AN ABSTRACT OF THE THESIS OF

Walter C. Janzen for the Master of Science

in Psychology presented on

Title: THE EFFECTS OF THE INTERACTION OF REWARD-

MAGNITUDE CONTRAST AND DELAY OF REINFORCEMENT ON ODOR
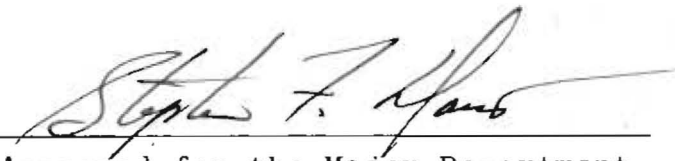
PRODUCTION AND UTILIZATION BY THE RAT

Abstract approved:

Over the past fifteen years a considerable body of re-
search has consistently demonstrated that albino rats exude
odors as a function of experimental manipulations (i.e., re-
ward and nonreward) in a variety of experimental situations,
but especially in the straight runway maze apparatus. The
cumulative findings of this research area indicate that odor
production and/or utilization is not constrained to elicit
only innate responses. Odors can become discriminative
stimuli which affect the behavior of conspecifics when such
experimental measures as the hurdle-jump response, T-maze
responding, escape from a compartment containing odors of

conspecifics, and latency of responding in the straight runway apparatus are employed. A major focus of many of the investigations in this area has been to place the odor phenomena into an adequate theoretical framework. As such, frustration theory has been the most popular theoretical account employed, but this account has not adequately explained all of the relevant data.

The purpose of the present study was to investigate the interaction of reward magnitude contrast and delay of reinforcement as it concerns the odor phenomena. Contrary to initial considerations, the results of the present experiment suggest that entrance into an empty goalbox is neither a sufficient nor necessary condition for the development of patterned responding in the straight runway. Conversely, the results showed that the presence of a single pellet in a goalbox can eliminate patterned responding under certain conditions. The results are discussed in terms of a frustration theory explanation, and possible modifications to that theory which could account for the present results.

Approved for the Major Department

Approved for the Graduate Council

THE EFFECTS OF THE INTERACTION OF REWARD-MAGNITUDE

CONTRAST AND DELAY OF REINFORCEMENT ON ODOR

PRODUCTION AND UTILIZATION BY THE RAT

———————————

A Thesis

Presented to

the Department of Psychology

EMPORIA STATE UNIVERSITY

———————————

In Partial Fulfillment

of the Requirements of the Degree

Master of Science

———————————

by

Walter C. Janzen

June, 1982

ACKNOWLEDGEMENTS

I first wish to acknowledge my graditude and appreciation to Dr. Stephen F. Davis, not only for his guidance, understanding, and patience in the preparation of this thesis, but also for the help and guidance he has extended to me over the past few years. Without a doubt, I consider Dr. Davis the single most important influence in my academic and professional career thus far. Dr. Davis is an excellent scholar and scientist. However, beyond that, he is a great human being. Mere words cannot express my appreciation for all his help and encouragement.

Second, I wish to thank my parents, Henry and Darlenea Janzen, for their love and support over the years. Again, mere words cannot express my feelings adequately. Thank you, Mom and Dad.

Finally, I want to express my love and appreciation for my wife, Vicky. Over the past few years, she has encouraged and supported me in my academic endeavors. Her love and support have been very important in the accomplishment of my goals. Because you are such an important dimension of my life, this thesis is especially dedicated to you, Vicky.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The study of animal behavior in psychology is inextricably intertwined with the rich history of our science. Early functionalistic psychologists who were impressed by the theoretical implications of Darwin's theory of the origin of species were inspired to demonstrate the presence of "mind" in lower organisms and thus, empirically establish the continuity between man and beast. Probably the single most important antecedent to Watson's behaviorism was the development, and initial conclusions, of psychological studies employing animals as subjects. Certainly, the experimental findings of Pavlov were instrumental in the development of Watson's program of behaviorism. However, other early researchers such as E. L. Thorndike, C. Lloyd Morgan, and Robert Yerkes, who employed a wide range of animals such as primates, cats, and chickens as subjects, were undoubtedly also instrumental during the early twentieth century in establishing the study of animal behavior as a legitimate area of psychological research. In 1900 W. S. Small introduced the rat maze, and the white rat and maze bacame standard methods of studying learning processes in psychology (see Shultz, 1975).

1

The albino rat's performance in the maze apparatus has since had a venerable history in the psychological study of learning. Some of the early formal theories of learning, such as those of Hull (1943, 1952) and Tolman (1932, 1938), relied almost exclusively on data generated from studies employing rats as subjects. These early theorists, as well as most contemporary theorists, assumed that the basic learning process is similar for all organisms. Thus, theories derived from the study of the rat's behavior in an apparatus such as the straight runway were assumed to be tenable points of departure toward more complex theories which would account for the complex behaviors displayed by such organisms as homo sapiens. However, as pointed out by Beach (1950), the rat's hardiness, inexpensiveness, ease of rearing, and general adaptiveness to a laboratory existence have effectively resulted in the preclusion of the study of other species over the past few decades.

Beach (1950) also pointed out that in addition to the apparent supremacy of the Norwegian albino rat (Rattus norvegicus) as the paramount subject for animal psychology investigations, psychologists as a group have also limited the topics investigated primarily to studies of conditioning and learning. Beach then discussed some of the advantages and disadvantages of this concentration in approach as it concerned psychological investigation.

This author is in agreement with the opinion of many

that the albino rat is a legitimate subject in the study of
basic learning processes. However, a considerable amount of
research over the past fifteen years has corroborated several
of the implicit implications contained in Beach's (1950)
classic article. For instance, because of the interest of
American psychology in learning, the heavy reliance upon
rats as subjects, and the basic tendency to anthropomorphize
our findings derived from rats, many explicit and/or implic-
it assumptions of various theories may not be tenable. What
I am alluding to is the very real possibility that, in the
historical process of the development of the science of psy-
chology, our intense interest in learning in conjunction with
our desire to discover correlates between rat and human be-
havior may have effectively resulted in years and years of
research employing a subject that has evolved mechanisms of
learning and communication that are possibly quite unique in
comparison to human abilities. Specifically, I am referring
to the role of olfaction as a determinant of a rat's behavior
in a maze apparatus.

Certainly, the hallmark of scientific investigation is
control. When investigating specific subject matter, the sci-
entist attempts to control all relevant variables which could
potentially influence the results of his/her research. As
such, an experimental environment is typically employed to
achieve such control. This is certainly true of the experi-
mental endeavors of psychologists interested in basic learning
processes. However, as already briefly mentioned and implied,

the assumptions that the scientist brings to the animal-psychology experiment may contribute to a basic misunderstanding of the data. The topic of this discussion is an analysis of some fifteen years of research which has shed considerable light on a control problem which had been largely ignored.

