

University of Nevada, Reno

**Effects of MO Magnitude on the Acquisition of Operant Responding and  
Discrimination Learning**

A thesis proposal submitted in partial fulfillment of the requirements for the degree of  
Master of Arts in Psychology

by Melanie Stites

Dr. Linda J. Parrott Hayes / Thesis Advisor

August, 2020

Copyright by Melanie S. Stites

2020 All Rights Reserved.



## THE GRADUATE SCHOOL

We recommend that the dissertation  
prepared under our supervision by

MELANIE STITES

Entitled

Effects of MO Magnitude on the Acquisition of Operant Responding and Discrimination  
Learning

be accepted in partial fulfillment of the  
requirements for the degree of

Master of Arts in Psychology

Linda J. Hayes, Ph.D., Advisor

Matthew Lewon, Ph.D., Committee Member

Patrick M. Ghezzi, Ph.D., Committee Member

Kenneth W. Hunter, Sc.D., Graduate School Representative

David W. Zeh, Ph.D., Dean, Graduate School

August, 2020

## Abstract

Two groups of mice were exposed to a series of acquisition and discrimination training/testing sessions under different combinations of motivational conditions to study a) the effects of motivating operations (MOs) during the initial acquisition of operant responding and discrimination learning, and b) interactions between MOs during initial training and those prevailing during subsequent assessments of learning. One group received all acquisition and discrimination training sessions under 24-hr food deprivation conditions while the other received all sessions under 0-hr food deprivation (i.e., satiation) conditions. While learning was evident in both groups, mice who received this training under 24-hr food deprivation conditions exhibited greater changes in behavior across training sessions and a greater overall level of food-related behavior during training. Subsequent to discrimination training sessions, subjects in both groups received two discrimination tests to assess whether MOs affect the degree of discrimination learning that had occurred. One test was conducted under 24-hr food deprivation and the other was conducted under 0-hr food deprivation. Results of the tests indicated no difference between groups as measured by discrimination ratio, but subjects trained under 24-hr deprivation made more responses in the 24-hr test, while subjects trained under 0-hr deprivation made more responses in the 0-hr test. These results and their implications are discussed in terms of motivational state-dependent learning.

## Acknowledgements

To my husband, thank you for your love, support, and endless cups of coffee. I'm awfully glad to be stuck with you.

To my advisor Dr. Linda Hayes, thank you for all of the opportunities you have afforded me, and your continuing support.

To my friends Dr. Matthew Lewon and Christina Peters, thank you for your mentorship and support throughout the ordeal that is graduate school. You have both helped shape me into the behavior scientist I am today.

To Richa Sharma, Angel Depriest, Tony Magana, Jaime Crick, Jennifer Hernandez, Jack Samath, Kennedy Sparling, Monard Munoz, and Sara Lake, thank you for being awesome research assistants.

### **Statement on the Welfare of Animals**

All research herein was conducted in accordance with guidelines approved by the University of Nevada, Reno's Institutional Animal Care and Use Committee under protocol #00669.

## Table of Contents

Abstract.....	i
Acknowledgements.....	ii
Statement on the Welfare of Animals.....	iii
Table of Contents.....	iv
List of Tables.....	v
List of Figures.....	vi
Introduction.....	1
MOs Effects on Stimulus Generalization Gradients.....	2
MOs Effects on Discriminated Responding.....	5
State-Dependent Learning.....	7
Purpose.....	10
Method.....	11
Subjects.....	11
Apparatus.....	12
Motivating Operations and Food Deprivation Regimen.....	13
Acquisition Training.....	13
Discrimination Training Sessions.....	16
Discrimination Tests.....	18
Acquisition Learning Results and Discussion.....	19
Results.....	19
Discussion.....	22
Discrimination Training/Test Results and Discussion.....	24
Results.....	24
Discussion.....	27
General Discussion.....	29
References.....	34
Tables.....	38
Figures.....	41

## List of Tables

1. Order and Number of Sessions .....	38
2. Lever Training Procedural Details .....	39
3. Discrimination Training and Testing Details by Subgroup .....	40



**List of Figures**

1. Measures of Responding in Dipper Training Procedure.....	41
2. Measures of Responding in Lever Training Procedure .....	42
3. Measures of Responding in Reinforcement and Extinction Training Procedure .....	43
4. Absolute Responding in Discrimination Tests .....	44
5. Discrimination Ration in Discrimination Tests .....	45

## Introduction

Within behavior analytic theory, two classes of antecedent events (i.e., events that precede the occurrence of behavior) contribute to the evocation of operant behavior. The first class is discriminative stimuli. Discriminative stimuli are stimulus conditions which have been correlated with the differential availability of a particular consequence for a particular response (Michael, 1982). In other words, when a particular response-contingent consequence has been consistently correlated with specific antecedent stimuli, these antecedent stimuli come to function as discriminative stimuli, and their presence alters the probability of responses which have produced them in the past.

The second class of antecedent events that affect operant behavior are motivating operations (MOs). MOs are environmental events, operations, or stimulus conditions which are held to have two functions. The first function has been described as an evocative effect: MOs alter the probability that a member of the class of responses that have produced a particular outcome in the past may occur. The second function has been described as a value altering effect: MOs alter the reinforcing or punishing efficacy of an event. (Laraway et al., 2003; Michael, 1993; Hayes, 2020). MO is an omnibus term for both establishing operations and abolishing operations. Establishing operations (EOs) increase the reinforcing or punishing efficacy of an event, and therefore increase the probability of behaviors that have been followed by the event in the past. Abolishing operations (AOs) decrease the reinforcing or punishing efficacy of an event and therefore decrease the probability of the class of responses that have produced that event in the past.

While both motivating operations and discriminative stimuli fall under the category of antecedent events, it is important to distinguish between the two for practical and theoretical purposes. A distinction has been drawn between these two types of antecedent events on the basis of their relationships with consequential events.

Discriminative stimuli are held to relate to the differential availability of a reinforcer or aversive stimulus given a response, whereas MOs are held to relate to the differential effectiveness of reinforcers or aversive stimuli, regardless of their availability (Michael, 1983). Despite these conceptual distinctions, various discriminative stimuli and MOs are always present when behavior occurs, and both classes of events contribute to the evocation of operant responding. Nearly all applications of behavior science involve bringing a particular response under the appropriate stimulus control. A fundamental issue then, is to understand how MOs and discriminative stimuli interact during the development and assessment of discriminated responding. There have been several lines of research relevant to this issue. We consider these in the subsequent sections.

### **MOs Effects on Stimulus Generalization Gradients**

A literature review conducted by Lotfizadeh, Edwards, Redner, and Poling (2012) suggested that MOs alter the degree of stimulus generalization as it is measured in generalization gradient experiments. The authors examined 11 articles pertaining to relations between the levels of food deprivation at the time of testing for generalization and the shape of generalization gradients. In the studies reviewed, discriminated responding was first established by reinforcing responses occurring in the presence of a particular discriminative stimulus (S+) while responses in occurring in its absence (S-) went unreinforced. This discrimination training was typically conducted under a single

MO condition (e.g., when the animals were maintained at 85 percent of their free-feeding weights). Following this training, stimulus generalization was assessed by sequentially presenting S+, as well as a range of other similar stimuli along a particular physical dimension, and measuring the number or proportion of total responses occurring in the presence of each stimulus value. These generalization tests typically occurred under extinction conditions. The independent variable of interest in the generalization tests was the level of food deprivation (MO level) at the time of testing. Lotfizadeh et al. compared the generalization gradients obtained at different MO levels and reported that higher food deprivation conditions during testing a) increased the number of responses occurring in the presence of S+, and b) increased the number of responses occurring at the other tested stimulus values. From these findings, the authors concluded that EOs increase stimulus generalization. If stimulus generalization and stimulus discrimination are taken to be opposite endpoints on the continuum of stimulus control (Rilling, 1977), another implication is that EOs may serve to *decrease* stimulus discrimination. In other words, higher EO levels may be expected to also increase the number of responses occurring in the presence of S- during discrimination training through generalization.

Despite this, certain methodological features of the studies reviewed by Lotfizadeh et al. raise some questions regarding the relation between MO level and stimulus control. First, discrimination training in these studies was conducted under a single MO level, whereas the subsequent tests for generalization were conducted under various different MO levels. Because of this, it is unclear whether Lotfizadeh et al.'s conclusion that EOs increase generalization is representative of a general relationship between MOs and discriminative stimuli, or if this relation is an artifact of that

procedural detail. It is possible that increased generalization was not simply due to higher levels of food deprivation and that the results of these studies were a function of the difference between MO levels during training and testing.

Another issue is related to how stimulus discrimination and generalization are measured. In the studies reviewed by Lotfizadeh et al., generalization was most often measured by evaluating the absolute number of responses which occurred in the presence of the S+ and the other test stimuli. An alternative metric of stimulus discrimination/generalization is discrimination ratio (DR). DR is calculated by dividing the number of responses in the presence of S+ by the number of responses occurring in the presence of S+ and all other tested stimuli. Perfectly discriminated responding would result in a DR of 1.0 (i.e., all responses occur in the presence of S+ and none occur in the presence of any of the other tested stimuli). Alternatively, nondiscriminated responding would result in a DR for S+ responding that is roughly equivalent to the DR obtained for all other tested stimuli (i.e., responses occur as frequently in the presence of S+ as they do in the presence of non-S+ stimuli). DRs therefore measure discriminated responding in relative rather than absolute terms.

