

DISCRIMINATIVE ODOR CUES IN THE RUNWAY;
FURTHER VALIDATION AND A METHOD FOR CONTROL

A Thesis
Presented To
the Faculty of the Department of Psychology
University of Houston

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

by
Jim M. Phillips
December, 1971

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ABSTRACT

Twenty-four albino rats were tested in a 5' straight alley on a double alternation pattern of reward and non-reward--a pattern which previous work has shown to be impossible for the rat to perform on the basis of internal cues or memory. During acquisition, the Ss were rotated through their eight daily trials with the order of running reversed each day. The pattern of reward and non-reward was that of RRNNRRNN, where R and N designate rewarded and non-rewarded trials, with all Ss receiving the same goal event on any given trial.

By using an exhaust fan which was mounted beneath the goal box, a continuous stream of air could be drawn through the entire length of the alley to evacuate any odors which might serve as discriminative cues regarding the presence or absence of reward in the goal box. Two groups, "fan" and "odor", were designated on the basis of the availability of odors as defined by whether the exhaust fan was operated for that group.

A total of sixteen days of acquisition were given, consisting of eight trials per day. The "odor" group exhibited appropriate patterning (fast on rewarded trials, slow on non-rewarded trials), whereas the "fan" group showed no such patterning during the sixteen day acquisition period.

Two days of transfer training were given. During transfer, the "odor" and "fan" groups were subdivided into four groups with acquisition and transfer conditions as follows: O-O, O-F, F-O, and F-F. Since the operation of the fan was the only change which occurred in the method during transfer, the stimulus properties of the fan as they affected the subject's behavior could be investigated.

Three days of extinction were given. Days 1 and 2 of extinction were given with the fan operating for all Ss. On day 3, the "odor condition" was introduced for all Ss.

Evidence obtained by a comparison of the data from the conditions of acquisition, transfer, and extinction indicates that, although the initial response to odor is an unconditioned one, if a particular goal event is consistently paired with the presence or absence of odor, the presence or absence of that odor will begin to function as a conditioned S^D for subsequent Ss.

In addition, it was shown that the presence of such odor results in lessened resistance to extinction and a general decrement in running speeds on both rewarded and nonrewarded trials for the "odor" Ss as compared to those Ss for which the use of the exhaust fan precluded odor-mediated discriminations.

Finally, it was determined that the use of an exhaust fan is acceptable as a convenient and effective means of control for this possible source of contamination.

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Chapter I

Introduction

A recurrent problem in the experimental study of behavior is that of the discovery and control of extraneous variables. Treatments given to experimental subjects are generally assumed to have no effect on control group behavior; an assumption which can be violated by faulty design or by ignorance of the variables which influence behavior in a particular experimental setting. The latter case is of interest here.

Recent evidence suggests that the albino rat, in an enclosed apparatus such as the straight alley or any of several types of mazes, often has access to direct sensory information regarding the occurrence of rewarded (R) or nonrewarded (N) trials prior to entering the goal area. These cues have been demonstrated to occur in the form of odors laid down by preceding subjects and, under several rather common experimental designs, can be pervasive enough and persistent enough to influence the responding of subsequent subjects in a manner appropriate to the reinforcement contingencies. The present study represents

an attempt to further validate the occurrence of this phenomenon, to cast some light on the dynamics of its operation, and to specify a satisfactory means of control.

Chapter II

History of the Problem

Several recent investigations (McHose and Ludvigson, 1966; Spear and Spitzner, 1966; Ludvigson and Sytsma, 1967; Valenta and Rigby, 1968; Ludvigson, 1969; Morrison and Ludvigson, 1970; and Seago, Ludvigson and Remley, 1970) have reported the apparent existence of discriminative cues in the form of odors exuded by albino rats following the occurrence of electric shock (Valenta and Rigby, 1968), non-rewarded trials, and possibly, a qualitatively or quantitatively different odor following rewarded trials (Ludvigson, et al.). The existence of such cues, if confirmed, would require a re-evaluation of those past studies which, as a result of the design or the apparatus employed, were susceptible to this possible source of contamination.

In 1965, Surridge and Amsel warned against behaving toward the albino rat "as though this animal can only respond differentially to cues we intentionally provide" without careful consideration of the possibility of extraneous, unintentionally provided discriminanda in the experimental setting (p. 373). The discrimination most often reported thus far--and of primary concern in this study--is the differential responding of the S to rewarded (R) and non-

rewarded (N) trials on the basis of cues not intentionally provided by the experimenter. The possible origin of such cues has been postulated by these authors to be auditory (differential auditory stimulation associated with R or N trials), visual discriminations, temporal discrimination of differential I.T.I.s associated with R or N trials, or olfactory cues contained within the alley itself. Although olfactory discriminations were particularly suspected by Surridge and Amsel in both this and a previous study by Capaldi and Spivey (1964), such cues were believed to have been eliminated by scattering food crumbs along the space beneath the runway. A re-examination of this study suggests that olfactory cues may indeed have been the source of contamination, although of a different nature than that for which a control was instituted.

In 1966 (experiment II), Spear and Spitzner investigated the possibility of extraneous olfactory cues because of a "needling tendency" for control groups not receiving a shift in reward magnitude to behave as did experimental Ss which were receiving differential reinforcement. Although it had not achieved statistical significance in either case, the tendency had been observed in the previous study by Spear and Hill (1965), and in Experiment I of the 1966 Spear and Spitzner study.

The apparatus used in the Spear and Hill study and in all three experiments reported by Spear and Spitzner was a T-maze in which contrast effects between the responses to a less favorable alternative (LFA) and a more favorable alternative (MFA) were compared. "Favorability" was determined by reward magnitude and the response measures were both choice behavior and running speed. The observed tendency for the control group to choose the MFA, although not differentially reinforced, was most noticeable when the majority of the experimental Ss were consistently going to the MFA. The authors labeled the control group behavior "tracking" and suggested that it was due to the discrimination of odors left in the apparatus by the prededing experimental Ss.