Animal psychologists typically assume that the placement of a subject into an experimental environment does not significantly alter that environment or the behavior of subjects subsequently placed into it. However, in 1966 McHose and Ludvigson, and Spear and Spitzner independently found, while studying discrimination learning in albino rats in the straight-runway apparatus, that control subjects which had received the same reward in two discriminanda tended to respond differentially in a manner similar to experimental subjects which had received differential reinforcement. Specifically, McHose and Ludvigson (1966) found, as would be expected, that if experimental subjects had previously experienced a desirable reward in a discriminanda (S+), they consequently ran fast. However, if nondifferentially rewarded control subjects were run in the same runway following these experimental subjects, then they also tended to run fast. Likewise, these same control subjects tended to run slower in the small-reward discriminanda (S-) when following experimental subjects experiencing a contrasting small reward. Certainly, the performance of the control animals was not predicted. As they received the same reward on all trials, they should have displayed non-

differential performance. After ruling out various alternative explanations, McHose and Ludvigson (1966) proposed that experimental subjects had laid down quantitatively and/or qualitatively different odors in the two discriminanda. It was further proposed that these odors had elicited differential responding from the control subjects.

In 1967 Ludvigson and Sytsma reported that they were successful in conditioning albino rats to respond appropriately (fast to reward and slow to nonreward) on a double-alternation (DA) schedule of reward (R) and nonreward (N) in the straight runway. It is interesting to note that Capaldi's (1966) sequential hypothesis had hypothesized that rats were incapable of mastering appropriate responding under this sequence of goal events. However, Ludvigson and Sytsma (1967) were able to condition such responding by maximizing odor cues. Odor maximization was accomplished by employing a homogeneous sequence of goal events on a given trial. A daily eight-trial DA sequence (i.e., RRNNRRNN) was employed with all subjects. All subjects received Trial 1 before any received Trial 2, etc. Thus, all subjects on a given trial experienced either R or N. In this manner any unique R and N odors exuded by subjects traversing the runway had an opportunity to accumulate and acquire discriminative value over the course of the experiment. When this procedure was employed, subjects were able to master appropriate responding. Conversely, when a heterogeneous DA sequence of goal events was employed, odors did not have an opportunity to accumulate

and/or predict the impending goal event, and subjects were unable to master appropriate responding.

Ludvigson and Sytsma (1967) discussed some of the methodological and theoretical implications of their finding. For example, until 1967 there probably were very few, if any, runway extinction studies in which, in addition to the removal of reward, there was not also a corresponding accumulation of odors associated with nonreward. While Ludvigson and Sytsma's data and the subsequent research concerning these findings do not necessarily invalidate all rat-generated research data, such data have, nonetheless, prompted psychologists to reexamine much of it.

Since the publication of the now-classic Ludvigson and Sytsma (1967) study, support for the generality of the "odor hypothesis" has been repeatedly demonstrated. For example, Pratt and Ludvigson (1970) obtained evidence that the latent-extinction effect is partially attributable to responses to residual odors. Pitt, Davis, and Brown (1973) found that patterned responding under a DA schedule of homogeneous goal events could be attenuated when a standard hardware-cloth lid was employed on the runway. This presumably allowed the dissipation of odors from the apparatus. Appropriate responding was established when a solid lid was employed, thereby containing odors within the apparatus. More recently, Taylor and Ludvigson (1980) have reported evidence indicating that odors are exuded on both R and N trials, but that the odors exuded on N trials appear to be more salient. Eslinger

and Ludvigson (1980b) obtained evidence that odor production and utilization is common across sexes in albino rats.

It has further been established that other species produce and utilize odors, and that odors from one species can be used as discriminative stimuli for another species. For example, Davis (1970) was able to replicate the findings of Ludvigson and Sytsma (1967) using albino mice. Dember and Kleinman (1973) found that odor was the only alternation cue in the T-maze apparatus, which under testing conditions, produced significant alternation in gerbils as it did for rats. Davis, Crutchfield, Shaver, and Sullivan (1970) found that homogeneous odors left in a straight runway by gerbils could be used by albino rats to master appropriate DA responding.

In addition to the investigations which have supported the generality of R and N odors, there has been considerable interest concerning the parameters involved in the production and discriminative use of these hypothesized odors. For example, studies by Ludvigson (1969); Seago, Ludvigson, and Remley (1970); and Prytula, Davis, and Fanning (1981) have shown that odors (especially N odors) laid down by animals traversing a runway accumulate and display their most pronounced effect in the goal section of the runway. Moreover, Prytual and Davis (1976) were able to condition DA responding in the start and run sections of a runway apparatus via the placement of "odor donor" subjects in those specific alleyway segments.

Another interesting dimension of this area of research is that the establishment of incongruent deprivation states between "odor donor" (who were placed directly into the apparatus) and "run" subjects (who were allowed to travel the runway) may affect odor production and/or utilization. For example, Davis, Prytula, Harper, Tucker, Lewis, and Flood (1974); and Davis, Prytula, Noble, and Mollenhour (1976) found that "run" subjects were apparently unable to use the odors produced by "odor donors" if the donor and run groups were tested under incongruent deprivation states (i.e., when donors were water deprived and run subjects were food deprived and vice versa). However, when deprivation states were made congruent, (i.e., when the deprivation state of run subjects was shifted to that of donors) appropriate DA responding developed.

These findings would suggest that odor production and/or utilization differs across deprivation states. However, this conclusion is not without a potential interpretation problem. When rats were tested under the different deprivation states, they were also receiving quantitatively and/or qualitatively different reinforcers. Thus, the lack of patterning shown under the conditions cited above could be attributable to reinforcer differences, as opposed to deprivation state differences. A study by Davis and Weaver (Note 1) attempted to test the reinforcer difference hypothesis by employing two groups of rats that experienced identical deprivation states (i.e., food deprivation), but received different reinforcement conditions (i.e., nonreward versus quinine pellets). As the

subjects that received quinine responded in a manner almost identical to those subjects who received nonreward, the results of this particular investigation were interpreted as strengthening the case for the existence of motivationally specific odors.

However, a study by Eslinger and Travis-Neideffer (Note 2) found that if both run and donor subjects were initially conditioned under identical deprivation states, then when deprivation states were made incongruent, the run subject continued to display appropriate patterned responding. This finding suggests that specific deprivation conditions do not pose absolute limits on the discriminative use of odors. Similarly, Eslinger and Ludvigson (1980a) found that rats could learn to utilize R and N odor cues to discriminate opposite goal events (i.e., R odors signaling N, and N odors signaling R), although the subjects in the "opposite" condition were slightly slower to learn the discrimination.

At this point it would appear appropriate to briefly examine some of the theoretical issues attendant to this research area. For example, some investigators (e.g., Ludvigson, Note 3; McNeese & Ludvigson, Note 4) initially considered an alarm pheromone interpretation of the N and R odor phenomenon. Such an interpretation suggests: (1) a distinct biological source of the odor(s); (2) a specific chemical produced in response to some specific environmental condition; and (3) an unlearned escape or withdrawal response as a function of odor/pheromone production. That the

cumulative data of this area poses problems for this hypothesis, as well as others, will become apparent. In a similar vein, the expression "frustration odor" has often been employed (Ludvigson, Note 3) as much for convenience as for suggesting organismic states or causal operations associated with the observed data. Determining whether the accumulated data in this area deserve the designation "frustration odor" is a major goal of this project.