There exist some studies which have measured the relationship between MOs and stimulus generalization in this way. For example, Thomas and King (1959) plotted data from generalization tests conducted at four different levels of deprivation both in terms of total responses at each test value (absolute measure) and in terms of DR at each test value (relative measure). When plotted in terms of total responses, their data supported Lotfizadeh et al.'s conclusion that higher deprivation levels promote generalization (i.e., more responses in the presence of stimuli similar to S+). However, when plotted as DR,

higher deprivation levels had no significant effect on the relative proportion of responses that occurred in the presence of each stimulus value. In other words, higher MO levels increased responding in the presence of S+ and all other test values proportionally.

### **MOs Effects on Discriminated Responding**

As noted above, stimulus discrimination and generalization may be understood as opposite endpoints on the continuum of stimulus control. As discrimination between stimulus conditions increases, generalization decreases, and vice versa. The studies in the previous section studied the relationship between MOs and discriminative stimuli by means of stimulus generalization gradients. The studies reviewed in this section examined this relationship by assessing discrimination instead of generalization. These procedures generally involved establishing discriminated responding through discrimination training (i.e., reinforcing responses occurring in the presence of one stimulus and extinguishing them in the presence of another) and then examining the effects of different MO levels on performance under extinction.

Dinsmoor (1952) deprived rats to 85 percent of their previously established free-feeding weights and exposed them to discrimination training in which lever pressing was reinforced with food in the presence of a stimulus light and extinguished in its absence. Following this training, the rats were exposed to test sessions in which this discrimination performance was assessed under deprivation levels ranging from 75 to 100 percent of free-feeding weight. Subjects tested under higher deprivation levels made more responses in the presence of both S+ and S- than those tested under lower levels of deprivation. However, increasing deprivation increased responding in the presence of S+ and S- proportionally, meaning that increasing deprivation had no appreciable effect on

discrimination as measured by DR. This finding supports the notion advanced in the previous section that EOs increase the *absolute* number of responses in the presence of various stimuli, but they increase responding to those stimuli proportionally and therefore have no appreciable effect on *relative* numbers of responses to each stimulus (i.e., DR).

Edrisinha, Reilly, Sigafos, Lancioni, & Choi (2011) used a procedure similar to Dinsmoor's with human participants in an applied setting. In their study, two participants who engaged in challenging behavior underwent discrimination training in which the behavior was reinforced in the presence of an S+ stimulus and extinguished in the presence of an S- stimulus. Following discrimination training, pre-session MOs for the reinforcer that maintained the challenging behaviors were systematically altered and assessed under extinction. For both participants, very little responding occurred in the presence of S+ or S- in the pre-session AO condition. In other words, for both participants, the S+ and S- stimuli were equally ineffective in evoking responding in the absence of an EO. On the other hand, pre-session EOs greatly increased responding in the presence of both S+ and S-. While EOs increased responding in the presence of both stimuli, the increase in S+ responding was larger. Because so little responding occurred in the absence of the EO for the reinforcer that maintained these behaviors (regardless of the presence of S+ or S-), it is difficult to draw conclusions regarding the effects of MOs in terms of DR.

The effects of MOs on discriminated responding also appear to depend on the extent to which a discrimination is learned. In a study with pigeons responding under multiple variable-interval/extinction or variable-ratio/extinction schedules, Powell (1971) demonstrated that discrimination performances which were learned to a greater degree of

accuracy (as measured by higher DRs) were less susceptible to change when food deprivation level was altered. In these studies, subjects underwent discrimination training at a single deprivation level. Once a stability criterion was met, discriminated responding was tested under varying magnitudes of food deprivation. Because the criterion only stipulated stability, and not a particular performance level, different subjects achieved different levels of discrimination. When these performances were tested under different deprivation levels, subjects for whom DRs were lower following initial training (i.e., poorer discrimination) exhibited larger decreases in DR when tested under higher deprivation levels. Furthermore, the decreases in DR for these animals under higher deprivation levels was largely due to increased responding during S-. Conversely, increasing food deprivation had relatively little effect on DRs and responses during S- for subjects that achieved more accurate discrimination during initial training. Results similar to these were reported in a follow-up study (Powell, 1973). These studies suggest that a) MO effects on discrimination depend on the extent to which a discrimination has been learned, and b) when increased deprivation does adversely affect a relatively poorly learned discrimination, it largely does so by disproportionately increasing responding to S-. This latter effect seems to provide support to the aforementioned notion that increased MO levels promote generalization (Lotfizadeh et al., 2012), but it also implies that this is more likely to occur when the discrimination between S+ and S- is less well-established.

### **State-Dependent Learning**

Research on state-dependent learning (SDL) is also relevant to understanding the relationship between discriminative stimuli and MOs in the context of discrimination learning. SDL theory states that what is learned can become specific to or come under the



discriminative control of the state of the organism at the time of learning (Overton, 1985). One example of SDL is provided by drug discrimination studies (e.g., Lubinski & Thompson, 1987; Overton, 1966). In these sorts of studies, a particular response may be reinforced in the presence of interoceptive stimuli induced by a certain drug and extinguished either in a non-drug state or in the presence of interoceptive stimuli induced by a different drug. This essentially involves discrimination training in which the interoceptive conditions of a drug serve as an S+, while their absence, or the presence of interoceptive conditions associated with another drug, serve as an S-. SDL is said to be observed when the trained response differentially occurs in the presence of the S+ drug state.

Although most studies of SDL have examined the discriminative properties of drug states, some have investigated the discriminative properties of interoceptive conditions brought about by MOs such as food deprivation/satiation. One example of this is a series of studies conducted by T. L. Davidson and colleagues (Davidson, 1987; Davidson, 1993; Davidson, Flynn, & Jarrard, 1992). In these studies, the authors used a fear conditioning paradigm in which food deprivation or satiation states were a discriminative stimulus for shock. Typically, half of the subjects were placed in the experimental apparatus and received shock in a food deprivation state but did not receive shock in the apparatus in a food satiation state. Conditions for the other half of the subjects were the opposite: they received shock in the food satiation state but not in the deprivation state. These studies demonstrated that animals come to differentially freeze (a measure of conditioned fear) in the deprivation/satiation state in which they have received shock, and the employment of various control measures across the various

experiments strongly suggests that this discrimination is specifically under the control of the interoceptive conditions induced by food deprivation and satiation MOs.

Some recent research has studied SDL in a different way by showing that the effects of extinction may be specific to the motivational state in which it occurs. For example, Schepers and Bouton (2017) established operant responding with rats through reinforcement while the animals were in a state of food satiation. Responding was then extinguished in a series of sessions in a state of food deprivation. Following this, the renewal of extinguished responding was assessed in two tests under extinction conditions, one occurring in the satiation state (i.e., the acquisition context) and the other occurring in the deprivation state (i.e., the extinction context). Renewal of responding was greater in the satiation test, a result the authors interpreted as being due to the fact that the satiation state was the one in which responding was originally acquired. The authors further suggested that responding may have been suppressed in the deprivation state because it was the one in which the animals experienced extinction. Lewon, Thomas, Peters, and Hayes (2020) have demonstrated that state-dependent renewal of extinguished responding can also be observed when a food deprivation state serves as the acquisition context, and extinction occurs in a food satiation state.

Studies of SDL suggest that what is learned during discrimination training may be somewhat specific to the motivational condition in which the training occurs. This means that any discriminative functions that S+ and S- may acquire during training may be differentially observed across different motivational contexts. This possibility has implications in applied settings, where generalization from treatment settings to individuals' natural environments is often an important consideration. Additionally, we

have noted that the stimulus generalization gradient studies reviewed by Lotfizadeh et al. (2012) involved discrimination training under a single motivational condition and then testing for generalization under multiple different motivational conditions. This raises the question of whether higher MO magnitudes during testing actually promote generalization as claimed by the authors, or if they are observed to do so because responding is tested in a motivational context that is different from the one in which discrimination learning occurred. Studying the relationship between MOs during discrimination training and MOs in place when discriminated responding is assessed on a subsequent occasion can contribute to our understanding of these issues.

### **Purpose**

In light of the issues considered above, the aim of this study was to further investigate the interaction between discriminative and motivational variables during operant acquisition and discrimination learning. Two groups of mice underwent a series of operant response acquisition sessions followed by discrimination training sessions under two different motivational states. To assess the role of MOs in these learning sessions, one group (Group 24-hr) received all training sessions under 24-hr food deprivation conditions. The other group (Group 0-hr) received all sessions under food satiation conditions (0-hr food deprivation).

In acquisition sessions, mice learned to approach a receptacle and consume a liquid reinforcer presented on a response-independent variable-time (VT) schedule of reinforcement and subsequently learned to press a lever for the same liquid reinforcer on a fixed-ratio 1 (FR-1) schedule. Following this training, mice were exposed to

discrimination training sessions in which reinforcement and extinction sessions alternated across days. In reinforcement sessions, responding was reinforced in the presence of one compound auditory/visual stimulus (S+). In extinction sessions, responding went unreinforced in the presence of a different compound auditory/visual stimulus (S-). After discrimination training, both groups received two discrimination test sessions in which the S+ and S- stimuli were presented successively in a pseudorandom fashion within sessions. One test was conducted while the subjects were under 24-hr deprivation and one was conducted while the subjects were under 0-hr deprivation. Discrimination in these tests was measured both by the absolute number of responses occurring in the presence of S+ and S- stimuli and by the relative DR measure described above. Comparing the performances of Group 24-hr and Group 0-hr subjects in all phases of the experiment allowed us to assess the effects of motivational states on both acquisition and discrimination learning.

