one discrimination problem tends to facilitate the learning of subsequent problems such that an extra-dimensional learning set may be established.

These results indicate that rats can utilize more than one stimulus component in learning a discrimination. From the results of experimental Ss it is clear that the two relevant pairs of stimuli from different modalities were used as a compound with neither being superior or overshadowing the others as has been suggested with other techniques and stimuli (Mackintosh, 1965; Baker, 1968). The control group results indicate that a stimulus not correlated with reinforcement (black or white alley) can lead to a preference for that stimulus by rats and, furthermore, rats trained on one discrimination demonstrate rapid learning of subsequent discriminations in other modalities as if an intermodal learning set had developed.

## CHAPTER IV

### DISCUSSION

The primary purpose of this study was to ascertain the extent to which rats would utilize either olfactory or brightness cues in learning a discrimination. When these cues were used as compound stimuli in a two choice Grice type discrimination it was predicted that more learning would occur about the cue from the more discriminable stimulus modality. This prediction follows from models of attentional learning theory (Mackintosh, 1965; Lovejoy, 1968), implying that Ss presented more than one set of relevant cues in a discrimination situation will attend to one set only. From data on the natural history of the rat (Barnett, 1963; Gleason and Reynierse, 1969) it was concluded that this prediction should favor the olfactory cue more than the brightness cue, since olfaction appears to be more important than vision in intra-specific communication in rats. From Sutherland's (1964) position it was hypothesized that the "olfactory analyzer" is prepotent to the "visual analyzer." Two experimental tests of this prediction failed to support this hypothesis.

Experimental Ss trained with both olfactory and brightness cues relevant were tested with the components separately and performed equally well with brightness or olfactory cues. Interpreting these results in terms of Lovejoy's (1968) attentional learning theory it must be concluded that the olfactory and brightness components were equally discriminable. Acquisition data from the control groups also

suggested this same conclusion as trials to criterion for the olfactory groups were not significantly different from the brightness groups. Rate of acquisition as a measure of cue discriminability was previously used by Berkimer (1969) who stated that the effectiveness of components of a compound cue situation could be predicted by the relative rate of acquisition of the components presented separately. Thus in two separate measures of the relative discriminability of odor as opposed to brightness cues, there was good agreement that neither was superior to the other. Although Lovejoy's model could handle these results other theories of selective attention could not (Machintosh, 1965; Sutherland, 1964).

#### Interpretation of Experimental Ss Results

A comparison of the trials to criterion between the experimental Ss (those with compound cues present) and the control Ss (those with single cues present) indicated that experimental Ss reached criterion in significantly fewer trials than controls. This result would be predictable from Lovejoy's attentional model since two pairs of equally discriminable cues have a greater probability of being attended to on any particular trial than a single cue. This result would suggest, therefore, that these cues were used in an additive fashion. Further support for this contention comes from the data indicating a stimulus generalization decrement in testing with single modality cues after training with compound cues (Figure 3). Had these Ss not used the relevant cues in an additive manner, that is learned the two discriminations independently, the test performance with single components would have been equal to the criterion performance during training as Liu and

Zeiler (1968) reported.

These results are in direct conflict with the prediction that was made in terms of Sutherland's (1964) stimulus analyzer hypothesis. Sutherland's position assumes that organisms possess stimulus analyzers that act in such a fashion that only one stimulus dimension (i.e., brightness) is attended to and learned about in a discrimination situation. Sutherland, however, based his hypothesis largely upon visual discrimination data from rats, therefore, it may be that within a single modality the information processing mechanisms are such that only certain aspects of the stimulus complex may be learned. This study, however, suggests that the presentation of relevant information to more than one modality will result in the learning of stimulus relations in two dimensions, brightness and odor. Since Sutherland (1964) and Mackintosh (1965) failed to examine intermodal compound stimuli, it may be argued that this study in no way presents conflicting data to their theory. Recent experimental efforts by Thomas (1969) and Thomas et al. (1970) have suggested that even within the visual mode pigeons will utilize more than one component of a stimulus compound. Using an operant paradigm they found that pigeons could develop discrimination simultaneously with both color and line position stimuli. Switalski, Lyons and Thomas (1966) used this technique and found a stimulus generalization decrement during testing of the component stimuli. Thomas (1970) therefore suggested that organisms will attend to all stimuli in a compound stimulus situation and the degree of control exacted by the components will be reflected in the generalization gradients around these stimuli when they are tested separately in extinction. This procedure was developed by Guttman and Kalish (1956).