In support of a "frustration" designation, Collerain and Ludvigson (1972) found that experimentally naive albino rats consistently avoided the arm of a T-maze in which odor-donor rats had previously experienced frustrative nonreward. The subjects displayed only indifference toward arms in which donor rats had been rewarded or merely placed without experimental manipulation. The odor-donor subjects were placed directly into the goalbox of the T-maze during reinforced placements before being "frustrated" (i.e., experiencing nonreward). Thus, odor production was apparently not contingent on any substantial instrumental response, except prevention of the act of consumption as a function of the nonoccurence of reward when it was expected. It should be noted that this study found the avoidance response to be short lived, disappearing after twelve-to-sixteen exposures.

Likewise, another T-maze study by Ludvigson (Note 3) found that although the reaction took a few trials to develop, rats initially avoided frustration odor. However, this reaction was short lived. Additionally, this study found that after avoidance declined, there gradually ap-

peared a rather strong and persistent attraction for the odor in most subjects. However, three out of the twelve subjects did not develop a permanent attraction. Instead, there emerged a stable avoidance tendency following a period of apparent conflict. When the odor was then shifted to the other arm of the T-maze the subjects immediately reversed their choices.

Similarly, Mellgren, Fouts, and Martin (1973) found that rats will approach a location in which a previous rat had experienced reward significantly faster than they would escape from that location. The opposite effect was obtained when the location had been previously occupied by a rat undergoing extinction. This study also found that the mere presence of an odor associated with another rat had the effect of producing much slower locomotion as compared to a no-odor condition.

Likewise, Collerain and Ludvigson (1977) found that rats escaped a compartment containing frustration odor faster than controls, although this reaction was short lived. In contrast, subjects escaping from R odors were slower to escape than controls. This study's findings were also useful in addressing an unanswered question from the previous Collerain and Ludvigson (1972) study. The 1977 study produced good evidence that the withdrawal, or escape, response was short lived because recipient subjects habituated to the odor, and not because the donor subjects ceased producing odors.

Investigations have also been conducted in an attempt to specify the chemical nature of the hypothesized odor(s) as

well as its anatomical source. McNeese and Ludvigson (Note 4)
reported that the discriminable odor cue necessary for the
development of patterned responding was not a function of
the preputial gland, nor the androgen dependent accessory
glands. Studies that have employed visible observation of
urine on the apparatus floor as an indication of odor (Eslinger
& Ludvigson, 1980a) and studies that have employed fluorescent-
emissions analysis of the apparatus floor in order to detect
minute, non-visible amounts of urine as an indicator of odor
production (McNeese & Ludvigson, Note 4) have also yielded
negative results.

Although at present the anatomical source of the odor(s)
remains unclear, certain crude inferences are possible re-
guarding its chemical properties based on behavioral studies.
As it concerns the volatility of frustration odor, Ludvigson
(Note 3) reported that it was unclear if odors were exuded
onto the paper flooring (which he employed as both an odor
collection device as well as an odor control procedure) of
the runway and then vaporized into the air and/or possibly
exuded directly into the air. However, the tentative con-
clusion at the time was that the odors were sufficiently
volatile to vaporize from the paper to reach effective be-
havioral concentrations in the apparatus atmosphere in only
a few seconds. As it concerns stability, Ludvigson (Note 3)
employed the T-maze to determine that frustration odor was
behaviorally effective for at least fifteen minutes.

Because much of the evidence indicates that the odors are initially deposited on the apparatus floor, Weaver, Whiteside, Janzen, Moore, and Davis (1982) investigated the possibility that the rat's foot pad sweat gland may be the source of odor-cue production. Contrary to initial considerations, Weaver et al. (1982) found that precluding odors from this source accentuated patterning. Specifically, they found that N-trial speeds were significantly slower when odors from the rat's foot pad were precluded. Although not statistically significant, a slight elevation in R-trial speeds was also observed. These researchers concluded that the rat's foot pad sweat gland was not the source of odor cue production, but rather, it apparently is a source of a natural animal odor which typically serves to partially mask the odors of reward and nonreward.

Voorhees and Remley (1981) have obtained physiological evidence via single cell recordings in the mitral layer of the rat's olfactory bulb that there are quite possibly two specific odors. More specifically, Voorhees and Remley (1981) found that certain individual mitral cells responded differentially to R and N odors, and that this differential responding was distinct from responses to the odors of food and urine. One particular group of mitral cells displayed both excitation and inhibition of firing as a function of which odor (R or N) was presented. That finding suggests that a rat's responses on rewarded trials are not merely a function of the absence of frustration odor. It is also interesting to

note the Voorhees and Remley (1981) found the odors to be quite volatile, as well as chemically stable, as they remained behaviorally effective for at least eight hours when the paper flooring which had been used to collect them from a runway was contained in a sealed glass flask with air passed over it.

In summary, the research discussed up to this point is equivocal and does not permit a simple theoretical analysis. For example, a strict pheromone interpretation has its problems. First, neither the chemical nature nor the anatomical source of the odor(s) has been demonstrated. Second, rats gradually habituate to frustration odor and often even develop an attraction to it (Ludvigson, Note 3). Finally, as demonstrated by Eslinger and Ludvigson (1980a), R and N odors appear to be olfactory stimuli which are not constrained to signal only "pre-wired" responses.

On the other hand, it would seem apparent that rats do produce odors as a function of experimental R and N manipulations. Amsel's (1958) frustration theory proposes that primary frustration results whenever non-reinforcement is experienced in the presence of stimuli previously assoicated with reinforcement. Research stimulated by this theory is hardly new to the literature, and, as may have already become apparent, many investigators have interpreted the results of the many odor investigations in terms of this theory. For example, Daly (1972) has shown that the hurdle-jump is a sensitive measure of the quantity of frustration elicited

by nonreward. The hurdle-jump response has been shown
(Collerain, 1978) to be a sensitive measure of changes in
the production of "frustration odor." Additionally, the ob-
servation (Collerain, 1978) that several prior rewards were
required before nonreward resulted in the production of an N
odor would suggest that frustration may be the mechanism by
which N odors are produced.

A consideration relevant to a frustration interpretation
of odor production concerns the highly probable presence of
a unique odor associated with reward. In this regard, there
is little controversy that N odors are the more salient
(Taylor & Ludvigson, 1980). However, Taylor and Ludvisgon
(1980) also found that odors associated with reward had be-
havioral consequences. Certainly, the findings of Mellgren
et al. (1973); Collerain and Ludvigson (1977); and Prytula
et al. (1981) strongly suggest the existence of a distinctive
R odor. For instance, Prytula et al. (1981) employed a
large squad (n=14) of animals. These researchers found a
significant increase in R-trial speeds on the part of sub-
jects run in the terminal positions of the sequence, relative
to subjects run early in the sequence. This finding suggests
the accumulation of R odor over trials.

Since odors appear to be exuded on R trials, a relevant
question would seem to be whether N-trial odor production
and/or utilization is a function of frustration, or simply
nonreward. Davis, Whiteside, Bramlett, and Petersen (1981)
attempted to firmly place the odor phenomenon within the
context of frustration theory by employing a DA schedule
which substituted reward magnitude contrast for the standard

RRNNRRNN sequence of goal events. That is, instead of simply employing R and N events Davis et al. (1981) attempted to demonstrate patterned responding under an alternating large (L), small (S) schedule (i.e., LLSSLLSS). According to frustration theory, receipt of large reward on L trials should lead to the development of the expectation of large reward. Hence, the subsequent receipt of a contrasting small reward should result in frustration and its attendant odors. Thus, patterning under an LLSSLLSS schedule would be predicted by a frustration-theory interpretation.