## **Method**

### **Subjects**

28 experimentally naïve female BALB/c mice (Charles River) 9 weeks of age at the beginning of training served as subjects. Subjects were randomly assigned to one of two groups. Subjects within each group were further divided into two subgroups in order to counterbalance discrimination training sessions and discrimination test order.

Outside of experimental sessions, subjects were housed in clear plastic home cages in groups of three or four. Within each cage, bedding, a small house, and enrichment in the form of a wooden chewing stick was available. Subjects had free

access to water throughout the experiment and free access to food when not deprived of food per the deprivation regimen described below. Home cages were kept in a temperature- and humidity-controlled colony room with a 12/12 light/dark cycle with lights on at 7:00 AM. Subjects were weighed daily prior to each experimental session. Subjects were transported to/from home cages and the experimental apparatus with clear plastic handling tubes.

### **Apparatus**

Sessions were conducted using Med Associates (St. Albans, VT) modular mouse operant chambers (ENV-307A). Dimensions inside each chamber are 12.7 cm high  $\times$  15.9 cm wide  $\times$  14.0 cm deep. Each chamber was located inside a sound attenuating cubicle equipped with a ventilation fan to mask ambient noise. A 100 mA house light was mounted to the back chamber wall 10 cm above the grid floor. The chamber was equipped with a dipper receptacle for mouse chamber (ENV-302M-S) (entry port measuring 2.5 cm high  $\times$  2.9 cm wide  $\times$  1.9 cm deep) in the center panel of the front chamber wall. Receptacles were equipped with head entry detectors. The insertion of subjects' heads at least 1 cm into the receptacle broke a beam that allows for the recording of the number and duration of head entries. Reinforcement during both pre-experimental training and experimental sessions was delivered via a 0.06 mL cup attached to the dipper arm. The activation of the dipper raised the cup up into the receptacle where subjects may consume its contents. The chamber was also equipped with a retractable lever (ENV-312-3M) located 3 cm to the left of the dipper receptacle and 2.2 cm above the grid floor. Responses during experimental sessions were defined as subjects using a minimum of 2 grams of force to push the lever down. The recording of

responses and presentation of all stimulus events was controlled using Med-PC IV software (Med Associates, St. Albans, VT).

### **Motivating Operations and Food Deprivation Regimen**

For both groups, experimental sessions were conducted every other day, and both groups were exposed to an alternating 24-hr deprivation/24-hr feeding cycle starting six days prior to the acquisition training sessions described below. During the deprivation periods, food troughs were removed from the subjects' home cages and they had free access to water but no access to food for a 24-hr period. During the feeding periods, food troughs were present in the home cages and subjects had free access to both food and water for a 24-hr period.

For Group 24-hr, all sessions described below were conducted at the end of a 24-hr deprivation period (i.e., under 24-hr food deprivation; see Table 1). Food was returned to the subjects' cages following their sessions. For Group 0-hr, all sessions described below were conducted at the end of a 24-hr free-feeding period (i.e., under 0-hr food deprivation), and food was removed from the subjects' cages following their sessions.

### **Acquisition Training**

Prior to discrimination training, we assessed acquisition learning in dipper and lever press training. These training sessions were designed to teach skills prerequisite to discrimination training: approaching the receptacle/consuming the reinforcer during dipper training and lever pressing for the reinforcer during lever press training. These are described below.

**Dipper Training.** The purpose of these sessions was to train subjects to approach the dipper receptacle and consume the reinforcer from the dipper cup when it was

presented on a VT schedule and establish the sound of the dipper as a discriminative stimulus for the availability of the reinforcer. The reinforcer was a 50/50 mixture of water and sweetened condensed milk (SCM) delivered via a 0.06 mL dipper cup. Sessions began with the illumination of the house light, and the reinforcer was presented on a VT 45-s schedule. The intervals for the VT schedule were programmed through the use of a Fleshler-Hoffman random probability distribution (Fleshler & Hoffman, 1962). When the dipper was presented, it stayed available until the subjects placed their heads in the receptacle. Once a head entry into the receptacle occurred, it broke the head entry detector beam inside the receptacle and the dipper cup remained available for 6-s. After 6-s elapsed, the dipper was lowered and remained unavailable until the VT schedule stipulated the next reinforcer presentation. Throughout all dipper training sessions, the response lever was unavailable. Dipper training sessions ended once the reinforcer was presented and consumed 10 times. The number and duration of head entries when the dipper was up (i.e., available) and down (i.e., unavailable) were recorded. Latencies from the presentation of the dipper to a head entry were also recorded. All subjects completed five dipper training sessions. As shown in Table 1, subjects in Group 24-hr received these sessions under 24-hr food deprivation. Group 0-hr subjects received this training under 0-hr food deprivation.

**Lever Press Training.** The purpose of this training was to train animals to press the lever for the SCM reinforcer. This training occurred in four phases (see Table 2). As in dipper training, all of these sessions occurred under 24-hr food deprivation for Group 24-hr and under food satiation conditions for Group 0-hr. The features of each phase of lever press training is described below.

*Phase A.* At the beginning of the session the house light was illuminated. Following a 10-s interval, the lever was inserted into the chamber. When a response on the lever occurred, the lever was retracted immediately and the dipper was presented (i.e., FR-1 schedule). The lever remained retracted and the dipper cup was available until subjects placed their heads in the dipper receptacle (i.e., no further responding on the lever could occur until the reinforcer was consumed). Once subjects made a head entry into the dipper receptacle, the dipper remained available for 6-s. Following this, the dipper was lowered and the lever was presented again. Sessions ended when subject made five lever presses or 20-min, whichever occurred first. All subjects completed a total of five sessions in this phase.

*Phase B.* Since many subjects were not completing sessions during Phase A (i.e., making five lever presses within 20-min), modifications were made to the training program. Training during this phase was identical to Phase A sessions with two exceptions. First, when a response on the lever occurred, there was a 0.5-s delay between the response and the retraction of the lever (the lever was retracted immediately following a response in Phase A). This was included to provide subjects with additional tactile feedback (i.e., resistance from the lever) when they successfully made a response. Second, a stimulus light was installed directly above the lever. The stimulus light was illuminated anytime the lever was extended into the chamber. This was intended to make it more likely that subjects would coincidentally press the lever when rearing to investigate the stimulus light. Subjects completed five sessions of this procedure.

*Phase C.* An additional modification was made in this phase to make it more likely that subjects who had yet to press the lever after the 10 sessions of Phase A and B



training sessions would do so. The procedure for this phase was identical to Phase B with the exception that three “autoshaping” trials occurred for subjects who did not make a lever press response for 10-min during a given session (these trials did not occur for subjects who were already responding regularly). If 10-min passed without a response, three autoshaping trials separated by 2-min were initiated. On each autoshaping trial, the lever was retracted/inserted into the chamber three times, and this was accompanied by the flashing on/off of the stimulus light above the lever. Following this, the dipper cup was presented noncontingently for 6-s. Following these autoshaping trials, the session returned to the procedure described in Phase B (i.e., no further autoshaping trials occurred and reinforcement only occurred contingent upon lever presses). Subjects completed a total of three Phase C sessions.

*Phase B'.* Following Phase C, subjects were exposed to two additional Phase B sessions as described above.

### **Discrimination Training Sessions**

Following the acquisition training described above, subjects underwent discrimination training. Discrimination training consisted of nine reinforcement and nine extinction sessions<sup>1</sup>. Reinforcement or extinction sessions occurred every other day in a pseudorandom alternating treatments design, with no more than two sessions of the same type (reinforcement or extinction) occurring consecutively. The order of session types was counterbalanced between subgroups. The main dependent variable in these sessions

<sup>1</sup> 15 reinforcement and extinction sessions were proposed initially but nine were ultimately conducted due to institutional research regulations related to COVID-19.

was rate of responding. Reinforcement and extinction session details are described below and in Table 2.

**Reinforcement (RF) Sessions.** Sessions began with the illumination of the house light, the insertion of the lever into the chamber, the illumination of the stimulus light above the lever, and the onset of a 5 kHz tone. The auditory stimulus and the stimulus light above the lever were on continuously during the sessions and were designed to serve as a compound S+ stimulus. Lever pressing during these sessions was reinforced on a variable-ratio 3 (VR-3) schedule with 6-s presentations of the dipper cup containing the same 0.06 mL SCM mixture used during acquisition sessions. The lever was retracted while the dipper was available such that no additional responses could occur while the reinforcer was available. Sessions were terminated when subjects made 15 responses and earned five reinforcers or 20-min, whichever occurred first. At the end of sessions, the house light, auditory stimulus, and stimulus light above the lever were turned off and the lever was retracted.