In Experiment II of the 1966 series by Spear and Spitzner, the number of Ss which traversed each arm of the T-maze were equated and feces and urine traces were removed after each trial and prior to the test trials of the Ss which received equal rewards in either arm (group 1-1). Differentially reinforced Ss, (group 12-1) which received a twelve to one ratio of food pellets in the MFA over the LFA, were run prior to group 1-1 to establish differential odors to the MFA or LFA. No conclusive evidence for preference by group 1-1 of the MFA over the LFA was found.

It should be noted, however, that the authors emphasized that the conditions for the occurrence of the "tracking" phenomenon were not maximized due to other, concomitant aims of the study. These authors concluded that if equal numbers of preceding Ss traverse each alternative and if fecal material and urine traces are removed, the "tracking" phenomenon does not seriously affect control group behavior.

Although Spear and Spitzner interpreted their negative findings as being damaging to an olfactory hypothesis of extraneous discriminative cues, positive results reported by McHose and Ludvigson (1966) during the same year were viewed as providing tentative support for odor mediated discriminations. These authors were also investigating contrast effects in differential instrumental conditioning, when it became apparent (Experiment I) that differential responding was occurring in the non-differentially reinforced control group. Two parallel alleys, one black, the other white, were used together with a start box which could be attached to either. All Ss were placed on a food deprivation schedule and divided into four groups. Three groups of Ss received the following reinforcement (amounts in pellets/delay in seconds respectively): 1-0, 10-0, and 10-10 in the alley designated S+. The "control" group re-

ceived one pellet after ten seconds delay in both alleys, as did the discriminations Ss in the S- alley. The results of Experiment I showed that control Ss ran significantly faster in the S+ alley than in the S- alley although having received identical rewards in both. In Experiment II, the amount of reward was equalized for both alleys to control for differential amounts of food crumbs, etc., which may have remained in the alley, and only the delay in seconds differentiated the S+ from the S- alley. Again, the control group ran significantly faster in the S+ alley. The faster running by control Ss in the S+ alley was attributed to their discrimination of qualitatively or quantitatively different odors exuded by the differentially reinforced Ss which preceded them. It was also suggested that the "odor trail" left in the S- alley elicited more competing responses than occurred in the S+ alley. Finally, McHose and Ludvigson cautioned that such odors could, if consistently paired with R or N trials, acquire discriminative characteristics for subsequent Ss.

The following year, Ludvigson and Sytsma (1967) reported an experiment which was explicitly addressed to the problem of discriminative odor cues. These authors suggested that an unconditioned response to the odors laid down by previous Ss resulted in the greater latencies reported

by McHose and Ludvigson. However, if such odors were consistently followed by reward (R) or nonreward (N), then conditioned responses to the presence of such odors might be expected to develop, thereby establishing a discriminative cue function to their presence or absence. The design employed was one favorable to the development of differential conditioning to odors while employing a pattern of reinforcement (double alternation of reward and nonreward) which the albino rat is apparently unable to learn (Bloom and Capaldi, 1961). A straight 7' runway was used and the reinforcement pattern followed the sequence of RRNNRRNN where R and N designate rewarded and nonrewarded trials respectively. Two groups were designated group P and group NP. Group P Ss received the same reward schedule as did the S which preceded them in the runway for all eight trials per day. Group NP Ss however, on any given R or N trial, were equally likely to follow either an R or an N trial for the preceding S. Thus, differential conditioning to odors was highly likely for the Ss in group P since reward conditions were consistent for any one trial across that entire group. Differential conditioning for group NP was highly unlikely, since either an R or N trial might accompany the presence or absence of odor in the runway. Before the initial S of any group was run, the alley was swabbed

with a damp sponge to eliminate odors from the previous set of trials.

The results showed strong appropriate patterning to R or N trials in group P and no such patterning in group NP. In addition, a large decrement in resistance to extinction was found for group P, which the authors suggested was due to an accumulation of the "odor associated with nonreward" in the apparatus (p. 284). According to this hypothesis, an external stimulus change additional to the removal of food might account for the more rapid extinction of group P -- a stimulus change which would have been associated equally often with rewarded trials for group NP. Since for group NP the occurrence of an R or an N trial was not consistently paired with an R or an N trial for the preceding S, differential conditioning to odors would not be expected to occur and resistance to extinction would remain at a higher level.

In 1969, Ludvigson extended his earlier findings using essentially the same design as was previously employed in his studies with McHose and with Sytsma. In this study, however, four groups of Ss were used in an attempt to determine the effect of constant vs variable daily schedules of reward and nonreward on odor cue discrimination. The various groups received schedules as follows: group NC received the constant schedule of RRNNRRNN for all Ss on all days; group N

received a schedule of RRNNRRNN on days 1 and 2, and the converse of that on days 3 and 4 in a repetitive four day cycle throughout the study; group R Ss, on any given trial, received the opposite (R or N) condition from that received by the preceding Ss; finally, the group RN schedule was so arranged that the Ss received the same condition as the preceding S 50% of the time and the opposite condition 50% of the time.

As expected, groups N and NC showed a highly significant patterning effect, whereas groups R and RN did not. This work extended the previous studies on discriminative odor cues in two respects: (1) response patterning and the rate of extinction appeared to be greater for group NC (with a constant schedule throughout acquisition) than for group N and (2) no response patterning developed if rewarded trials always followed the nonrewarded trials of the immediately preceding S or the converse arrangement, i.e. response patterning does not occur if each S in rotation receives the opposite goal event than that received by the preceding S. In summary, Ludvigson suggests that contamination by odor effects, although readily produced, can be controlled by careful selection of inter-subject goal event sequences.