In a series of five experiments, these investigators found that a simple contrast in the magnitude of reinforcement was not sufficient to elicit odor production. However, the experimental manipulations of the last two experiments in the series demonstrated patterned responding when: (1) subjects received the small reward at the end of a goalbox confinement period; and (2) when subjects had the time of pellet delivery shifted from the beginning to the end of a goalbox confinement period.

The results of the Davis et al. (1981) investigation prompted the present experiment. Davis et al. (1981) hypothexiaed that entrance into an empty goalbox is an important, if not necessary, condition for the production of N odor. More specifically, it was suggested: (1) that N odor may not be exuded under theoretically frustrating conditions such as contrasting reward magnitudes (i.e., odor production and/or utilization does not perfectly mirror the occurrence

of frustration), or (2) that conditions of contrasting large vs. small reward are simply not frustrating. Certainly, the variable of delay of reinforcement is important, although the full extent of its influence in the case of odor production is not well deliniated.

The present study was designed to specifically illuminate the interaction of delay of reinforcement and reward-magnitude contrast in the production of odor cues, especially N-odor. Certainly, such data would have implications with regard to the frustration interpretation of the odor phenomenon.

Two groups of subjects were tested during a three-phase experiment. During the first phase one group received a daily eight-trial DA sequence of immediate small reward and delayed large reward, while the other group received a DA schedule of delayed large reward and nonreward. In Phase Two the subjects who experienced the DA schedule of immediate small reward and delayed large reward continued to experience this sequence of goal events, except that the delay on large reward trials was increased. Likewise, the subjects in the group that experienced delayed large reward and nonreward continued to experience that particular schedule, except that the confinement period on nonreward trials was significantly shortened. In Phase Three the group which had experienced a DA schedule of immediate small reward and delayed large reward in Phases One and Two was switched to a sequence of immediate small reward and nonreward. The group which had experienced the DA schedule of delayed large reward and

nonreward in Phases One and Two was switched to a sequence of delayed large reward and immediate small reward.

Based upon the entrance-into-an-empty-goalbox considera-tion made by Davis et al. (1981), it would be predicted that the group which experineces the DA schedule of immediate small reward and delayed large reward in Phases One and Two would display patterned responding (i.e., fast, fast, slow, slow, etc.) as a function of these subjects entering an empty goalbox on large reward trials. Subsequently, the switch to a DA schedule of immediate small reward and nonreward in Phase Three should not disrupt the already established pat-terned responding. On the other hand, the group which experi-ences the DA schedule of delayed large reward and nonreward should display nondifferential responding in Phases One and Two due to the fact that these subjects enter an empty goal-box on all trials. Conversely, the switch from a delayed large reward and nonreward schedule to a delayed large reward and immediate small reward sequence in Phase Three should result in differential responding becasue the presence of a pellet in the goalbox as subjects enter it should pre-clude N-odor production on those trials. Confirmation of these experimental hypotheses would prompt an interpretation that frustration is not the primary mechanism for odor pro-duction on N trials, but rather, it is the strict occurrence of initially encountering an empty goalbox, as such, which is primarily responsible for odor production on N trials.

CHAPTER 2

METHOD

Subjects

Fourteen female albino rats of Holtzman decent served as
subjects. The subjects were approximately 120 days old at
the beginning of the study, and were individually caged with
water available on an ad libitum basis.

Apparatus

A single straight runway (11.4-cm wide by 12.70-cm high)
consisting of a 38.10-cm gray startbox, 91.44-cm black run
section, and 30.48-cm black goalbox served as the experimental
apparatus. Two masonite guillotine doors separated the start
and run sections, and run and goal sections, respectively.
A microswitch located on the start door and three photoelectric
beams (located 15.20, 92.40, and 116.80-cm beyond the start
door) in conjunction with three electronic digital timers
(Lafayette model 54030) yielded start, run, and goal latencies
for all subjects on all trials. A plastic receptacle re-
cessed into the distal end of the goalbox served as the goal
cup. It should be noted that the last photobeam (i.e., the
one 116.80-cm beyond the start door) was located 5.08-cm in
front of the recessed goal cup. A thin sheet of transparent

20

plastic was securely attached to the hardware cloth lids of the apparatus to prevent the dissipation of odors.

Procedure

Four days prior to the start of pretraining the subjects were randomly assigned to two equal groups (n=7); Group 1-12 and Group 12-0. Subjects within each group were then randomly assigned a permanent running-order number (1-7), and placed on a food deprivation regimen designed to maintain each subject at 85% of its free-feeding body weight.

A six-day-pretraining phase immediately preceeded experimental testing. During the first three days of pretraining the subjects were individually tamed and handled for three minutes daily. During the last three days of pretraining each subject was given an individual five-minute exploration period in the baited (10, 45-mg pellets) apparatus with all electrical equipment operational. Throughout pretraining subjects were habituated to the 45-mg reward pellets while in their home cages.

Experimental testing lasted 22 days for a total of 176 trials. During experimental testing all subjects received a daily 8-trial DA schedule of goal events. Subjects were run in a fixed order (1-7) within each group on all days. Trial 1 was administered to all subjects in a group before any received Trial 2, and so forth. Between trials the apparatus was swabbed with a water-dampened sponge and allowed to air dry for five minutes with the lids open. Thus, Subject 1 in each group was always tested in a clean experimental environment

on all trials. The order for running groups was alternated
from day to day with all eight daily trials being administered
to a group before the other group was tested. Maintenance of
the deprivation schedule for all subjects took place follow-
ing the completion of each daily experimental session.

Phase 1 lasted 12 days for a total of 96 trials. In
Phase 1 Group 1-12 was administered a DA schedule of small
(S) and large (L) reward (i.e., SSLLSSLL) with the delivery
of the small reward being immediate, and the delivery of the
large reward being delayed. Specifically, one 45-mg reward
pellet was present in the goal cup as the subject entered the
goalbox on S trials. On L trials 12, 45-mg reward pellets
were delivered into the goal cup 10-seconds after the last
photoelectric beam was interupted. The specific procedure
for running subjects in Group 1-12 in Phase 1 was as follows.
As soon as a subject broke the last photobeam on S-trials,
thereby stopping the third timer (goal latency), the guillotine
door separating the run and goal sections was lowered and
simultaneously a confinement light (controlled by a Lafayette
Model 5810 timer) was manually activated by the experimenter.
After a 20-second confinement period the subject was removed
from the goalbox. The L trials in Phase 1 for Group 1-12
entailed entrance into an empty goalbox. As soon as the last
photobeam was broken, the goalbox containment door was low-
ered and the confinement light was activated. After a 10-
second confinement period, 12, 45-mg reward pellets were
manually placed in the goal cup by a second experimenter

who was present at the distal end of the runway on all trials for both groups. The subject was removed from the goalbox as soon as the 12 pellets were consumed on these trials.

During Phase 1, Group 12-0 received a daily eight-trial DA schedule of large reward and nonreward (i.e., LLNNLLNN). As with Group 1-12, and L-trial consisted of 12, 45-mg pellets delivered in the goal cup 10-seconds after the last photobeam was broken. An N-trial consisted of 20-second confinement to the empty goalbox. Thus, the subjects in Group 12-0 entered an empty goalbox on all trials.