**Extinction (EX) Sessions.** Sessions began with the illumination of the house light, the insertion of the lever into the chamber, and the onset of a 70 dB click stimulus. The stimulus light above the lever was not illuminated as it was during RF sessions. The click stimulus and the absence of the stimulus light were intended to function as an S- compound stimulus. Lever presses were counted but produced no programmed consequences. Although responses were not reinforced during these sessions, SCM was placed in the inactive dipper so that the absence of the olfactory stimulation from the mixture did not come to serve as an inadvertent extinction cue. Sessions were terminated when subjects made 15 responses or 20-min, whichever occurred first. Upon termination

of the session, the house light and click stimulus were turned off and the lever was retracted.

### **Discrimination Tests**

Following the discrimination training sessions described above, subjects were exposed to two discrimination tests. Within discrimination test sessions, the compound auditory/visual stimuli that served as S+ (tone with stimulus light) and S- (click with no stimulus light) during reinforcement and extinction sessions were presented successively, with a blackout period between each presentation. The first presentation of the S+ or S- compound stimuli occurred randomly (i.e., there was a 50% chance of either stimulus being presented first in the session). Following the first presentation of either S+ or S-, stimuli were alternated for the remainder of the session (e.g., S+, S-, S+, S-, etc.). Each compound stimulus was presented five times, with each presentation lasting 45-s. Each presentation was followed by a 3-s blackout during which the houselight, stimulus light, and auditory stimuli were extinguished and the lever was retracted. Tests occurred under extinction conditions: lever presses occurring in the presence of S+ and S- were recorded but produced no programmed consequences. Nevertheless, as during the extinction sessions, the SCM mixture was placed in the inactive dipper during these tests in an effort to prevent any olfactory cueing. Once the S+ and S- stimuli had been presented five times each, the house light, stimulus light, and auditory stimuli were terminated, the lever was retracted, and the session ended. Both groups received two discrimination tests, one under 24-hr food deprivation and the other under 0-hr food deprivation. The order of tests was counterbalanced between subgroups within Groups 24-hr and 0-hr (Table 2). The dependent variables for these tests were a) the absolute number of responses occurring in

the presence of S+/S- during each test, and b) the DR in each test. This allowed for both within- and between-subjects comparisons of the effects of discrimination training under 24- and 0-hr deprivation.

### **Statistical Analysis**

The experimental design allowed for both within- and between-subject comparisons. Mixed ANOVAs were utilized to conduct statistical analyses on the main effects of group (between-subjects factor) and sessions (within-subjects factor), as well as the session/group interaction. This allowed for comparisons between groups across repeated measures (i.e., across repeated measures obtained in training sessions and discrimination tests).

## **Acquisition Learning Results and Discussion**

### **Results**

**Dipper Training.** Training for all subjects began with five dipper training sessions in which subjects learned to approach and consume the reinforcer from the dipper receptacle when the dipper arm was raised on a VT 45-s schedule. Panel A of Figure 1 shows the mean latency from dipper presentation to head entry into the food receptacle in seconds across dipper training sessions. Subjects in Group 24-hr had a shorter mean latency from the dipper up to head entry in the food receptacle in comparison to Group 0-hr. For subjects in both groups, latency from dipper presentation to head entry decreased across sessions. A mixed ANOVA was conducted on latency measures as described above. This analysis found statistically significant effects for session ( $F_{4, 104} = 13.96, p < 0.001, \eta^2 = 0.35$ ), group ( $F_{1, 26} = 18.59, p < 0.001, \eta^2 =$

0.42), and session/group interaction ( $F_{4, 104} = 3.27, p = 0.01, \eta^2 = 0.11$ ). The significant session/group interaction means that while both groups exhibited shorter latencies to enter the receptacle following the delivery of the reinforcer, Group 24-hr showed more improvement in this measure across the dipper training sessions.

Panel B of Figure 1 shows the mean total number of head entries made across sessions. While the mean number of total head entries increased slightly across dipper training sessions for Group 24-hr, head entries for Group 0-hr stayed approximately the same. A mixed ANOVA found that the main effect for session was significant ( $F_{4, 104} = 29.97, p < 0.001, \eta^2 = 0.54$ ). However the group effect ( $F_{1, 26} = 0.30, p = 0.86, \eta^2 = 0.001$ ) and sessions/group interaction ( $F_{4, 104} = .63, p = 0.64, \eta^2 = 0.24$ ) were not found to be significant. While the visual analysis suggests a higher number of head entries and an increasing trend across sessions for Group 24-hr in comparison to Group 0-hr, this data was not found to be statistically significant. The significant session effects does suggest that the total number of head entries increased across the dipper training sessions.

Panel C shows the mean total duration of head entries in the food receptacle with the dipper up during dipper training sessions. As 10 dipper presentations occurred in each dipper training session and the dipper remained available for 6-s following a head entry, the maximum amount of time subjects could have their heads in the receptacle while the dipper was up in a given session was 60-s. The average duration of head entries for both groups increased over dipper training sessions, but subjects in Group 24-hr consistently kept their heads in the food receptacle while the dipper arm was up for a longer mean duration than for those subjects in Group 0-hr. The mean duration for Group 24-hr approached 50-s by the end of dipper training. In contrast, the mean duration for the

Group 0-hr subjects was approximately 30-s. As duration in the receptacle while the dipper is up can be considered an indirect measure of the amount of the reinforcer consumed, this suggests that Group 24-hr subjects consistently consumed more of the reinforcer than the Group 0-hr subjects with each dipper presentation. A mixed ANOVA found that group effects ( $F_{1, 26} = 0.04$ ,  $p = 0.85$ ,  $\eta^2 = 0.001$ ) were statistically significant. However, session effects ( $F_{4, 104} = 0.81$ ,  $p = 0.52$ ,  $\eta^2 = 0.03$ ) and session/group interaction ( $F_{4, 104} = 1.08$ ,  $p = 0.37$ ,  $\eta^2 = 0.04$ ) were not. These results show that a) the total duration of head entries increased for both groups across sessions (significant session effect), and b) this increased at approximately the same rate for both groups with repeated training (no significant group/session interaction).

**Lever Training.** Following dipper training, subjects received fifteen sessions of lever training during which VT deliveries of the reinforcer were discontinued and the reinforcer was contingent upon pressing a lever on a FR-1 schedule. Figure 2 shows the data from this training. Panel A of shows the mean responses per minute (i.e., rate of responding) for both groups across all phases of lever training. While rate of responding started at approximately the same level in the first session and increased for both groups across training sessions, Group 24-hr subjects consistently responded at a higher rate than Group 0-hr subjects. The mixed ANOVA found that session effects ( $F_{14, 364} = 0.81$ ,  $p < 0.001$ ,  $\eta^2 = 0.485$ ) and group effects ( $F_{1, 26} = 0.04$ ,  $p = 0.003$ ,  $\eta^2 = 0.297$ ) were statistically significant. Session/group interaction was also found to be statistically significant ( $F_{14, 364} = 1.73$ ,  $p = 0.05$ ,  $\eta^2 = 0.485$ ). The significant group and session effects and sessions/group interaction indicates that while rate of responding increased

for both groups across all phases of lever training, Group 24-hr's rate of responding increased more across sessions in comparison to Group 0-hr.

Panel B of Figure 2 shows the mean latency in seconds from a lever press to head entry into the food receptacle. Latency decreased for both groups across lever training sessions. Statistical analysis found that session effects were significant ( $F_{14, 364} = 2.38$ ,  $p = 0.004$ ,  $\eta^2 = 0.84$ ), while group effects ( $F_{1, 26} = .093$ ,  $p = 0.76$ ,  $\eta^2 = 0.004$ ) and group/session interaction ( $F_{14, 364} = 0.58$ ,  $p = 0.88$ ,  $\eta^2 = 0.02$ ) were not significant. This shows that the mean latency decreased across all phases of lever press training for both groups, but the difference between the groups was not significant.

Panel C of Figure 2 shows the total number of subjects completing sessions (i.e., making five lever responses within 20-min) across lever training sessions/phases. While the total number of subjects completing lever training increased for both groups, the number of subjects completing lever training continued to gradually increase for subjects in Group 24-hr. These results make it difficult to identify if the procedural modifications affected subjects in Group 24-hr. However, for Group 0-hr, the procedural changes, specifically phases B and C, seemed to increase the total number of subjects completing the session. By the final lever training session, all 14 subjects completed sessions in Group 24-hr and 10 of 14 subjects completed sessions in Group 0-hr.

## **Discussion**

Figure 1 shows that subjects in Group 24-hr consistently entered the receptacle with shorter latencies when the dipper was presented, made more head entries across all sessions, and kept their heads in the receptacle for longer durations while the dipper available. Although the 24-hr subjects consistently outperformed the 0-hr subjects in

these measures, the improvements observed for both groups across training sessions suggest that the SCM functioned as a reinforcer for subjects in both groups, even though the subjects in the 0-hr group were not deprived of food. Increasingly shorter latencies to receptacle entries for both groups also suggest that dipper training was successful in establishing the sound of the dipper as a discriminative stimulus for receptacle entry behavior for both groups. While these changes in food-related behavior were observed in all measures for Group 24-hr and two of the three measures for Group 0-hr, the degree of change across sessions was greater for the Group 24-hr subjects.