To this point in the review of the literature relevant to the function of odors as discriminative cues, the conditioned cue value of such odors had yet to be demonstrated

per se, for, as Morrison and Ludvigson (1970) indicated, an unconditioned "avoidance reaction" to the odor itself, or merely the response to changes in olfactory stimulation could have confounded any conditioned cue function of an "odor of nonreward" in the previous studies. The odor specificity was also an area of uncertainty, i.e. were the odors under consideration those of "reward" or "nonreward" or both.

In order to investigate these considerations, Morrison and Ludvigson (1970) employed a T-maze which would permit response measurement in terms of correct choice behavior rather than the previously used response measures of running speeds or latencies. To establish the odor of reward or nonreward, "odorant subjects" were confined for thirty seconds, with or without food according to the requirements of the following trial, at the choice point of the maze. Following the odor establishment interval, experimental Ss were introduced. Four groups were employed in each of the three replications done. Group RN received the "odor of nonreward" vs the "odor of reward" as defined by the contingency given to the preceding odorant S. Group RC received the "odor of reward" condition vs the "clean" condition in which clean floor paper followed the removal of the odorant S. Group NC received the "odor of nonreward" vs the "clean" condition, and group CC received clean floor paper on all trials. Each S received six trials per day, consisting of three trials under

each condition; the order of which was randomly assigned. The particular odor present (or the lack of odor) signalled the correct choice, right or left, to be made to obtain a food reward.

Both groups (RN & NC) receiving the "odor of nonreward" condition exhibited a "clear, though imperfect, discrimination which increased over trials". Following an A.O.V. performed on the mean number of correct choices, the "odor of non-reward" was found to achieve significance, although the "odor of reward", trials effects, and all interactions did not. These results support the notion that such odors, at least the odor of nonreward, can acquire a discriminative cue function if consistently paired with a particular reinforcement contingency.

In order to determine that olfaction was the basis for the apparent sensory discrimination of rewarded trials from nonrewarded trials, Seago, Ludvigson and Remley (1970) removed the olfactory bulbs and connecting tracts from half of the 36 Ss to be used in their experiment. Of the remaining Ss, half were sham-operated with no tissue removed and half were left as normal controls. In addition, nine of the anosmic Ss were provided a cue light which was lighted on rewarded trials and dark on nonrewarded trials to determine whether discrimination was possible in anosmic rats on the basis of visual cues. Except for the introduction of the

cue light for one of the four groups, the experimental design, the double alternation pattern of reward and nonreward, and the apparatus (a straight runway) were identical to those used by Ludvigson and Sytsma (1967) and by Ludvigson (1969).

The obtained results showed strong appropriate patterning of responses by both normal and sham-operated Ss. As had been reported previously, the effectiveness of odor cues was increased as the S neared the goal area (in run and goal sections) and as the number of previous Ss experiencing the same goal event increased. The anosmic Ss which had access to the light cue did not demonstrate these incremental response characteristics even though appropriate double alternation of slow and fast running did clearly occur. The authors point out that the S^D light is an unchanging stimulus which does not gain in strength as the S approaches or as the number of preceding Ss increases. The accumulation of odors presumably laid down in the goal area would be expected to affect responding in both these ways. Further, the appropriate responding of the anosmic Ss utilizing visual cues demonstrates that post-operative anosmic Ss were capable of performing the discrimination task if cues were available.

An incidental finding which had been reported earlier by Issacson and Moss (1969) and was supported by this study was that anosmic rats were extremely vicious and aggressively hostile. Nine of the sixteen anosmic Ss were "biters"

and by day 2 of acquisition, one such S had to be dropped from the study because of his intractability. A further result concerning the removal of the olfactory bulbs was that such Ss ran considerably faster on both rewarded and non-rewarded trials than did controls. The performance of the anosmic Ss to which the S^D light was available was consistent with this finding under discriminatory conditions also. In view of the changes in tractibility following removal of the olfactory bulbs and tracts, the authors offer two possible explanations for the observed differences in running speeds: (1) the enhancement of running speeds (as well as what might be termed "emotionality") by surgical anosmia, and (2) the possibility that normal S's running speeds are slowed by attending to odors associated with the goal area whether such odors have a discriminative cue function or not.

Southall and Long, in studies published in 1969 and in 1971, have demonstrated that odors can serve as discriminative cues in the acquisition of correct choice behavior in a T-maze, although the odors in these studies were presumably not those exuded by rats.

Wasserman and Jensen (1969) demonstrated the unconditioned response to odors by showing that continuously rewarded Ss would run slower on trials immediately following those of a S which was receiving extinction. This effect was termed "pseudo-extinction" and was attributed to com-

peting responses to runway stimuli versus the odors exuded by rats undergoing extinction trials--an interpretation similar to that of Seago, Ludvigson, and Remley in the study reported earlier.

The experiments reported here represent the recent work which has been done regarding the existence and operation of discriminative odor cues in runway type studies using the albino rat as a subject.

The present study was designed to investigate both the conditioned and unconditioned responses of the Ss to odor cues by manipulating the presence or absence of such cues in the apparatus. Since the odors are assumed to be carried by air, an exhaust fan was mounted beneath the goal box with its intake at the start box. This arrangement should insure complete evacuation of the alley. This method for odor control would have the advantage of being more convenient than methods previously employed, e.g. swabbing the runway or re-covering the walls and floor of the maze with clean paper after each trial, and would allow greater experimental manipulation of the "functional anosmia" which would result if such fans proved to be an acceptable odor control. The ability to transfer a particular S from a "fan" to an "odor" condition, and vice versa, would enable the experimenter to study conditioned and unconditioned effects of such odorants during the conditions of acquisition, transfer, and extinction.