Phase 2 immediately followed Phase 1 and lasted four days for a total of 32 trials. In this Phase Group 1-12 continued to receive the same daily eight-trial SSLLSSLL schedule, with one exception. The reward delay on L-trials was extended from 10 to 20 seconds. Likewise, Group 12-0 continued to receive the Phase 1 daily eight-trial LLNNLLNN schedule with the exception that the subjects were immediately removed from the goalbox on N-trials.

Phase 3 immediately followed Phase 2 and lasted six days for a total of 48 trials. In this phase the DA schedule for Group 1-12 was switched to an SSNNSSNN sequence. Under this schedule, S trials consisted of one 45-mg pellet which was present in the goal cup as the subject entered the goalbox. A 20-second confinement was experienced on S trials. Conversely, an N trial consisted of 20-seconds confinement to the empty goalbox.

Group 12-0 received their daily Phase 3 trials in an

LLSSLLSS sequence. An L trial consisted of 12, 45-mg pellets delivered 10 seconds after the last beam in the goalbox had been broken. On S trials a single pellet was present as the subject entered the goalbox, and the subject was removed as soon as the pellet was consumed. The specific group sequences for each phase are shown in Table 1 in the Appendix.

CHAPTER 3

RESULTS

In order to satisfy the normality of distribution assumption of the analysis of variance procedure, all latencies were transformed to reciprocals. These reciprocals, when multiplied by the appropriate constant, yielded speed scores in meters per second.

Prior to analysis and graphing, the speed scores for the daily DA sequence were combined as follows for each subject: The first two trials were averaged to yield a composite score, the next two trials were averaged to yield a composite score, and so forth. Hence, the daily DA sequence was reduced to four scores for each subject in each segment of the runway. The data from the initial subject in each group were not included in statistical analysis or graphs, since these animals were always tested in a clean, odor-free apparatus and served as odor-donor animals for the remaining subjects in their respective groups. Group mean start, run, and goal speeds for the three phases of the experiment are shown in Figures 1-3, respectively, in the Appendix.

A repeated-measures analysis of variance, incorporating one between-subjects factor (Groups), and two within-subjects

factors (Days and Trials Within Days) was performed on the start, run, and goal speeds for each phase of the experiment. The Newman-Keuls procedure was employeed to make specific comparisons. The results of each phase will be presented separately.

Phase 1

The last three days of Phase 1, the point at which appropriate patterned responding appeared to have been developed in the goal measure for Group 12-0, were selected for analysis. Both start- and run-measure analysis failed to yield significant results. Supportive of the graphical impressions created by Figure 3, significant Groups, F $(1, 10)$ = 12.17, p < .01, and Groups x Trials Within Days, F $(3, 30)$ = 5.45, p < .01, effects were found in the goal-measure analysis. Subsequent Newman-Keuls tests indicated that subjects in Group 12-0 approached the goal significantly (p < .01) faster on Trials 1-2 and 5-6 than they did on Trials 3-4 and 7-8. The only other statistically reliable difference occured on Day 10 when it was shown that Group 1-12's performance on Trials 1-2 was significantly (p < .01) slower than all other trials.

Phase 2

As with the Phase 1 analysis, significant results were not obtained in the start and run measures. The goal-measure analysis yielded significance for the Groups, F $(1, 10)$ = 10.66, p < .01, and Groups x Trials Within Days, F $(9, 90)$ = 3.34, p < .01. As in Phase 1, Newman-Keuls tests indicated

that Group 12-0 subjects continued to approach the goal sig-
nificantly ($p < .01$) faster on Trials 1-2 and 5-6 than they
did on Trials 3-4 and 7-8. Additionally, it was found that
subjects in Group 1-12 approached the goal significantly
($p < .01$) slower on Trials 1-2 than on the other trials on
Days 1-3. On Day 4 these subjects approached the goal sig-
nificantly slower ($p < .01$) on Trials 1-2 and 5-6 than they
did on Trials 3-4 and 7-8. On Day 4 Trials 1-2 and 3-4 did
not differ significantly from the corresponding trials of
Group 12-0.

Phase 3

Consonant with the results of Phases 1 and 2, significant
results were not found in the start- and run-measure analyses.
Corroborating the graphical impression suggesting that Phase
3 treatments had a rather pronounced effect in reducing
between-group differences, no significant effects were ob-
tained in the goal measure analysis.

CHAPTER 4

DISCUSSION

The results of the present experiment showed that Group
1-12 did not display appropriate differential responding in
any phase of the experiment. Conversely, Group 12-0 did
display differential responding in Phases 1 and 2; however,
this patterned responding disappeared in Phase 3. The finding
that there were no within- or between-group differences in
the start- and run-sections of the runway is consistent with
the literature (e.g., Ludvigson & Sytsma, 1967; Prytula &
Davis, 1976) concerning the development of DA responding
when small groups of subjects are employed. Hypothetically,
odors are exuded at the point in the apparatus where the
subjects encounter the goal event. Therefore, it would be
expected that odors are exuded, accumulate, and display
their most pronounced effect in the goal-section of the ap-
paratus. Because of the small number of subjects in each
experimental group (n=7) of the present experiment, odors
did not have an opportunity to disseminate farther back in
the apparatus. As such, patterned responding, when it
appeared, was confined to the goal section. However, it
has been demonstrated that when a large squad of animals

28

is employed (e.g., Prytula et al., 1981) R-N discriminations are established in all measures of the runway. Nonetheless, the finding of no significant difference between speeds in the start- and run-sections of the apparatus was expected as a function of the small number of subjects in each experimental group.

The between-group differences found in the goal section in Phases 1 and 2 are diametrically opposed to the experimental hypotheses of the present study. On the basis of the Davis et al. (1981) data it was expected that Group 1-12 would display differential responding in Phases 1 and 2 as a function of entering an empty goalbox on trials 3, 4, 7, and 8. Likewise, it was predicted that Group 12-0 would not display patterned responding in Phases 1 and 2 as these subjects entered an empty goalbox on all trials. The results of Phase 3 were also contrary to initial considerations in several respects.

Davis et al. (1981) proposed that entrance into an empty goalbox is a sufficient, if not necessary, condition for the production of odor on N trials. The performance of Group 1-12 in Phases 1 and 2 would indicate that entrance into an empty goalbox is neither a necessary, nor sufficient condition for N-odor production. In Phase 1 subjects in this group experienced immediate small reward on Trials 1, 2, 5, and 6, and delayed large reward on Trials 3, 4, 7, and 8. However, appropriate patterned responding did not develop in Phase 1 when the large reward was delayed 10-seconds, or in Phase 2

when the delay was extended to 20-seconds. Further, when this group's DA schedule was switched (Phase 3) from immediate small reward and delayed large reward to immediate small reward and nonreward, patterning still did not develop. This is particularly interesting since Phase 3 lasted six days (48 trials) and research has repeatedly demonstrated (e.g., Ludvigson & Sytsma, 1967; Ludvigson, 1969) that six days is typically an adequate length of time for patterned responding to develop.