Aside from the fact that Thomas et al. (1970) employed a very sensitive operant discrimination technique and Sutherland (1964) and Mackintosh (1965) based their theoretical positions on maze or jumping stand data, the main difference between their results appears to rest upon the difference in visual ability between rats and pigeons. This again serves as a reminder of the warning by Driver and Corning (1969) that the sensory predisposition of laboratory Ss must be taken into account when theories are developed concerning the mechanisms of learning.

#### Interpretation of Control Ss Test Results

The test data from control Ss (Figure 4) indicated two specific effects in terms of the utilization of stimulus information by rats. First of all it was apparent that the rats trained with odor cues in an apparatus with black alleys preferred the black alley when tested with brightness cues. A subsequent control group trained with odor cues in an apparatus with white alleys preferred the white alley during a brightness discrimination. This indicated that the results of the original control group was not due to the effect of the black alleys alone or the rats' general preference for darker areas. Thus, although there was no differential reinforcement of the black alley something was learned about the black alley to cause this strong preference. Thomas et al. (1970) reported a similar phenomenon with pigeons trained to make a line position discrimination with the line superimposed upon a green background. When tested on the stimulus generalization around the green stimulus a sharp gradient was obtained, indicating a preference for green over other wavelengths. This same procedure with line

angle as the constant stimulus and wavelength as the discrimination verified the generality of these results. Pate (1967) also found a similar effect when rats were fed in a black box and subsequently tested in a black-white alley brightness discrimination. His Ss consistently preferred the black alley during the choice test. Therefore, the results of Thomas et al. (1970) and Pate (1967) together with the results of the present study clearly indicate that an irrelevant cue may be attended to by rats in the course of learning another discrimination.

Ss in this group displayed a great deal of emotional behavior when transferred from the odor problem to the brightness problem. There was extensive defecation and urination both in the start box and in the alley after the response. Accompanying this behavior were very long response latencies with some Ss taking as long as 5 minutes to make the first response. While there was no systematic or quantified determination of this disruption of responding, it does suggest that the transfer from an odor problem to a brightness problem is stressful for rats. This may also be contrasted with Ss trained with brightness and shifted to the odor problem who did not exhibit any such emotional behavior or greatly increased response latency.

The second significant finding with regard to the test performance of the control Ss was the tendency for those Ss trained with brightness cues and tested with odor cues to significantly improve their performance from test day one to test day two. This trend may be contrasted with the training performance of naive Ss who took an average of four days of training to reach the level of performance that these shifted

Ss reached in two days. According to Lawrence (1949, 1950) training with brightness cues should have made the brightness dimension the more distinctive dimension for these Ss and performance with odor cues should have been retarded until orientation to the brightness dimension had extinguished. The same prediction would have to be made by both Sutherland (1964) and Mackintosh (1965) according to their theoretical positions. Again, however, the research of Thomas (1969) and Thomas et al. (1970) on interdimensional transfer problems offers some insight into the results of the present study. For example, Eck, Noel and Thomas (1969) reported that the learning of one discrimination significantly facilitated the subsequent learning of a discrimination in another dimension. They were again using pigeons with line angle and wavelength discriminations. Based upon those results Thomas (1969) proposed that discrimination training produces "a set to discriminate" or a "general attentiveness" which facilitates differential responding along all stimulus dimensions including those not involved in the training. Thomas et al. (1970) suggested that this "attentiveness" is more general than the intradimensional learning set (Harlow, 1949, 1959). Thomas (1969) made the point that this "general attentiveness" effect is seen during subsequent discriminations that are "orthogonal" or independent of the original discrimination.