CHAPTER III

METHOD

Subjects

24 naive male rats from the Holtzman Company, Madison, Wisconsin, approximately 120 days old at the start of the experiment, were used as subjects.

Apparatus

The apparatus was an enclosed 5' straight alley consisting of a $17\frac{1}{4}$ " start box, a $25\frac{1}{2}$ " run section, and a $17\frac{1}{4}$ " goal section. The entire apparatus, with the exception of a wire mesh floor and a clear plexiglas top, was painted flat gray. Photocells were placed (measuring from the start box wall) at $4\frac{1}{2}$ " for the beginning of the start section, $17\frac{1}{2}$ " for the beginning of the run section, and $43\frac{1}{2}$ " for the beginning of the goal section. A final photocell at $56\frac{1}{2}$ " terminated the timing devices and allowed a section of the plexiglas top to swing down as a goal box door. A $4\frac{1}{2}$ " 105/115 VAC, 50-60 cps, 7 watt "Whisper-fan" from the Delwyn Company was used to move air from an open space 12" in length beneath the start box. The fan was mounted directly beneath the goal box. To prevent the Ss from seeing the contents of the food cup, a gray metal barrier, rising 2" in height from the floor, was mounted across the end of the goal box between the subject and the food cup.

Procedure

All Ss were placed on a schedule of 23 hr. food deprivation, with ad lib feeding for one hour each day, two weeks prior to the first day of acquisition. During this period they were handled and gentled for approximately five minutes per day. On the final three days before acquisition began, the Ss were given placements of five minutes per day in the goal section of the apparatus with 97 mg. Noyes food pellets present in the food tray. Drinking water was provided ad lib throughout the experiment.

Experimental Design

A double alternation schedule of reinforcement following the daily sequence of RRNNRRNN, where R and N designate rewarded and nonrewarded trials respectively, was used during both acquisition and transfer.

Acquisition. Initially, the Ss were divided into two groups: an "odor" group in which the exhaust fan was not used and such odors as might have been in the apparatus were left undisturbed, and a "fan" group, in which a continuous stream of air was pulled through the entire length of the runway from the start box and exhausted through a fan mounted beneath the goal box. On day 1 of acquisition, the Ss in the "odor" group received their eight trials in rotation, i.e. with each S receiving trial 1 before any S received trial 2, prior to the rotation of the "fan" group through their daily

trials. On alternate days, the order of running the groups was reversed. In changing from the odor to the fan condition, the exhaust fan was allowed to operate for 10 minutes to insure complete evacuation of any odors which might have been present. Since the first S of each group was used to establish the odor cue, his scores were not included in the analyses performed on the data. A total of 16 days of acquisition, with 8 trials per day, was given to both groups.

Transfer. Two days of transfer training were given. The original groups, each with an n of 12, were subdivided into a "fan" and an "odor" group, resulting in four such groups, each with an n of 6. Acquisition and transfer conditions for these groups were as follows: F-F, F-O, O-F, and O-C. The procedures and reinforcement schedule used for transfer trials was identical to that followed during acquisition.

Extinction. During extinction, which consisted of three days at eight trials per day, the fan condition was used concomitantly with the removal of reward for all subjects on the first two days. On day three, the odor condition was used for all Ss along with nonrewarded trials. Otherwise, the procedures were identical to those used during acquisition and transfer.

CHAPTER IV.

RESULTS

Acquisition

An inspection of the response times on day 16, the final day of acquisition, showed clear appropriate double alternation occurring in the "odor" group with Ss running fast on rewarded trials and slow on non-rewarded trials. No evidence of appropriate double alternation was seen at any time in the "fan" group.

For purposes of analysis, the response times were transformed to log (10X) times and the group means are shown in figure 1. This figure reveals that although neither group showed any evidence of double alternation in the start section of the runway, the effect is clearly visible in the run and goal sections for the "odor" group. An inspection of the data for each S showed that all of the Ss in the "odor" group showed double alternation in the goal section, whereas none of the "fan" Ss did. Figure 1 also suggests that the Ss in the "odor" group were running slower on rewarded trials than were the Ss in the "fan" group.

An analysis of variance performed on the rewarded trials for day 16 of acquisition shows significantly slower running speeds in the goal section for the "odor" group as compared to those of the "fan" group ($F= 15.1$, $df\ 1/21$, $p.<.05$).

Finally, figure 1 suggests that the running speeds for the second N trials (N2 and N4) in each pair of nonrewarded trials were slower than the first N trials (N1 and N3) for the "odor" group, although an analysis of these trials proved to be non-significant ($F = 1.91$, $df\ 1/20$, $p > .05$). An inspection of the data suggested that increased variability in the "odor" group responding may have been a factor in the failure to attain significance.

Transfer

The data from transfer is very similar to that from acquisition in that no odor effects were visible in the start section of the runway. Run times and goal times were quite similar with respect to the relationships among groups and the presence or absence of double alternation of responding.

The goal times are presented in figure 2. Response measures for goal times are shown in terms of group means after the individual scores were transformed to $\log(10X)$ times required to complete the goal section of the runway. Note that the Ss in group O-O continued to show appropriate double alternation without exception. Groups O-F, F-O, and F-F failed to show any evidence of double alternation throughout transfer. A comparison of the response times of group O-F during the conditions of acquisition to those of transfer demonstrates the immediate cessation of appropriate patterning when the "fan" condition was introduced at the beginning of

transfer.

For purposes of analysis, a single score was obtained for each S by collapsing over trials on day 1 of transfer. An analysis of variance performed on the goal times for the F-F and O-F groups indicates that response times were significantly slower for the O-F group than for the F-F group ($F = 5.66$, $df\ 1/8$, $p < .05$). Figure 2 also reveals that day 2 was similar to day 1 with the exception that, by day 2 of transfer, this difference in response times appears to have attenuated to some degree.