Similarly, the initial considerations of the present study predicted that Group 12-0 would not display differential responding in Phases 1 and 2 because subjects entered an empty goalbox on all trials. Yet, patterned responding was established in these Phases, again indicating that entrance into an empty goalbox, as such, is not the primary mechanism by which odors are exuded on N-trials. However, when Group 12-0's DA schedule was altered in Phase 3 such that a single pellet was present on the previously nonrewarded trials, patterned responding disappeared. This finding is in agreement with the Davis et al. (1981) data.

The most parsimonious explanation of Group 1-12's performance in Phases 1 and 2 would seem to be that when rats are initially trained on the DA schedule employed in Phase 1 of this experiment, the delay interval serves as a temporal CS signaling the eventual delivery of a large reward. If this interpretation is adopted, then generalization can account for this group's performance in Phase 2 when the

delay interval was lengthened. Likewise, it would appear that after 16 days (128 trials) of such training a switch to nonreward on the previously delayed large reward trials (Phase 3) is initially perceived by the subjects as an even longer delay of reinforcement. Perhaps six days (48 trials) is simply not long enough for the subjects to learn the change in reinforcement contingencies.

Group 1-12's performance in Phases 1 and 2 would seem to indicate that a DA schedule of immediate small reward and delayed large reward is not necessarily frustrating, in the traditional sense. This group's performance would also seem able to support either of the hypotheses proposed by Davis et al. (1981), namely that N-odor may not be exuded under theoretically frustrating conditions such as contrasting reward magnitudes (i.e., odor production and/or utilization does not perfectly mirror the occurance of frustration); or that such conditions of contrasting large vs. small reward are not frustrating, as the term is typically employed. Unfortunately, the results of the present experiment do not allow us to choose between these alternative explanations.

Although Group 12-0 entered an empty goalbox on all trials of Phases 1 and 2, patterned responding did develop. Again, it would appear that a delay in reinforcement can function as a temporal CS signaling the eventual delivery of reinforcement, and further, that rats can learn to discriminate a delay in reinforcement from nonreward. It is interesting that when the conditions on N trials were altered

from 20-second confinement to an empty goalbox (Phase 1) to immediate removal (Phase 2) patterning was maintained. This finding is consistent with the findings of Davis et al. (1981), and indicates that odors are exuded very rapidly.

When Group 12-0's DA schedule was altered in Phase 3 such that a single pellet was present on the previously non-rewarded trials, patterned responding disappeared within eight trials. This finding would indicate that, while entrance into an empty goalbox is neither necessary or sufficient to produce N-trial odor, the presence of a single pellet in a goalbox can preclude the production of N odors (see Davis et al., 1981), given that the reward is desirable (Davis & Weaver, Note 1).

One aspect of Group 1-12's performance would seem to merit further consideration. There was a tendency (significant at times) for speeds on Trials 1-2 to be depressed for this group. Perhaps these trials also acted as a CS which forecast the occurrence of large reward on Trials 3-4, (and thereby enhanced performance on Trials 3-4) or perhaps this group occasionally took a few trials to "warm up". The present results do not lend themselves to a clear statement on this point. Consequently, further systematic investigation of this effect would seem warranted.

The seemingly contradictory nature of the findings of this experiment, as well as this research area collectively, certainly indicate that further research is needed if we are to adequately account for the data in a theoretical manner.

It would seem that frustration theory, as such, will not be able to account for the experimental data we have discussed without some modification. However, if frustration theory could/would accept the notion that frustrating experiences are on a continuum, then perhaps we could account for the findings of the present experiment.

For instance, goalbox events for rats could be ordered along a continuum ranging from nonreward on one extreme of the continuum through various reward conditions such as delay of small reward, delay of large reward, immediate small reward, immediate large reward, and so forth. As such, immediate large reward would lie farther away from nonreward on the continuum than would immediate small reward. If we accept the basic tenet of frustration theory, the present proposal would assume that for rats frustration results in the production of odors. However, the present proposal would contend that the quantity and/or quality of odor produced, as well as the utilization of these odors, is a function of the "degree" of frustration which, in turn, is a function of where specific goal events lie on the postulated continuum.

Suppose that for the rat the goal events of immediate small reward and delayed large reward lie very close together on the continuum, but both types of event are a considerable distance from nonreward on the continuum. For Group 1-12 of the present experiment, training on DA schedules of immediate small reward and two types of delayed large reward (two types in terms of delay interval) did not produce frustration

because all of the goal events experienced during testing
were too dissimilar to nonreward, or the contrast between
goal events was not significant enough, for primary frus-
tration to develop (Phases 1 and 2). Further, this group's
extensive experience with the experimental manipulations
employed in Phases 1 and 2 apparently "inoculated" them in
some manner such that when their double-alternation schedule
was altered in Phase 3 to immediate small reward/nonreward
they either: (1) failed to "perceive" the change in reward
contingencies; or (2) were slower to experience primary
frustration than would normally be expected.

Likewise, the performance of Group 12-0 in the present
experiment would be explained by assuming that delayed large
reward is far enough away from nonreward on the proposed con-
tinuum (in other words, an R-N contrast) that subjects experi-
enced primary frustration after about five days (40 trials)
on the delayed large reward/nonreward schedule (Phases 1 and
2). When in Phase 3 the previously nonrewarded trials were
replaced with immediate small reward, the change was per-
ceived by the subjects rapidly and resulted in the preclusion
of odor production on N trials because an immediate small
reward, is perhaps almost as desirable as a delayed large
reward, and still preferable to no reward at all.

One supposition of the present proposal is that immediate
small reward lies farther away from nonreward on the postulated
continuum than does delayed large reward, but that delayed
small reward is closer to nonreward than is delayed large

reward. An interesting way to test this supposition would
be to test two groups of subjects under identical DA schedules
of delayed small reward and delayed large reward. Phase 1
of this proposed experiment would last 16 days (128 trials),
and the present account would not predict differential re-
sponding in either group at the end of the period. In
Phase 2 one group would be switched to a delayed small reward/
nonreward sequence, and the other group would experience a
nonreward/delayed large reward sequence. Assuming that
delayed small reward lies closer to nonreward on the goal
event continuum than delayed large reward, it would be pre-
dicted that the group switched to the delayed small reward/
nonreward sequence would develop primary frustration slower
than the other group as a function of a delayed small reward/
nonreward contrast being less frustrating than a nonreward/
delayed large reward contrast. Consequently, the group
which experiences the delayed small reward/nonreward sequence
in Phase 2 of this hypothetical situation would display
appropriate patterning later than the group experiencing a
nonreward/delayed large reward sequence in Phase 2.

The above speculation is similar to one of the Davis
et al. (1981) proposals (i.e., odor production and/or
utilization does not perfectly mirror the occurrence of
frustration) except that the present proposal postulates
that odor production and/or utilization is indicative of
the "perception" of a gradient of "satisfying states of

affairs" which do not perfectly mirror the occurrence of theoretically frustrating events as typically proposed. Of course, the speculation offered above must be subjected to empirical confirmation or rejection. However, even if the speculation offered is shown to be nonvalid, it would be a step toward a more intergrated approach which would take cognizance of the trend toward "cognitive" interpretations of animal behavior, and possibly result in a more adequate account of the odor phenomenon in rats than we have achieved so far by relying on traditional theories.