Similar trends were observed during lever training. Rates of responding increased and latencies to receptacle entries following lever presses decreased for both groups across lever training sessions. However, subjects in Group 24-hr responded at substantially higher rates in nearly all sessions and showed greater increases in response rates across sessions. Increases in response rates across sessions were relatively modest for Group 0-hr subjects.

Panel C of Figure 2 shows that the number of Group 24-hr subjects completing sessions (i.e., made five lever presses within 20-min) increased steadily across sessions, and the procedural modifications did not appear to produce any noticeable increases in the number of subjects completing sessions. However, there appear to be increases in the number of 0-hr subjects completing sessions when the modifications in Phases B and C were introduced. Informal observations suggested that once subjects actually made a response, their rates gradually increased across sessions and they were soon completing sessions. Those subjects who never made responses tended to be the ones who continued to not complete sessions. As such, an important issue in this training appeared to be



getting the first lever press to occur, and this generally happened sooner in training for the Group 24-hr subjects. This may be because food deprivation increases general activity and exploratory behavior in many species of rodents (Cornish & Mosrofsky, 1965). The addition of the stimulus light above the lever in Phase B and the autoshaping trials in Phase C seemed to induce more Group 0-hr subjects to emit the first response than had been the case when only the lever was present in Phase A. Future research may investigate whether the higher likelihood of the first lever press in hungry animals is an effect of increased activity/exploration brought about by deprivation and/or due to hungry animals spending more time exploring the front of the chamber where both the lever and the food receptacle are located. The modifications in Phases B and C may be studied systematically to identify the conditions under which non-deprived mice are most likely to emit their first response on a lever or other apparatus.

## **Discrimination Training/Test Results and Discussion**

### **Results**

**Discrimination Training.** Following the acquisition learning sessions, subjects received nine extinction (EX) and nine reinforcement (RF) discrimination training sessions. An important feature of this experiment involved comparing the discrimination test performance of Group 24-hr and Group 0-hr subjects who made the same number of responses during discrimination training (i.e., 135 responses during EX sessions and 135 responses during RF sessions). As such, data from subjects who did not complete all EX/RF discrimination training sessions are excluded from the analyses presented below,

which represent the performance of 12 of the original 14 subjects from Group 24-hr and 9 of the original 14 subjects from Group 0-hr.

Panel A of Figure 3 shows the mean number of responses per minute across EX (left) and RF (right) discrimination training sessions. The figure shows that mean rates of responding increased for both groups across both EX and RF sessions. Additionally, subjects in Group 24-hr consistently responded at higher rates than Group 0-hr. Mixed ANOVA results for rate of responding in EX sessions found significant effects for session ( $F_{8, 152} = 5.185, p < 0.001, \eta^2 = 0.214$ ) and group ( $F_{1, 19} = 14.82, p = 0.001, \eta^2 = 0.43$ ), but not for the session/group interaction ( $F_{8, 152} = 0.813, p = 0.592, \eta^2 = 0.041$ ). Statistical analysis for rate of responding in RF sessions revealed significant effects for session ( $F_{14, 364} = 0.81, p < 0.001, \eta^2 = 0.485$ ), group ( $F_{1, 26} = 0.04, p = 0.003, \eta^2 = 0.297$ ) and the group/session interaction ( $F_{14, 364} = 1.61, p = 0.05, \eta^2 = 0.49$ ). The lack of statistical significance for sessions/group interaction in EX sessions shows that rate of responding increased at approximately the same rate across sessions for both groups. Conversely, in RF sessions the statistical significance of session/group interaction means that Group 24-hr rates increased more rapidly across sessions than Group 0-hr.

Panel B of Figure 3 displays the mean latency to the first response in EX (left) and RF (right) sessions. Latency to the first response decreased for both groups across both EX and RF sessions, and latencies were consistently shorter for Group 24-hr. The mixed ANOVA analysis found a significant effect for group ( $F_{1, 19} = 13.82, p = 0.001, \eta^2 = 0.421$ ) and session effects ( $F_{8, 152} = 3.162, p = 0.002, \eta^2 = 0.92$ ), but not for the session/group interaction ( $F_{8, 152} = 0.306, p = 0.126, \eta^2 = 0.079$ ). The analysis for RF

found significant effects for session ( $F_{8, 152} = 3.162$ ,  $p = 0.002$ ,  $\eta^2 = 0.143$ ) and group ( $F_{1, 19} = 22.22$ ,  $p = 0.002$ ,  $\eta^2 = 0.396$ ) but the session/group interaction fell short of significance ( $F_{8, 152} = 1.925$ ,  $p = 0.06$ ,  $\eta^2 = 0.092$ ). The non-significant group/session interaction effects mean that first response latencies for the two groups decreased across RF and EX sessions at approximately the same rate.

**Discrimination Tests.** After discrimination training sessions, all subjects were exposed to two discrimination tests. One of these was conducted under 24-hr deprivation and the other was conducted under 0-hr deprivation. The dependent variables for these tests were a) the total number of responses, and b) the discrimination ratio (DR) for Groups 24-hr and 0-hr.

Figure 4 shows the mean number of responses made by both groups during each test, as well as the mean number of responses made in the presence of the compound S+ and S- stimuli. In the 24-hr test, subjects in Group 24-hr made more overall responses and more responses in the presence of both S+ and S-. Conversely, in the 0-hr test, Group 0-hr made more overall responses and more responses in the presence of both S+ and S-. In comparing total overall responses during the tests, there was a session effect ( $F_{1, 19} = 5.941$ ,  $p = 0.03$ ,  $\eta^2 = 0.238$ ) and session/group interaction ( $F_{1, 19} = 5.14$ ,  $p = 0.04$ ,  $\eta^2 = 0.213$ ) but the group effect was not significant ( $F_{1, 19} = 0.003$ ,  $p = 0.95$ ,  $\eta^2 = 0.00$ ). Likewise, for the analysis comparing the number of responses made during S+, there was a significant session/group interaction ( $F_{1, 19} = 4.34$ ,  $p = 0.05$ ,  $\eta^2 = 0.186$ ) but no group ( $F_{1, 19} = 0.014$ ,  $p = 0.908$ ,  $\eta^2 = 0.01$ ) or session effect ( $F_{1, 19} = 0.014$ ,  $p = 0.908$ ,  $\eta^2 = 0.01$ ). Finally, the comparison for total responses during S+ found significant effects for

session ( $F_{1, 19} = 7.84, p = 0.01, \eta^2 = 0.292$ ) and session/group interaction ( $F_{1, 19} = 4.312, p = 0.05, \eta^2 = 0.185$ ), but no group effect ( $F_{1, 19} = 0.002, p = 0.998, \eta^2 = 0.00$ ). The most important finding here is the significant sessions/group interactions for total responses, S+ responses, and S- responses. This means that Group 24-hr made significantly more of all types of responses in the 24-hr test, but Group 0-hr made significantly more of all types of responses in the 0-hr test.

Figure 5 shows the DR for the two groups in each test. DR is a measure of discrimination learning and was calculated as described above. Larger DR values indicate better discrimination learning, and the dotted line on Figure 5 marks a DR of 0.5 (i.e., undiscriminated responding; responses occurred as frequently during S+ as during S-). While discriminated responding was not exhibited by subjects in either group, both groups showed slightly better discrimination during the 0-hr test. Nevertheless, the difference between groups on the DR measures in these tests was not statistically significant in terms of test, group, or group/test interaction.

## **Discussion**

Results from discrimination training sessions show that subjects in Group 24-hr made more responses per minute in both RF and EX than subjects in Group 0-hr, but rates increased for both groups across both types of sessions. Similarly, first response latency for both groups decreased across both types of sessions, but subjects in Group 24-hr displayed consistently lower latencies than those in Group 0-hr. A larger difference in these measures of responding between groups can be seen during extinction sessions.

One interesting finding from discrimination training sessions was that response rates were consistently higher during EX sessions. This was likely due to the fact that the

reinforcer was never presented during EX sessions and higher response rates occurred because animals did not periodically have to interrupt responding to consume the reinforcer.

Another interesting result was that response rates gradually increased across EX sessions but remained relatively stable across RF sessions. This was the case for both groups. It is possible that the increases in response rates in EX sessions were due to generalization of the effects of reinforcement that occurred in acquisition learning and RF discrimination training sessions. Although different compound stimuli were designed to aid in bringing about discrimination between RF and EX conditions, most of the contextual circumstances present during EX sessions (including motivational ones) were also present during training sessions in which reinforcement was presented. Some research has suggested that the effects of reinforcement contingencies generalize across settings more readily than the effects of extinction (Bouton, Vurbic, Todd, & Winterbauer, 2011). This may explain the gradually increasing rates across EX sessions. However, we might expect response rates to decrease and/or latencies to the first response to increase in the presence of S- stimuli with more extended discrimination training. Future research should include more discrimination training sessions and monitor these measures of behavior as potential indicators that a discrimination between S+ and S- contexts is forming.

DRs for both groups in the discrimination tests provided further evidence that S+ and S- had not acquired substantive discriminative control over responding. The obtained DR values near 0.5 for both groups in both tests means that responding was essentially undifferentiated across presentations of S+ and S-. However, more extended

discrimination training and/or ensuring that S+/S- have acquired some degree of discriminative control over responding before testing may produce different types of test results.