Note also in figure 2 that for groups O-F, F-O, and F-F there was a tendency to respond on trials following reward by more rapid running and trials following nonreward by slower running. However, on day 2 this effect was not as pronounced as on day 1.

Extinction

Three days of extinction were given. On days 1 and 2, the fan was used for all Ss. The third day was run with the fan off for all Ss. An inspection of the data for start, run, and goal times revealed that the differences seen between the "odor" groups and the "fan" groups for goal times were very similar, though somewhat diminished, in the run section. As was noted in the results for acquisition and transfer, no effects of the "fan" or the "odor" conditions were visible in the data from the start section of the runway.

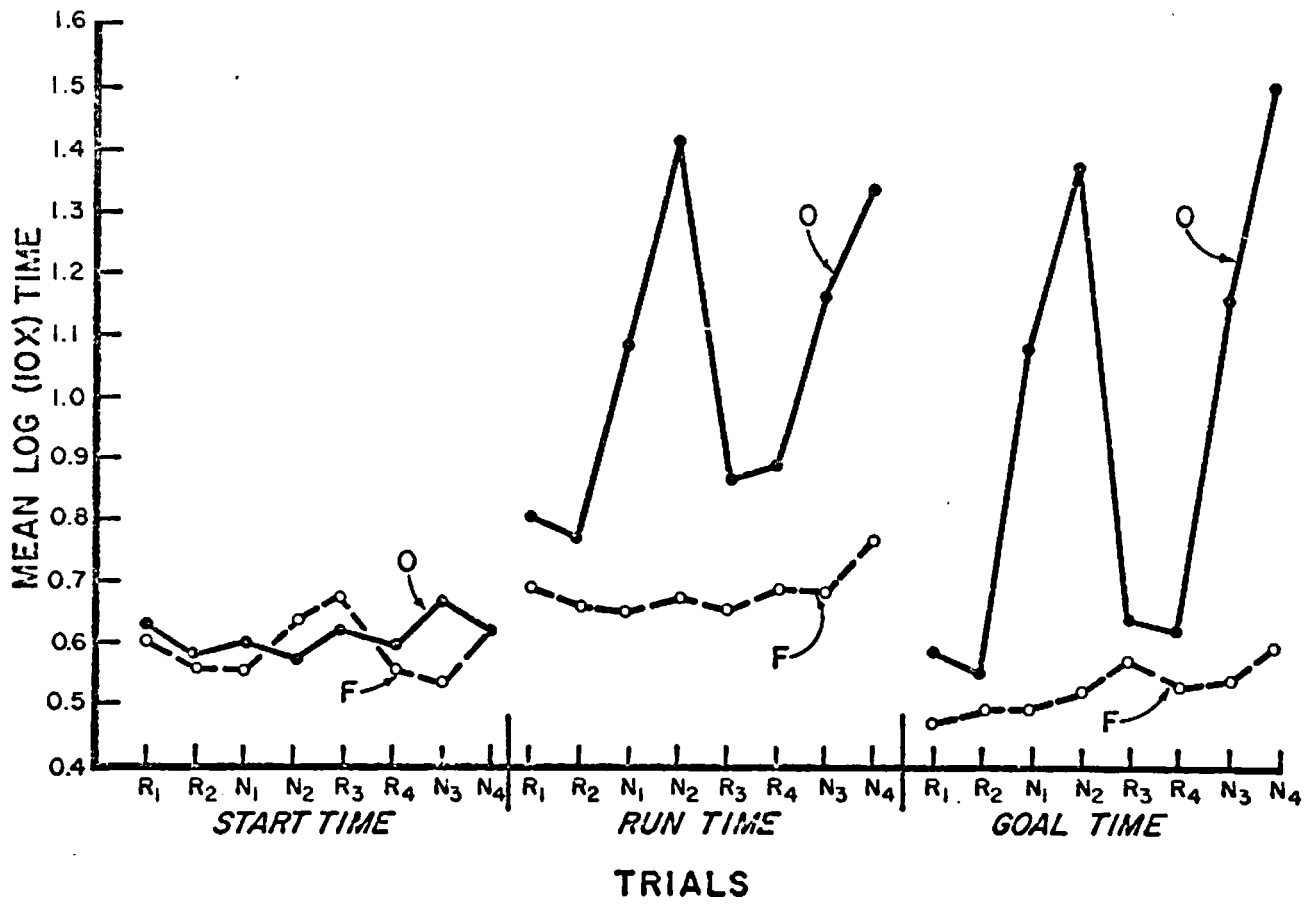
The goal times for extinction are shown in figure 3 in terms of group means of $\log (10X)$ transformations of individual scores. This figure shows that group F-F, which received all trials up to extinction under the "fan" condition, was most resistant to extinction. Group O-O, which received no trials prior to extinction under the "fan" condition was least resistant. The groups which received varying amounts of experience during acquisition and transfer with the fan were intermediate, with group F-O extinguishing more slowly than group O-F. This general trend continued throughout all three days of extinction.

For purposes of analysis, a mean of each S's eight daily trials was calculated, thus yielding a single score for each S per day. Factors in the analysis of variance for goal times were acquisition conditions, transfer conditions, and days. Ss trained during acquisition under the "odor" condition were found to be significantly less resistant to extinction than those receiving acquisition under the "fan" condition ($F = 20.89$, $df\ 1/23$, $p < .01$). The interaction of acquisition conditions by days was also found to be significant ($F = 3.44$, $df\ 2/48$, $p < .05$), indicating that group O extinguished more rapidly over days than did group F.