REFERENCE NOTES

REFERENCE NOTES

1. Davis S. F., & Weaver, M. S. Double-alternation run-way performance of the rat as a function of regular- and quinine-pellet reward contrast. Paper presented at the meeting of the Southwestern Psychological Association, 1982.

2. Eslinger, P. J., & Travis-Neideffer, M. N. Utilization of odor cues as a function of like or unlike motivation-reward operations in donor and test rats. Paper presented at the meeting of the Southwestern Psychological Association, 1979.

3. Ludvigson, H. W. "Frustration odor" in rats. Paper presented at the XXVIIth International Congress of Physiological Sciences, Paris, France, 1977.

4. McNeese, R. R., & Ludvigson, H. W. Searching for the source of frustration odor. Symposium on "Frustration Odor" In Rats. Presented at the 22nd annual meeting of the Southwestern Psychological Association, Houston, Texas, 1975.

REFERENCES

REFERENCES

Amsel, A. The role of frustrative nonreward in noncontinuous
reward situations. Psychological Bulletin, 1958, 55,
102-119.

Beach, F. A. The snark was a boojum. American Psychologist,
1950, 5, 115-124.

Collerain, I. Frustration odor of rats receiving small num-
bers of prior rewarded running trials. Journal of Exper-
imental Psychology: Animal Behavior Processes, 1978, 4,
120-130.

Collerain, I., & Ludvigson, H. W. Aversion of conspecific
odor of frustrative nonreward in rats. Psychonomic
Science, 1972, 27, 54-56.

Collerain, I., & Ludvigson, H. W. Hurdle-jump responding in
the rat as a function of conspecific odor of reward and
nonreward. Animal Learning & Behavior, 1977, 5, 177-183.

Daly, H. D. Learning to escape cues paired with reward re-
ductions following single-or multiple-pellet rewards.
Psychonomic Science, 1972, 26, 49-52.

Davis, S. F. Conspecific odors as cues for runway behavior
in mice. Psychonomic Science, 1970, 19, 169-170.

Davis, S. F., Crutchfield, W. P., Shaver, J., & Sullivan, T.
Interspecific odors as cues for runway behavior. Psycho-
nomic Science, 1970, 20, 166-167.

Davis, S. F., Prytula, R. E., Harper, W. E., Tucker, H. K., Lewis, C., & Flood, L. Double-alternation runway performance as a function of inter-and intra-reinforcement odor cues. Psychological Reports, 1974, 35, 787-793.

Davis, S. F., Prytula, R. E., Noble, M. J., & Mollenhour, M. N. Motivational specificity of the signal value of odor cues. Animal Learning & Behavior, 1976, 4, 407-410.

Davis, S. F., Whiteside, D. A., Bramlett, J. A., & Petersen, S. H. Odor production and utilization under conditions of nonreward and small reward. Learning and Motivation, 1981, 12, 364-382.

Dember, W. N., & Kleinman, R. Cues for spontaneous alternation by gerbils. Animal Learning & Behavior, 1973, 1, 287-289.

Eslinger, P. J., & Ludvigson, H. W. Are there constraints on learned responses to odors from rewarded and nonrewarded rats. Animal Learning & Behavior, 1980, 8, 452-456. (a)

Eslinger, P. J., & Ludvigson, H. W. Commonality among rats in production of reward and nonreward odors. Bulletin of the Psychonomic Society, 1980, 16, 191-193. (b)

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.

Mellgren, R. L., Fouts, R. S., & Martin, J. W. Approach and escape to conspecific odors of reward and nonreward in rats. Animal Learning & Behavior, 1973, 1, 129-132.

Pitt, S., Davis, S. F., & Brown, B. R. Apparent double alternation in the rat: A failure to replicate. Bulletin of the Psychonomic Society, 1973, 2, 359-361.

Pratt, L. K., & Ludvigson, H. W. The role of odor in latent extinction. Psychonomic Science, 1970, 20, 189-190.

Prytula, R. E., & Davis, S. F. The relationship between locus of odor cues and double-alternation responding in the rat. Animal Learning & Behavior, 1976, 4, 352-356.

Prytula, R. E., Davis, S. F., & Fanning, J. J. The acquisition of a running response as a function of odor buildup, squad rotation, and introduction of naive subjects. Animal Learning & Behavior, 1981, 9, 556-560.

Schultz, D. A history of modern psychology (2nd ed.). New York: Academic Press, 1975.

Seago, J. D., Ludvigson, H. W., & Remley, N. R. Effects of anosmia on apparent double alternation in the rat. Journal of Comparative and Physiological Psychology, 1970, 71, 435-442.

Taylor, R. D., & Ludvigson, H. W. Selective removal of reward and nonreward odors to assess their control of patterned responding in rats. Bulletin of the Psychonomic Society, 1980, 16, 101-104.

Tolman, E. C. Purposive behavior in animals and men. New
    York: Nailburg, 1932.

Tolman, E. C. The determiners of behavior at a choice point.
    Psychological Review, 1938, 45, 1-41.

Voorhees, J. W., & Remley, N. R. Mitral cell responses to the
    odors of reward and nonreward. Physiological Psychology,
    1981, 9, 164-170.

Weaver, M. S., Whiteside, D. A., Janzen, W. C., Moore, S. A.
    & Davis, S. F. A preliminary investigation into the
    source of odor-cue production. Bulletin of the Psycho-
    nomic Society, 1982, 19, 284-286.

APPENDICES

APPENDIX A

TABLES

Table 1.   Double-alternation Schedules

	PHASE I	PHASE II	PHASE III

Group 1-12   SSLLSSLL   SSLLSSLL   SSNNSSNN

S = 1 pellet present as Ss enter   S = same as in Phase I.   S = same as in Phases I & II.

goalbox; 20-sec. confinement.

L = 12 pellets delivered 10-sec.   L = same as in Phase I   N = 20-sec. confinement to

after Ss have broken last photo-   except delay interval   empty goalbox.

beam; Ss removed after consump-   extended to 20-sec.

tion of all pellets.

Group 12-0   LLNNLLNN   LLNNLLNN   LLSSLLSS

L = 12 pellets delivered 10-sec.   L = same as in Phase I.   L = same as in Phases I & II.

after Ss broke last photobeam;   S = 1 pellet present as Ss

Ss removed after consumption   enter goalbox; Ss removed as

of all pellets.   soon as pellet was consumed.

N = 20-sec. confinement to an   N = immediate removal

empty goalbox.   after last photobeam

                                      was broken.