Perhaps the most notable finding was the observation of clear differences in the number of responses made by the groups in the two tests. Group 24-hr made significantly more responses in the 24-hr test (both during S+ and S-), while Group 0-hr conversely made significantly more responses during both S+ and S- in the 0-hr test. It is possible that these results were obtained because the MO conditions under which responding had been reinforced during acquisition and discrimination training sessions for the respective groups preceding the tests acquired contextual control over responding. We consider some implications and avenues for future research in the subsequent section.

### **General Discussion**

One fundamental issue in the experimental analysis of motivation, and one that lies at the heart of interpreting the results of this study, is the distinction between *learning* and *performance* (Bouton & Balleine, 2019; Domjan, 2015). The distinction has largely arisen from the Pavlovian and associative learning theory traditions. Learning has been described as changes in measures of behavior that occur across repeated exposures to particular environmental stimulus-stimulus or response-stimulus contingencies when all features of a training context are held relatively constant. On the other hand, performance has been described as the extent to which a repertoire of behavior that has been acquired in the “learning” context occurs (and the extent to which it occurs) on subsequent occasions and in different contexts.

For example, arranging a consistent contingency between a response such as a lever press and the delivery of a reinforcer such as food for a hungry animal during training may result in learning that is observed as gradual increases in the rate of lever presses and perhaps shorter latencies to the first response across training sessions. However, even if this training brings about these measures of learning and the behavior reaches steady-state levels in training sessions, the performance of the response on certain occasions may be affected by factors such as changes in features of the exteroceptive stimulus context, fatigue, sickness, or other changes in motivational conditions. If an animal has learned to press a lever for food while food-deprived and is satiated prior to a test session, what has been learned (i.e., lever pressing for food) may not be apparent in terms of performance during the test. In colloquial terms, the animal may have “learned the relation between lever pressing and food” but the extent to which this is learned is not necessarily observed during the test conducted under satiation conditions.

While the conceptual distinction between learning and performance has arisen from scientists outside of the Skinnerian intellectual tradition, implicit interest in this area has appeared to manifest itself in the increasing amount of behavior analytic research in the areas of behavioral momentum (Nevin & Grace, 2000), fluency (Binder, 1996), and the recovery of behavior following extinction (Bouton & Todd, 2014). It also appears to be the basis for the increasing amount of applied behavior analytic research in the areas of maintenance and generalization of behavioral treatment effects (Podlesnik, Kelley, Jimenez-Gomez, & Bouton, 2017; Stokes & Baer, 1977). The shared concern in these research areas is the relationship between the conditions under which behavior is

acquired (i.e., learning) and the conditions under which behavior is assessed or measured under contextual circumstances more or less similar to those prevailing during learning (i.e., performance). Underpinning research in these areas is the acknowledgement that behavior analytic technology is of relatively little value if it is only effective in modifying behavior under the specific contrived conditions of treatment and treatment outcomes are not maintained in, or generalized to, non-treatment settings. The current study contributes to this general area of inquiry by providing some insights into a) the role of MOs during initial learning, and b) performance when MOs prevailing during initial learning are altered.

Comparisons between Groups 24-hr and 0-hr during acquisition learning (dipper training and lever training sessions) and discrimination training sessions illustrated some effects of the role of MOs during initial learning. Both food-deprived and non-deprived mice showed signs of learning from the contingencies involved in dipper and lever training, including shorter latencies to consume the reinforcer following its presentation during dipper training and increased rates of responding on the lever during lever training. However, as evidenced by the significant group/session interaction effects, the relative changes in behavior across training sessions were slightly greater for Group 24-hr. This suggests that if learning is considered to be *relative changes* (in some measure(s) of behavior with repeated exposure to particular contingencies, i.e., within-subject changes in behavior), then learning appears to be brought about slightly more quickly under EO conditions.

Despite the relatively small differences in changes in behavior across sessions, there were pronounced differences between Groups 24-hr and 0-hr in terms of



actual performance in nearly all sessions. Consistent with other studies investigating the effects of MOs on performance, Group 24-hr engaged in more reinforcer-related behavior: more receptacle entries, shorter latencies to consuming the reinforcer, longer durations of consuming the reinforcer, and higher rates of operant lever pressing both during lever training and discrimination training sessions.

The fact that deprived mice engaged in more food-related behavior than satiated mice during training of the sort described here, introduces an interesting methodological obstacle to assessing the role of MOs in learning and performance. Hungry animals are more likely to contact the relevant training contingencies sooner and more frequently than satiated animals, thereby giving them more learning opportunities during any given training session. We attempted to control for this by arranging it such that all training sessions were not time-based and ended only after the animals in Groups 24-hr and 0-hr had the opportunity to make the same number of responses and consume the reinforcer the same number of times. This does not control for any potential effects of rate of reinforcement on learning (Group 24-hr experienced consistently higher rates of reinforcement due to greater rates of receptacle entries and lever presses), nor does it guarantee that all animals actually consumed the reinforcer each time it was available. However, it did ensure that all animals had nominally contacted the same number of response/reinforcer contingencies in RF and EX discrimination training sessions, and the only difference between Groups 24-hr and 0-hr prior to the discrimination tests was the MO conditions under which they experienced these contingencies.

The results of the discrimination tests provided insight into interactions between MOs during initial learning and MOs prevailing during subsequent assessments of

performance. Specifically, they suggest that a response appears to be more likely to occur under the motivational conditions under which it is consistently reinforced. In terms of learning and performance, the results suggest that what is learned is most likely to be observed as performance in situations where the motivational conditions under which behavior is assessed closely match those in which the behavior was initially acquired. This is consistent both with recent research on the contextual control of behavior by exteroceptive stimuli (Bouton & Todd, 2014) and studies of state-dependent renewal where the effects of extinction are confined to the motivational conditions under which extinction occurs (Lewon et al., 2020; Schepers & Bouton, 2017, 2019). From this perspective, motivational states may serve as a part of the learning context and may acquire some discriminative control over responding under the relevant contingencies. One implication of this for application is that behavior analysts must consider the relationship between the MOs prevailing when learning occurs and those that will be in place when behavior is expected to be performed outside of treatment. Further research on the conditions under which motivational state-dependent learning occurs and how it may be mitigated will help develop treatment strategies that enhance maintenance and generalization of the effects of treatment.

## References

- Balleine, B. (1992). Instrumental performance following a shift in primary motivation depends on incentive learning. *Journal of Experimental Psychology: Animal Behavior Processes*, 18(3), 236–250. <https://doi.org/10.1037/0097-7403.18.3.236>
- Binder, C. (1996). Behavioral fluency: Evolution of a new paradigm. *The Behavior Analyst*, 19(2), 163–197. <https://doi.org/10.1007/BF03393163>
- Bouton, M. E., & Balleine, B. W. (2019). Prediction and control of operant behavior: What you see is not all there is. *Behavior Analysis: Research and Practice*, 19(2), 202-212. <http://dx.doi.org/10.1037/bar0000108>
- Bouton, M. E., & Todd, T. P. (2014). A fundamental role for context in instrumental learning and extinction. *Behavioural Processes*, 104, 13–19. <https://doi.org/10.1016/j.beproc.2014.02.012>
- Bouton, M. E., Todd, T. P., Vurbic, D., & Winterbauer, N. E. (2011). Renewal after the extinction of free operant behavior. *Learning & Behavior*, 39(1), 57–67. <https://doi.org/10.3758/s13420-011-0018-6>
- Cornish, E. R., & Mrosovsky, N. (1965). Activity during food deprivation and satiation of six species of rodent. *Animal Behaviour*, 13, 242-248. [https://doi.org/10.1016/0003-3472\(65\)90042-4](https://doi.org/10.1016/0003-3472(65)90042-4)
- Davidson, T. L. (1987). Learning about deprivation intensity stimuli. *Behavioral Neuroscience*, 101(2), 198–208. <https://doi.org/10.1037/0735-7044.101.2.198>
- Davidson, T. L. (1993). The nature and function of interoceptive signals to feed: toward integration of physiological and learning perspectives. *Psychological Review*, 100(4), 640–657. <https://doi.org/10.1037/0033-295X.100.4.640>

- Davidson, T. L., Flynn, F. W., & Jarrard, L. E. (1992). Potency of food deprivation intensity cues as discriminative stimuli. *Journal of Experimental Psychology: Animal Behavior Processes*, *18*(2), 174–181. <https://doi.org/10.1037/0097-7403.18.2.174>
- Dinsmoor, J. A. (1952). The effect of hunger on discriminated responding. *The Journal of Abnormal and Social Psychology*, *47*(1), 67–72. <https://doi.org/10.1037/h0061273>
- Fleshler, M., & Hoffman, H. S. (1962). A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior*, *5*, 529-530. <https://doi.org/10.1901/jeab.1962.5-529>
- Hayes, L., Jacobs, K., & Lewon, M. (2020). Chapter 2. In M. Fryling, R. Rehfeldt, J. Tarbox, & L. Hayes, *Applied behavior analysis of language and cognition: Core concepts and principles for practitioners* (pp. 6-19). Oakland: New Harbinger Publications.
- Laraway, S., Snyckerski, S., Michael, J., & Poling, A. (2003). Motivating operations and terms to describe them: Some further refinements. *Journal of Applied Behavior Analysis*, *36*(3), 407–414. <https://doi.org/10.1901/jaba.2003.36-407>
- Lotfizadeh, A. D., Edwards, T. L., Redner, R., & Poling, A. (2012). Motivating operations affect stimulus control: A largely overlooked phenomenon in discrimination learning. *The Behavior Analyst*, *35*(1), 89-100. <https://doi.org/10.1007/BF03392268>
- Lewon, M., Thomas, J., Peters, C. M., & Hayes, L. J. (2020). Interactions between motivational and discriminative functions of motivating operations in the renewal

of operant responding in mice. *The Psychological Record*, 70(1), 21–31.