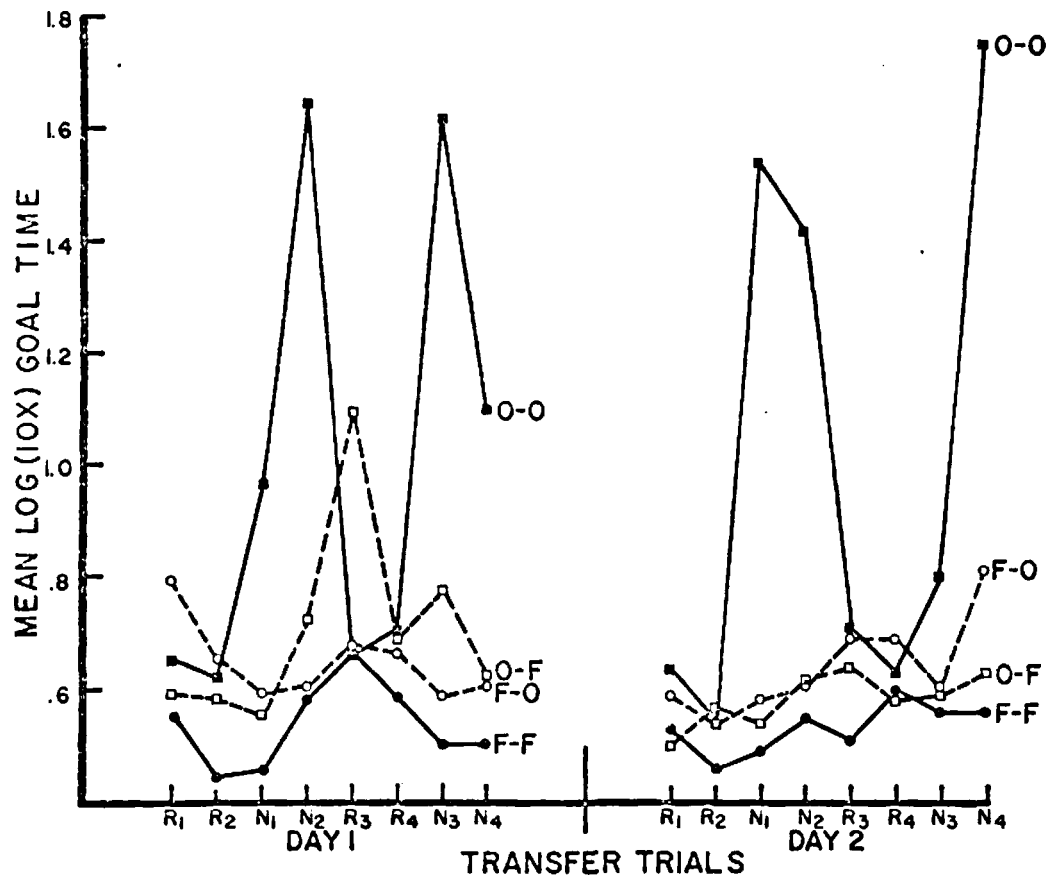
Transfer conditions had no effect on the level of extinction either as a main effect ($F = 1.01$) or in interaction with acquisition conditions ($F = .33$). Nor did the conditions

of transfer affect the rate of extinction in an interaction with days ($F= 1.21$). However, the acquisition conditions by transfer conditions by days interaction approached significance ($F= 2.51$, $df\ 2/40$, $p.>.10$), which reflects the apparent inverse relationship between the amount of odor training throughout acquisition and transfer and resistance to extinction. Note however, that figure 3 shows that the first trial of day three of extinction produced apparent slower responding in the Ss trained in acquisition under the "fan" condition than under the "odor" condition; although this effect was not significant ($F= 2.85$, $df\ 1/22$, $p.>.05$).

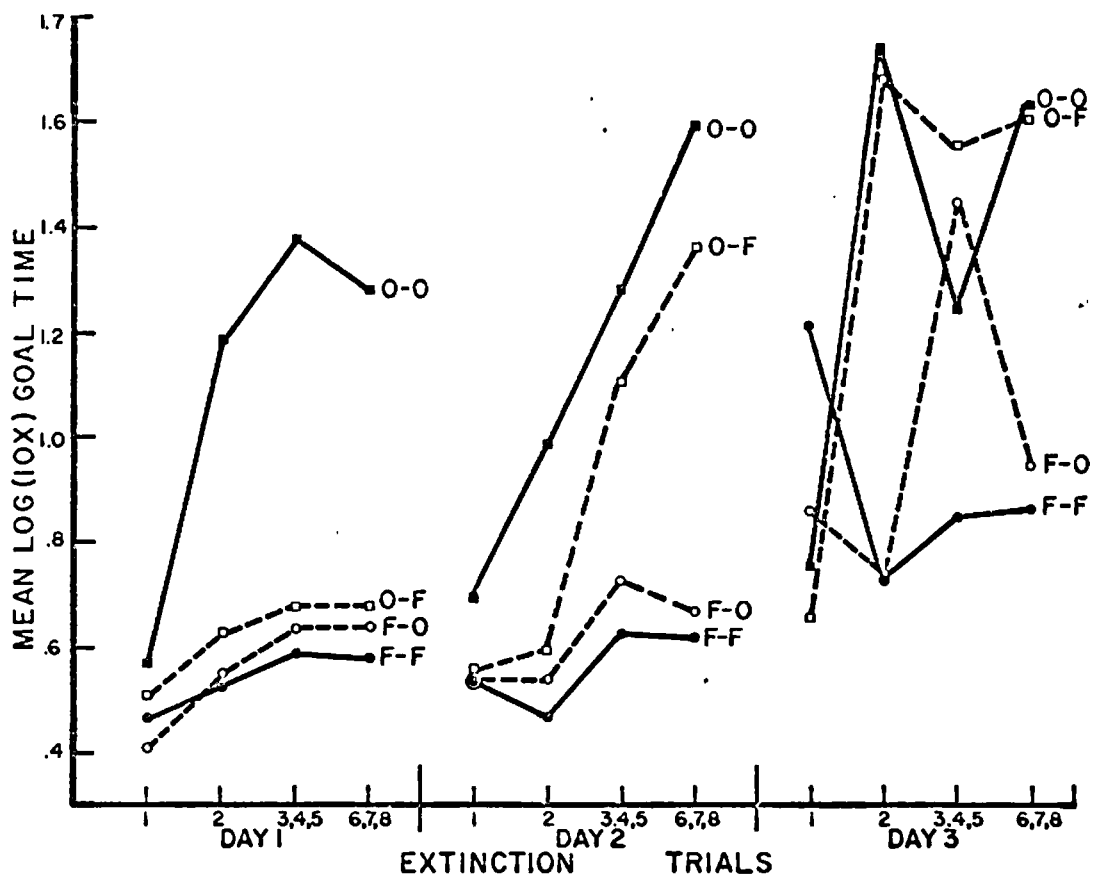
START, RUN, AND GOAL TIMES FOR DAY
SIXTEEN OF ACQUISITION
FIG. 1.