APPENDIX B

FIGURES

Figure 1. Mean Start Speeds

X̄ OF TRIALS
1-2 ●————●
3-4 ○————○
5-6 ●----●
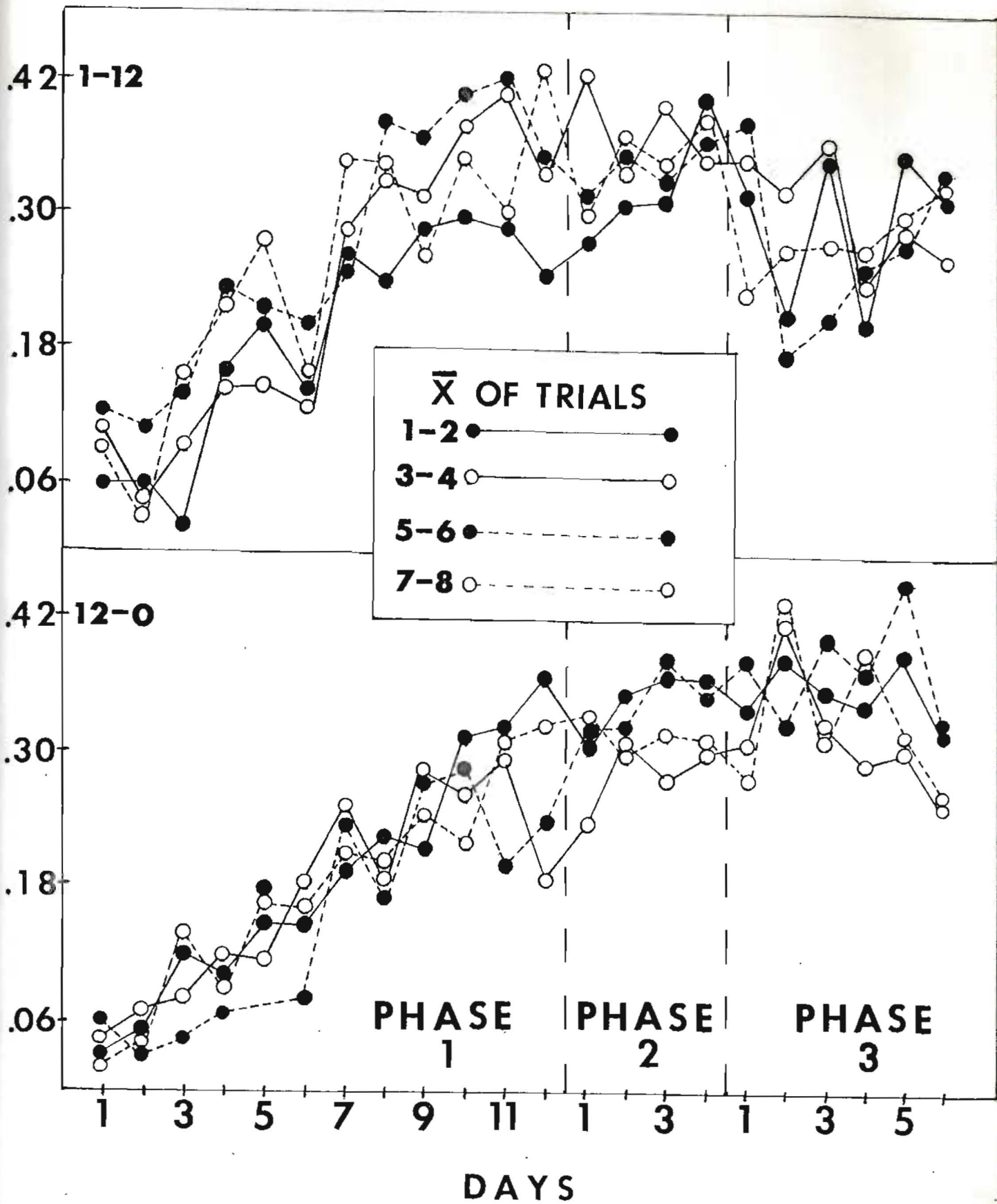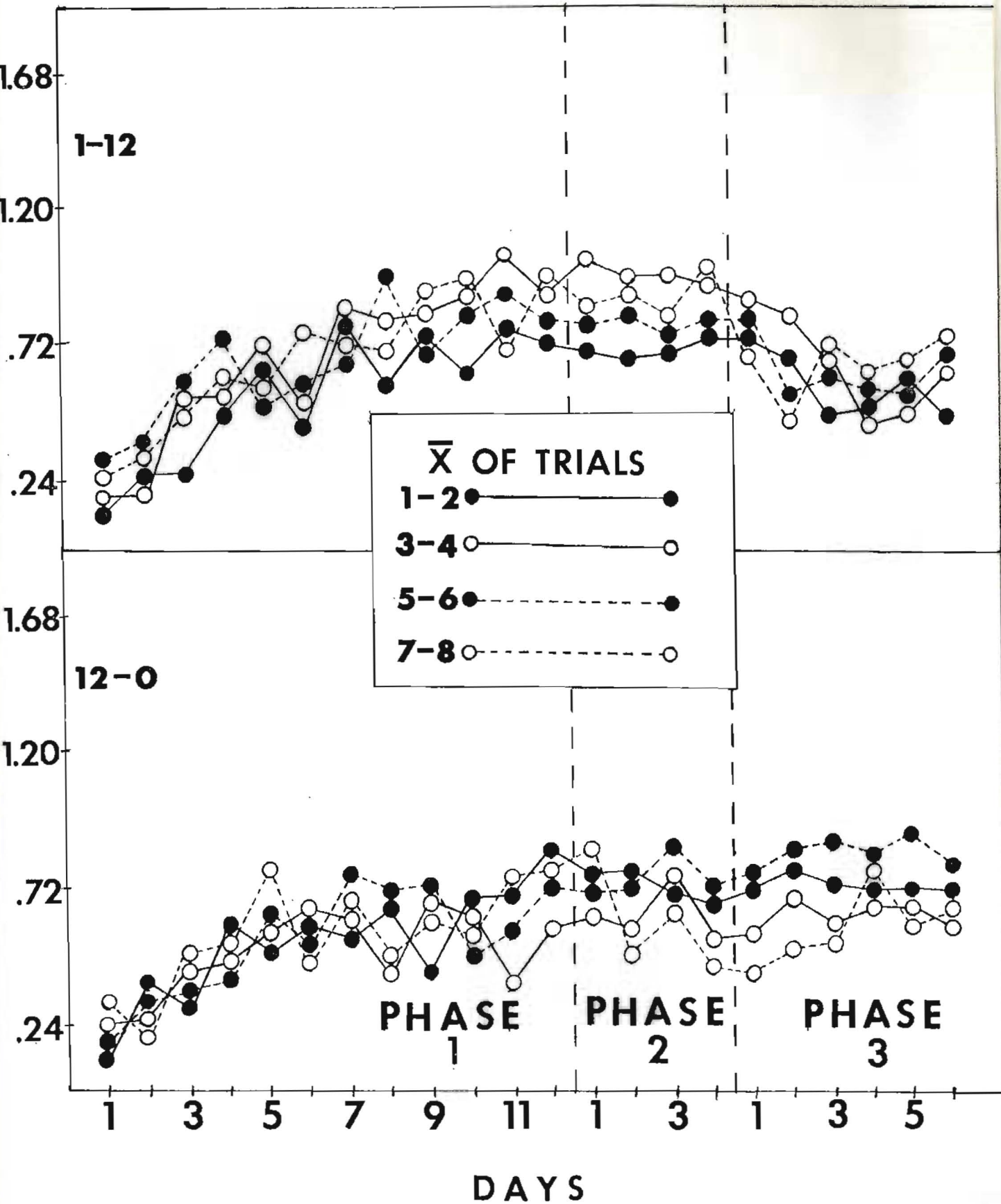7-8 ○----○

PHASE 1   PHASE 2   PHASE 3

DAYS

Figure 2.   Mean Run Speeds

Figure 3. Mean Goal Speeds