Sutherland (1964) and Mackintosh (1965) obtained almost opposite results for interdimensional transfers. This situation may again be attributed to their failure to consider the sensory predisposition of the rat Ss. This may serve as a good example of Driver and Cornings' (1968) warning against developing a theoretical framework around data

obtained from one species, responding to stimuli presented to a single modality, especially when those stimuli were chosen for the experimenter's convenience.

The present study meets Thomas's (1969) criterion for orthogonality only in the case of brightness trained Ss shifted to an odor discrimination. With these Ss the results support the findings of Eck et al. (1969) and extend Thomas's (1969) concept of general attentiveness to intermodal transfer problems as well as contributing to its interspecific validity.

#### Implications of the Study

This study has clearly indicated that rats can use sensory information concurrently from different modalities in learning discriminations. The question of stimulus preference may no longer be considered an all or nothing phenomenon with rats attending only to specific components of a complex array of stimuli. Instead, with the use of intermodal compound stimuli, research should be directed toward the examination of stimulus parameters such as intensity and stimulus complexity. The present study employed quite simple stimuli of equal discriminability and before these results can be generalized they should be replicated with stimuli having different degrees of discriminability. The present results suggest that with this situation the Ss should learn about the less discriminable cue but not to the extent that they learn about the more discriminable cue. An extension of this assumption would predict stimulus control by both cues if overtraining trials were employed. This prediction is contrary to that of Mackintosh (1968) who assumes that overtraining increases attention only to the most discriminable



stimulus dimension.

The results of the control Ss test trials suggest further research with intermodal transfer problems. These should be designed to ascertain whether the positive intermodal transfer effect noted in this study is limited to certain "easily discriminable stimuli" within modalities or whether learning an easy discrimination in one modality will facilitate the learning of a difficult discrimination in another modality.

Finally, the learning of multiple cue relations and the transfer of this learning to other stimulus problems should be investigated with ecologically significant stimuli in order for the results of this study to have any value in a comparative analysis. This ecological analysis should provide parallel results to this study since the learning of multiple cue relations would have a distinct biological advantage in a changing environment. This has been shown by Beach (1956) to be the case with mating behavior in the rat. He found that no single sensory modality was critical for mating and lesions of at least two sensory modalities was necessary to block mating.

## CHAPTER V

### SUMMARY

Hooded rats were trained to a criterion of two successive days of eight or more correct responses out of ten in a two choice Grice type discrimination. They were supplied with a relevant pair of brightness cues (white alley versus black alley) and a relevant pair of olfactory cues (pure extracts of orange and wintergreen). After reaching criterion these Ss were given two successive days of ten test trials per day with half the Ss tested on only the brightness component and half on the olfactory component. In order to determine the relative discriminability of these cues, control groups were trained with either the brightness or the olfactory component alone. These Ss were then given test trials with either the same cues that were used in training or shifted to the cues from the other modality.

Recent research has indicated that olfactory stimuli are quite important in reproductive and maintenance behavior of the rat and that rats are adept at solving various olfactory problems. It was therefore hypothesized that if the olfactory modality truly represented a pre-potent mode of orientation in the rat, then an olfactory cue would be utilized to a greater extent than a visual cue when both are presented concurrently.