<https://doi.org/10.1007/s40732-019-00370-5>

Lubinski, D., & Thompson, T. (1987). An animal model of the interpersonal communication of interoceptive (private) states. *Journal of the Experimental Analysis of Behavior*, 48(1), 1-15. <https://doi.org/10.1901/jeab.1987.48-1>

Michael, J. (1982). Distinguishing between discriminative and motivational functions of stimuli. *Journal of the Experimental Analysis of Behavior*, 37(1), 149–155.

<https://doi.org/10.1901/jeab.1982.37-149>

Michael, J. (1993). Establishing operations. *The Behavior Analyst*, 16(2), 191–206.

<https://doi.org/10.1007/BF03392623>. doi:10.1007/BF00401896

Nevin, J. A., & Grace, R. C. (2000). Behavioral momentum and the Law of Effect.

*Behavioral and Brain Sciences*, 23(1), 73–130.

<https://doi.org/10.1017/S0140525X00002405>

Overton, D. A. (1966). State-dependent learning produced by depressant and atropine-like drugs. *Psychopharmacologia*, 10(1), 6-31.

<https://doi.org/10.1007/bf00401896>

Overton, D. A. (1985). Contextual stimulus effects of drugs and internal states. In P. D. Balsam & A. Tomie (Eds.), *Context and learning* (pp. 357-384). Hillsdale, NJ: Erlbaum.

Podlesnik, C. A., Kelley, M. E., Jimenez-Gomez, C., & Bouton, M. E. (2017). Renewed behavior produced by context change and its implications for treatment

maintenance: A review. *Journal of applied behavior analysis*, 50(3), 675–697.

<https://doi.org/10.1002/jaba.400>

- Powell R. W. (1971). Evidence of interaction between deprivation effects and stimulus control. *Journal of the Experimental Analysis of Behavior*, 16(1), 95–104.  
<https://doi.org/10.1901/jeab.1971.16-95>
- Powell R. W. (1973). Effects of stimulus control and deprivation upon discriminative responding. *Journal of the Experimental Analysis of Behavior*, 19(2), 351–360.  
<https://doi.org/10.1901/jeab.1973.19-351>
- Rilling, M. (1977). Stimulus control and inhibitory processes. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 432-480). Englewood Cliffs, NJ: Prentice-Hall.
- Schepers, S. T., & Bouton, M. E. (2017). Hunger as a context: food seeking that is inhibited during hunger can renew in the context of satiety. *Psychological Science*, 28(11), 1640–1648. <https://doi.org/10.1177/0956797617719084>
- Schepers, S. T., & Bouton, M. E. (2019). Stress as context: Stress causes relapse of inhibited food seeking if it has been associated with prior food seeking. *Appetite*, 132, 131-138. <https://doi.org/10.1016/j.appet.2018.10.016>
- Stokes, T. F., & Baer, D. M. (1977). An implicit technology of generalization. *Journal of applied behavior analysis*, 10(2), 349–367. <https://doi.org/10.1901/jaba.1977.10-349>
- Thomas, D. R., & King, R. A. (1959). Stimulus generalization as a function of level of motivation. *Journal of Experimental Psychology*, 57(5), 323–328.  
<https://doi.org/10.1037/h0042183>

**Tables**

Table 1.

*Order and Number of Sessions*

Phase	Procedure	Sessions
Acquisition Training	Dipper Training	5
	Lever Training	15
Discrimination Training/Testing	Reinforcement Sessions	9
	Extinction Sessions	9
	Discrimination Tests	2

Table 2.

*Lever Training Procedural Details*

---

Phase	Details
Phase A	Lever only, lever retracted immediately upon response (i.e., no tactile feedback from lever resistance).
Phase B	Lever and stimulus light above lever. Lever retracted 0.5 s following a response (i.e., tactile feedback from lever resistance).
Phase C	Same as Phase B but three autoshaping trials if no responses in 10 min.
Phase B'	Same as Phase B.

---



Table 3.

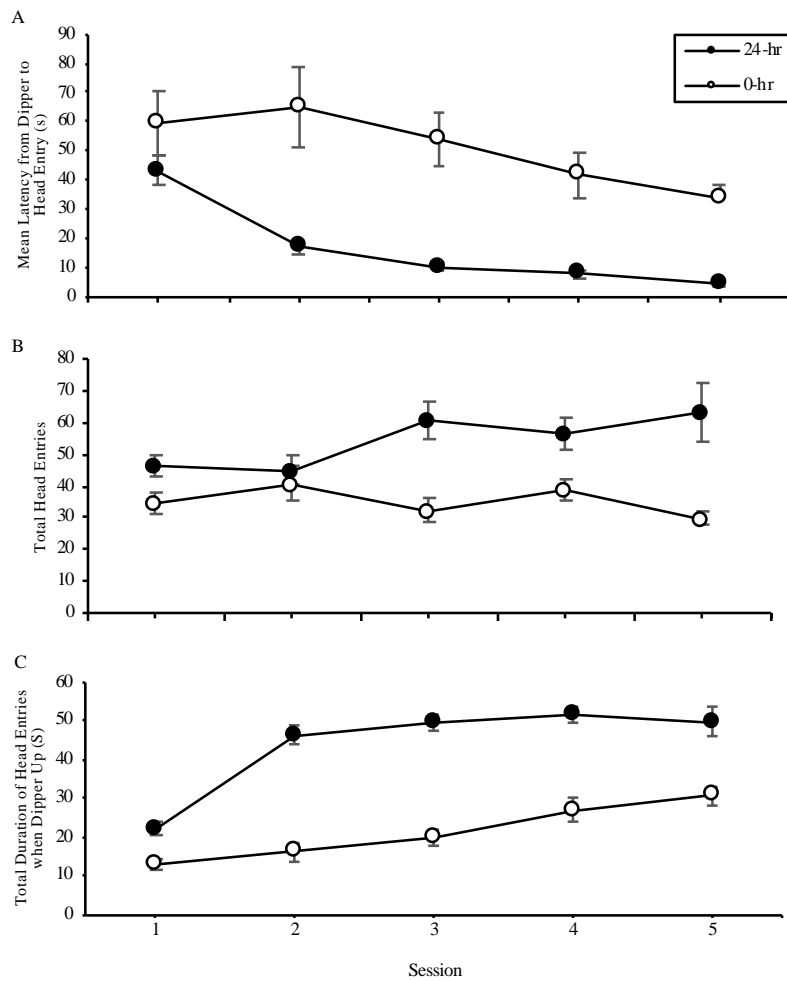
*Discrimination Training and Testing Details by Subgroup*

	Group A 0-hr (n=7)	Group B 0-hr (n=7)	Group A 24-hr (n=7)	Group B 24-hr (n=7)
1 <sup>st</sup> Session	RF	EX	RF	EX
RF/EX Session Deprivation	0-hr	0-hr	24-hr	24-hr
Test 1 Deprivation	0-hr	24-hr	0-hr	24-hr
Test 2 Deprivation	24-hr	0-hr	24-hr	0-hr