GOAL TIMES FOR DAYS 1 & 2 OF TRANSFER
FIG. 2.



GOAL TIMES FOR DAYS 1, 2, & 3 OF EXTINCTION TRIALS
FIG. 3.



CHAPTER V.

DISCUSSION

The results obtained in the present study support the use of an exhaust fan as a means of control for the presence of discriminative cues in runway type studies. This control was achieved by continuously evacuating from the apparatus the air upon which the odorants are assumed to be carried. In so doing, a condition which may be conceptualized as a "functional anosmia" is created for each S as it is placed in the apparatus. The term "functional anosmia" was chosen since, although the organism retains unimpaired the ability to smell, olfactory stimuli, which in the normal or "odor" group may function as discriminative stimuli signaling R or N trials, are effectively neutralized. These results closely parallel the effects obtained in the study by Seago, Ludvigson, and Remley (1970) in which the olfactory bulbs and the connecting tracts were surgically removed. A comparison of the goal times for the final day of acquisition in both studies reveals that clear appropriate double alternation of responding was present in those subjects to which odors were available. No evidence of appropriate patterning to the double alternation of rewarded and nonrewarded trials appeared at any time in either "functionally" or surgically anosmic subjects.

Both studies also show that the normal subjects ran slower on rewarded as well as non-rewarded trials than those subjects to which odors were not available. In support of the Ludvigson, et al. "olfactory hypothesis" concerning the occurrence of discriminative cues as a result of odors exuded by rats, both studies show what appears to be a cumulative "odor effect" occurring on the second trial of an R or N pair in a double alternation schedule. This effect is inferred from the tendency of normal subjects to respond faster on the second R trial than on the first R trial and slower on the second N trial than on the first N trial. This effect suggests a build-up of odor in the apparatus which occurs over trials.

Another parallel between the behavior of "functionally anosmic" and surgically anosmic subjects can be found in the data from extinction trials in both this study and that of Seago, Ludvigson, and Remley, (1970). Both studies showed that subjects to which odors were available during acquisition ran more slowly throughout extinction than did the anosmic subjects. The differences obtained in extinction in the Seago, et al., study were interpreted as being a result of control exerted by the presence of an "odor of nonreward" for the normal and sham-operated groups, with a light cue controlling the behavior of the anosmic group (group AL). Recall, however, that in the present study, the "fan condi-

tion" was used for all subjects for the first two days of extinction. Therefore, by creating a "functional anosmia" in all subjects, any differences in performance during the first two days of extinction could not have been due to any odors in the apparatus. Yet the fact remains that, throughout extinction, the groups trained during acquisition under the "odor condition" ran significantly slower than those receiving acquisition under the "fan condition".

Several possible explanations can be offered for the differences obtained between normal and "functionally anosmic" subjects in this study. One possible explanation is that the differential responding of the "odor" versus the "fan" groups was due to "stimulus control". Stimulus control here refers to any change in runway stimuli which may effect a consequent change in behavior. Since groups O-O and O-F were trained during acquisition with the fan off, it could be argued that the slower running seen during the first two days of extinction was the result of disruption of responding by the operation of the fan, e.g. through noise, tactile stimulation by the moving air, etc. The stimulus control exerted by the operation of the fan is most clearly revealed by the F-O and O-F groups during transfer trials. These trials show only the effect of activating the fan for odor-trained subjects or the effects of turning off the fan for the fan-trained subjects, since the reward schedule remain-

ed exactly the same. The effects, previously indicated in figure 2, appear to be relatively faster running for those subjects transferred from the "odor condition" to the "fan condition" and slower running for fan-trained subjects transferred to the "odor condition". On the first two days of extinction, the fan was operating for all subjects. If stimulus control were an important factor in determining the response characteristics of group O-O, days 1 and 2 of extinction should show a greater difference with day 3 in response times, i.e. running speeds should be faster. Figure 3 does not substantiate this prediction. By a similar application of the data from transfer for group F-O, day 3 of extinction should show a slowing of running speeds for group F-F. Day 3 of extinction, which is shown in figure 3, reveals such an effect in group F-F on trial 1. Trial 2 of day 3 shows, however, that the effect has disappeared. Thus, the effects of stimulus control during extinction were transitory for both groups and are viewed as being of little consequence to this study. The important finding is that throughout the three day extinction period the subjects trained under the "fan condition" were generally more resistant to extinction than were the odor-trained subjects.