The results of experimental Ss test trial performance indicated that the rats had learned both the olfactory and the brightness discrimination and that there was no significant difference between the

performance of the olfactory and the visual groups. There was, however, a significant reduction in performance during the test trials of both groups when these trials were compared with performance at criterion during training. This suggested that there was an additivity effect of the cues used during training with the compound. Since both the olfactory and the visual test groups performed at about the same level it may be assumed that these cues were equally discriminable. This assumption is further supported by the trials to criterion analysis within the control group that indicated that Ss trained with the olfactory cues reached criterion in about the same number of trials as the Ss trained with brightness cues. It is therefore concluded that while the olfactory and visual stimuli employed in this study are equally discriminable the rats had no distinct predisposition to use one cue in preference over the other. The results of control Ss test trials indicated two significant effects: 1) Ss trained with odor cues in a black apparatus preferred the black alley over the white when tested with brightness stimuli, and 2) Ss trained with brightness cues and tested with odor cues responded at chance level during the first test day but improved significantly during the second test day. The first effect suggests that rats are capable of learning about nondifferentially reinforced stimuli during the course of learning a discrimination. The second result was interpreted in terms of a general attentional process that may facilitate successive discriminations with cues from different modalities.

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## APPENDIX



## DESCRIPTION OF APPARATUS

The apparatus consisted of a modification of the Grice Box. Three such apparatuses were used. All side and interior 6 in. high walls, and floors were cut from  $\frac{1}{4}$  in. thick, clear plexiglas. The guillotine door separating the start box from the alleys was made of two aluminum upright channels, a top cross piece of  $\frac{1}{4}$  in. plexiglas and a door of  $\frac{1}{2}$  in. hardware cloth.

The start box was 10 in. deep and  $6\frac{1}{4}$  in. wide. Projecting at right angles to either side of the start box were 3 in. wide panels which served to cover the end of the alley not then facing the start box. This kept the odor in this alley from readily escaping. The clear plexiglas top was piano hinged at the back of the box and at right angles to the plane of the top so the rat could not see the hinges and conversely the hinges hid nothing from our view. The guillotine door was attached to the inside edge of the front or opening of the start box.

The three alleys were 3 in. wide and  $11\frac{3}{4}$  in. deep inside. The three alleys had one lid in common which was also of  $\frac{1}{4}$  in. clear plexiglas and hinged like the lid of the start box. When both lids were closed, they rested on  $\frac{1}{4}$  in. wide and thick strips of plastic foam glued to the top edge of all walls. The weight of the lids and the way they were hinged allowed them to rest evenly on the foam and slightly compress it which helped to form an air seal between the outside air and prevent passage of air between alleys.

The three alleys also shared a common floor. The floor was mounted on two  $\frac{1}{4}$  in. plexiglass runners, which in turn were set in aluminum

channels. For mechanical reasons, the unit with the three alleys slid back and forth rather than the start box. The channels in which it rode were of such a length that sliding the alley unit to either extreme of its travel automatically aligned two alleys with the door of the start box. The start box was raised to a height equal to the alley so their floors were flush.

On the center line of each alley and  $\frac{3}{4}$  in. from the end of each alley, there was a removable water cup. These cups were  $\frac{1}{2}$  in. in diameter and  $\frac{7}{16}$  in. high. They were held in position by a split skirt rivet which protruded through the bottom of the cup and fit snugly into a hole drilled in the floor of the alley. This arrangement made for easy, rapid removal and reinsertion of the cups for drying and cleaning. The cups were of sufficient size so that when loaded with 1 cc. of water by means of a hypodermic syringe, the water level was below the lip of the cup.

Three translucent right angled pipes projected from the end of the alley chamber. Each of these 2 in. O.D.,  $1\frac{3}{4}$  in. I.D. pipes led into the center of the end wall of one of the alleys with the center of the pipe  $1\frac{1}{2}$  in. above the floor of the alley. The rats were prevented from sticking their heads into the pipe as the openings were covered by a Franklin Metal and Rubber Co. Sink Strainer and Crumb Cup made of nylon. The lip of these cups were 2 in. in diameter while the bottom of the cups were  $1\frac{9}{16}$  in. deep. With the cup part projecting into the pipe they were easy to clean, almost chemically inert, well perforated and offered no purchase for a rat's teeth.

The three plexiglas pipes extended horizontally 3 in. beyond the wall of the alleys and then rose  $3\frac{1}{2}$  in. vertically along their longest