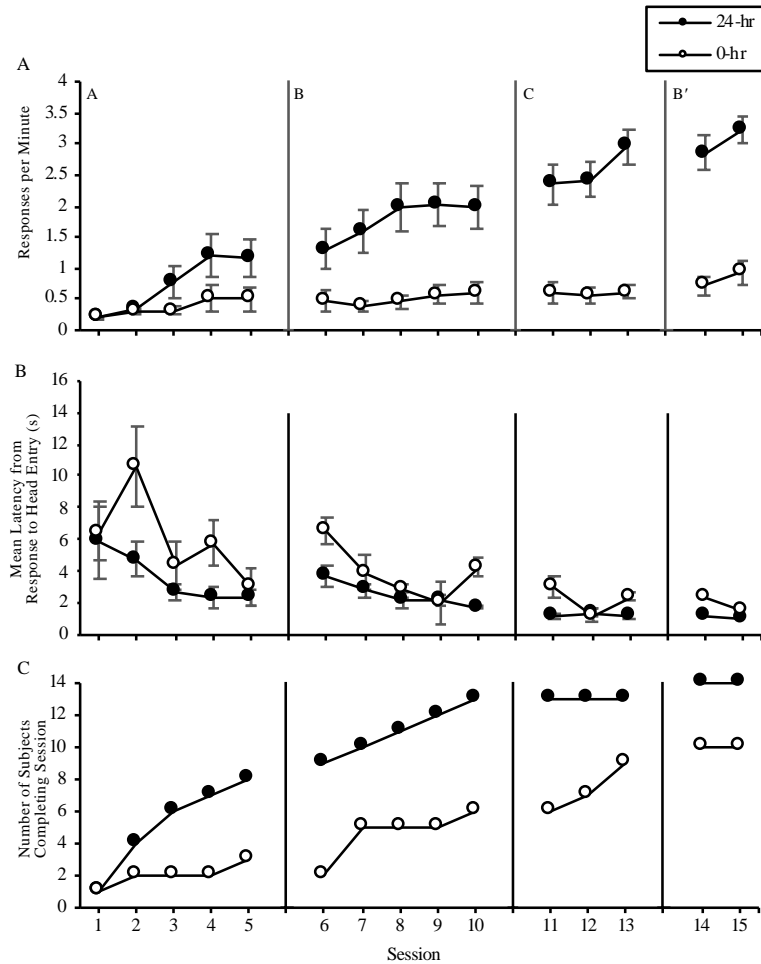
## Figures

**Figure 1**

*Measures of Responding in Dipper Training Procedure*

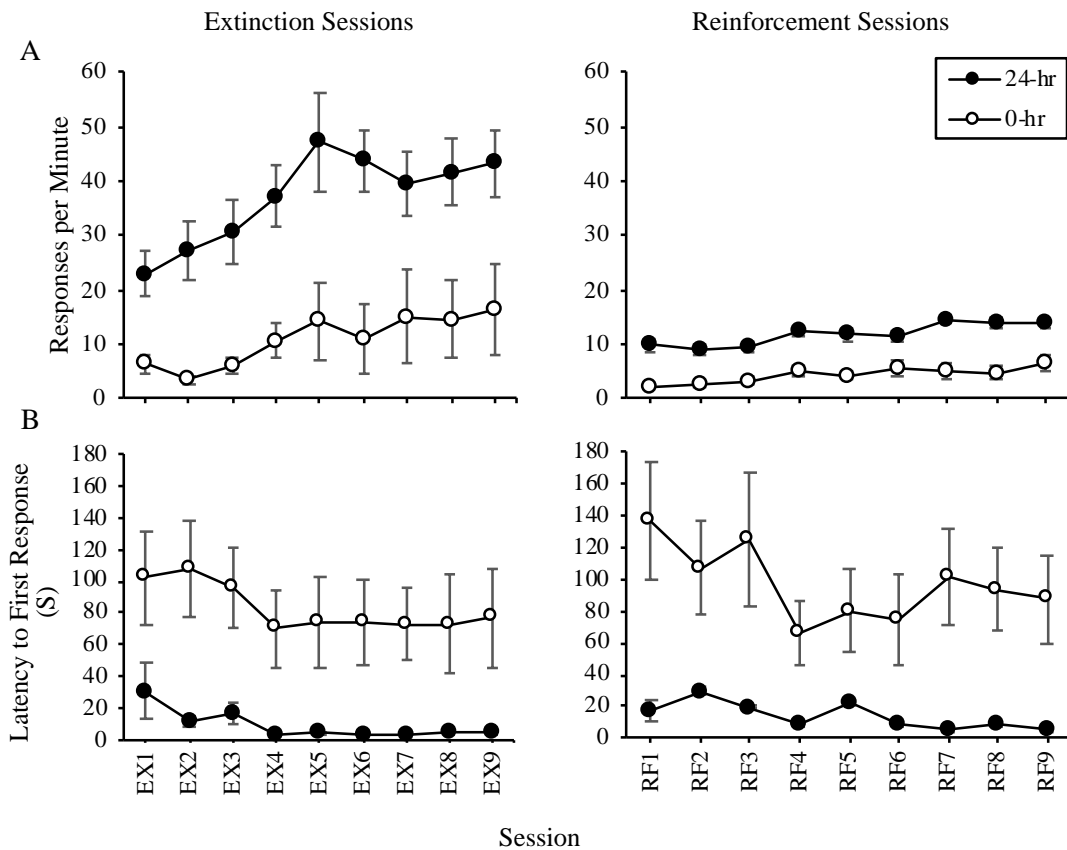


Note. Measures of responding ( $\pm$ SEM) in the 24-hr and 0-hr groups across dipper training sessions. Panel A shows the mean latency in seconds from dipper presentation to head entry into food receptacle. Panel B shows the mean number of total head entries occurring throughout dipper training sessions. Panel C shows the mean total duration of head entries into food receptacle while dipper is presented.

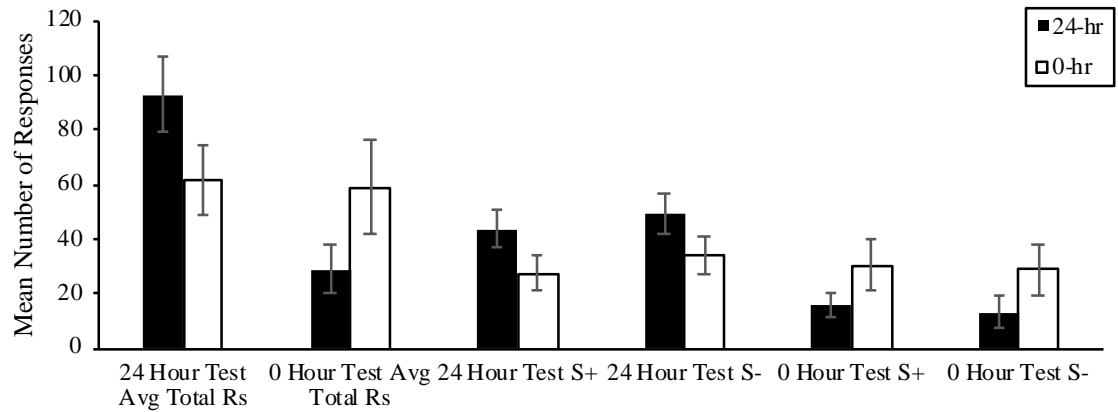
**Figure 2***Measures of Responding in Lever Training Procedure*

Note. Measures of responding across all phases of lever training sessions (+/-SEM).

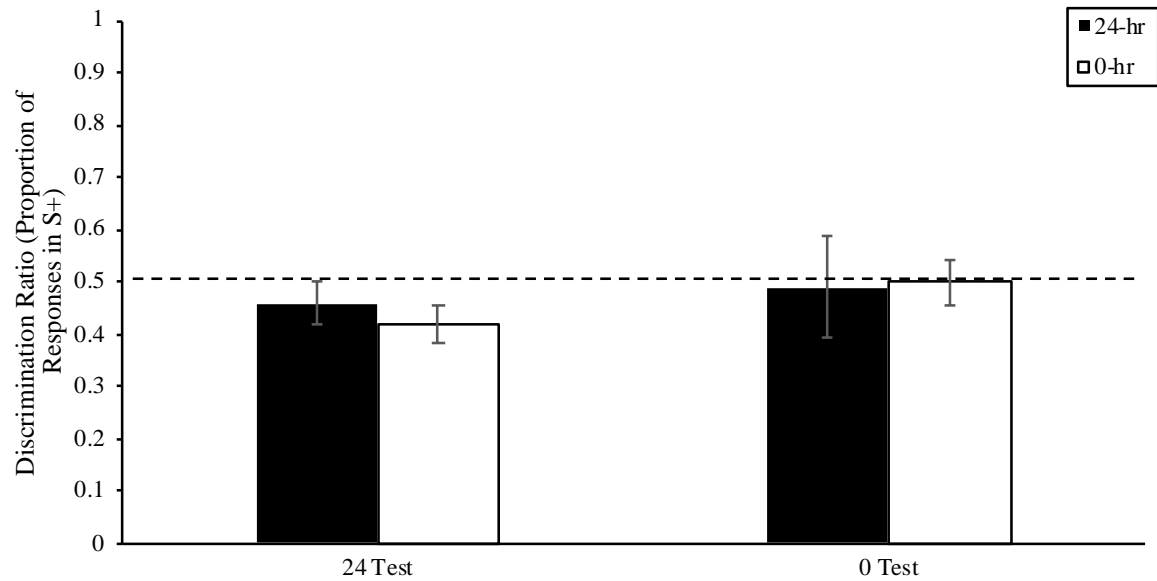
Panel A shows the mean responses per minute for the 24-hr and 0-hr groups during each phase of lever training. Panel B shows the mean latency from lever pressing (response) to head entry into the food receptacle. Panel C shows the number of subjects completing sessions during each phase of training.

**Figure 3***Measures of Responding in Reinforcement and Extinction Training Procedure*

Note. Measures of responding in extinction (EX; left) and reinforcement (RF; right) discrimination training sessions ( $\pm$ -SEM) for the 24-hr and 0-hr groups. Panel A shows mean responses per minute during each session. Panel B shows the mean latency to the first response in seconds for each session type.

**Figure 4***Absolute Responding in Discrimination Tests*

Note. Shows measures of subjects responding ( $\pm$ SEM) in the 24-hr and 0-hr discrimination tests for subjects in the 24-hr and 0-hr groups. The mean total of responses made in the presence of the S+ and S- stimuli are also shown in this figure.

**Figure 5***Discrimination Ratio in Discrimination Tests*

Note. Shows the mean proportion of responses made in the presence of the S+ stimulus (+/-SEM) during the 24-hr and 0-hr discrimination test for the 24-hr and 0-hr groups. The discrimination ratio was calculated by dividing the number of responses made in the presence of the S+ by the total number of responses made during the entire session.