Two other interpretations seem to be more acceptable in explaining the observed differences between the odor-trained and fan-trained groups during extinction. The

possibility exists that the "odor" group exhibited a generalization from the response "running slowly" on N trials to both R trials, during acquisition and transfer, and also to extinction trials. Another possibility is that attending to odors during acquisition, transfer, and extinction was, for the "odor" group, a response which was incompatible with rapid running. The operation of this phenomenon would have reduced running speeds on R trials during acquisition and transfer and on all trials during extinction. It is doubtful that the absence of odor in the apparatus during extinction would have eliminated this "attending response" during the two days of fan trials. The slower running found in the odor-trained groups (O-O and O-F) throughout the study could be due to a combination of these two factors, as the data from acquisition, transfer, and extinction seem to support these interpretations equally well.

While these effects are interesting, recall that the principal purpose of the experiment was to determine whether the use of an exhaust fan is an effective means of controlling discriminative between-trial odors. The data indicate that it is. Several distinct advantages are inherent in the use of an exhaust fan to produce a "functional anosmia" as a control for odor-mediated discriminations. The ability to transfer subjects from an "anosmic" to a normal state simply by turning off the fan, and vice versa, greatly

facilitated the study of odor-mediated discriminations. The immediate cessation of double alternation which occurred during transfer in the O-F group clearly demonstrated the effectiveness of the fan in producing "functional anosmia". The ability to transfer subjects from the "anosmic" condition during acquisition to a normal condition during transfer (group F-O), also demonstrated that the failure of group F-F to double alternate during acquisition was not a performance effect, but a consequence of the fan operating to neutralize odors. If appropriate double alternation were possible without prior conditioning, and if the operation of the fan itself were disruptive to the performance of the task, then appropriate double alternation would be expected immediately during transfer in the F-O group. This was not the case.

An additionally important advantage of the use of an exhaust fan is as a convenient method for odor control in studies which may not be directed toward investigations of odor-mediated discriminations per se. The need for such a control is apparent in those studies using an apparatus or design similar to those described here since conditioning to odor cues would be a powerful source of contamination.

Methods employed in the past to control for odor have been cumbersome, time consuming, or impossible to implement under some experimental designs. Ludvigson and Sytsma,

(1967), swabbed the alley with a damp sponge prior to each trial of the first subject in each group, a total of sixteen times per day. It is possible that such activity merely evacuated the air from the maze, rather than removing odor traces from the walls or floor of the apparatus. Ludvigson (1969) reported that the implications of his results were optimistic for the methodology of runway studies, and that the contamination produced by odor effects could be effectively "neutralized by a judicious sequence of goal events". The method proposed was a goal event sequence in which each subject should receive the opposite condition (R or N) from that received by the immediately preceding subject. This method is limited to those designs in which such a method for control is possible and, even then, would place restrictions on the methodology of such a design.

Another method for odor control is that which was used by Morrison and Ludvigson (1970). In this study, three rolls of paper toweling were mounted on the apparatus, a T-maze, with the paper threaded through slots along the walls and pulled along the maze floor in order to remove odor. Again, such a method for odor control is viewed as being unnecessarily expensive and time-consuming when compared to the use of an exhaust fan.

In view of the data obtained in this study, the use of an exhaust fan to control for discriminative odors in run-

way type studies is seen as an effective and necessary control method. In comparison with previous methods, it is also believed to be inexpensive, convenient, and flexible enough for application to a wide range of experimental designs.

BIBLIOGRAPHY

BIBLIOGRAPHY

- Bloom, J. M., & Capaldi, E. J. The behavior of rats in relation to complex patterns of partial reinforcement. Journal of Comparative and Physiological Psychology, 1961, 54, 261-265.
- Capaldi, E. J., & Spivey, J. E. Stimulus consequences of reinforcement and nonreinforcement: Stimulus traces or memory. Psychonomic Science, 1964, 1, 403-404.
- Douglas, R. J., Issacson, R. L., & Moss, R. L. Olfactory lesions, emotionality, and activity. Physiology and Behavior, 1969, 4, 379-381.
- Ludvigson, H. W. Runway behavior of the rat as a function of intersubject reward contingencies and constancy of daily reward schedule. Psychonomic Science, 1969, 15, 41-43.
- Ludvigson, H. W., & Sytsma, D. The sweet smell of success: Apparent double alternation in the rat. Psychonomic Science, 1967, 9, 283-284.
- McHose, J. H., & Ludvigson, H. W. Differential conditioning with nondifferential reinforcement. Psychonomic Science, 1966, 6, 485-486.
- Morrison, R. R., & Ludvigson, H. W. Discrimination by rats of conspecific odors of reward and nonreward. Science, 1970, 167, 904-905.
- Seago, John D., Ludvigson, H. Wayne, & Remley, N. R. Effects of anosmia on apparent double alternation in the rat. Journal of Comparative and Physiological Psychology, 1970, Vol. 71, No. 3, 435-442.
- Spear, N. E., & Hill, W. F. Adjustment to new reward: Simultaneous- and successive-contrast effects. results reported by Spear & Spitzner, 1966.
- Spear, N. E., & Spitzner, J. H. Characteristics of simultaneous and successive contrast effects of reward magnitude in selective learning. Psychological Monographs: General and Applied, 1966, Vol. 80, No. 10, 1-31.
- Surridge, C. T., & Amsel, A. A "patterning" effect that seems unrelated to after-effects from reward and non-reward. Psychonomic Science, 1965, 3, 373-374.

Southall, Philip F., & Long, Charles J. Odor stimuli, training procedures, and performance in a T-maze. Psychonomic Science, 1971, Vol. 24 (1), 4-6.

Valenta, J. G., & Rigby, M. K. Discrimination of the odor of stressed rats. Science, 1968, 161, 599-601.

Wasserman, Edward A., & Jensen, Donald D. Olfactory stimuli and the "pseudo-extinction" effect. Science, 1969, 166, 1307-1309.