Effects of Altering Motivation in Pigeons Performing a Titrating-Delayed-Matching-To-Sample Task

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EFFECTS OF ALTERING MOTIVATION IN PIGEONS PERFORMING A TITRATING-DELAYED-MATCHING-TO-SAMPLE TASK

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In order to better understand the role motivating operations (MOs) serve in preceding and evoking behavior, it is useful to examine the effects of whether manipulating motivation can influence performance on tasks with known behavioral outcomes. It is well established that altered stimulus control is responsible for changes in responding on tasks of generalization and discrimination. Therefore, if stimulus control could be influenced by MOs, then perhaps stimulus discriminations could be improved by manipulating the relevant MO. To this end, the effects of altering motivation via food deprivation were examined in pigeons using a titrating-delayed-matching-to-sample task. Additional pharmacological variables (i.e., scopolamine and nicotine) were introduced to determine if performance could be improved and/or deficits could be attenuated by these drugs, respectively. Results indicate that aspects of performance varied systematically as a function of deprivation level alone, though not in combination with acute administration of scopolamine and/or nicotine. Further research on the effects of motivation on current responding is needed to more effectively analyze environment/behavior relations.
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Zachary J. Zimmermann
TABLE OF CONTENTS

ACKNOWLEDGMENTS ........................................................................................................ ii

LIST OF FIGURES ........................................................................................................ v

INTRODUCTION ........................................................................................................... 1

  Motivation ................................................................................................................ 1

  Delayed-Matching-to-Sample .............................................................................. 4

  Models of Cognitive Impairment ..................................................................... 7

    Cognitive Impairment ................................................................................. 7

    Cognitive Enhancement .......................................................................... 9

METHOD ..................................................................................................................... 11

  Subjects ......................................................................................................... 11

  Apparatus ..................................................................................................... 12

  Procedure ...................................................................................................... 12

    Autoshaping ............................................................................................... 13

  Phase I .......................................................................................................... 13

    Training .................................................................................................... 13

    Testing .................................................................................................... 14

  Phase II .......................................................................................................... 15

    Training .................................................................................................... 15

    Testing .................................................................................................... 15

  Phase III ...................................................................................................... 16
Table of Contents — Continued

Training .................................................................................................................. 16
Testing ...................................................................................................................... 16
Phase IV .................................................................................................................. 17
  Training .............................................................................................................. 17
  Testing .............................................................................................................. 17
RESULTS .............................................................................................................. 18
  Phase I .............................................................................................................. 18
  Phase II .......................................................................................................... 20
  Phase III ......................................................................................................... 23
  Phase IV ......................................................................................................... 25
  Data Analysis ................................................................................................. 27
DISCUSSION ....................................................................................................... 27
REFERENCES .................................................................................................... 33
APPENDICES ...................................................................................................... 40
  A. Institutional Animal Care and Use Committee Approval Letter .................... 40
  B. Cumulative Record—Phase I ........................................................................ 42
  C. Delay Across Session—Phase I .................................................................... 44
  D. Cumulative Record—Phase II ...................................................................... 46
  E. Delay Across Session—Phase II .................................................................. 48
  F. Cumulative Record—Phase III ..................................................................... 50
  G. Delay Across Session—Phase III ................................................................. 52
Table of Contents — Continued

H. Cumulative Record—Phase IV ................................................................. 54
I. Delay Across Session—Phase IV ............................................................. 56
J. Grouped Response Measures Graph ..................................................... 58
K. Trials Initiated Graph ........................................................................... 60
L. Response Latency Graph ....................................................................... 62
LIST OF FIGURES

1. Phase I Accuracy ........................................................................................................... 19
2. Phase I Response Rate ................................................................................................ 19
3. Phase I Maximum Delay Reached .............................................................................. 20
4. Phase II Accuracy ........................................................................................................ 21
5. Phase II Response Rate ............................................................................................. 22
6. Phase II Maximum Delay Reached ........................................................................... 22
7. Phase III Accuracy ....................................................................................................... 23
8. Phase III Response Rate ............................................................................................ 24
9. Phase III Maximum Delay Reached .......................................................................... 24
10. Phase IV Accuracy ..................................................................................................... 25
11. Phase IV Response Rate .......................................................................................... 26
12. Phase IV Maximum Delay Reached .......................................................................... 27
INTRODUCTION

Motivation

The term *motivation* has been used fairly loosely in a wide variety of contexts both outside and within the field of behavior analysis (e.g., Lotfizadeh, Edwards, & Poling, 2014). However, within the experimental analysis of behavior, the definition of what constitutes and influences motivational variables is much more precise. Skinner (1938), in one of the earliest behavior analytic works, discussed the importance and role of motivation surrounding the occurrence of behavior. Specifically, the ways in which feeding and fasting influence the occurrence of behavior in the context of food or food-paired stimuli examined in a series of experiments with rats. Two types of effects on behavior are outlined as being relevant to the role of motivation in responding—both increasing and decreasing levels of deprivation were showcased as having differing effects on behavior, strengthening or weakening a consummatory response.

Though Skinner (1938) addressed the behavioral influences of motivation, the concept was left largely unexamined by behavior analysts for a prolonged period of time thereafter (see Michael, 1993). It was not until Michael (1982) reexamined motivation from a conceptual standpoint, that a more succinct and formal definition of the establishing operation (EO) was put forth. In addition to a number of publications in a series of others on the subject (see Laraway, Snyderski, Michael, & Poling, 2003), motivation was once again garnering the widespread attention of both experimental and applied behavior analysts alike.

Michael (1982) suggested that EOs have a variety of effects on behavior, both in evoking behavior as well as suppressing its occurrence. As such, these effects were
categorized as being either *evocative* or *abative* in nature. Additionally, the effects of EOs on altering the value of reinforcers were discussed as being either *establishing* or *abolishing* in nature. In presenting the concept of the EO, several different complex types of EOs were outlined, and the role of conditioning in the development of some of these extensions was posited as being a main contributor to some of the more complex situations often observed among human populations (Michael, 1993). These modified types of EOs are considered conditioned establishing operations (CEOs), of which there are three subtypes 1) surrogate, 2) transitive, and 3) reflexive.

Since Michael’s (1982) initial publication, the original terminology has been refined and amended to ‘motivating operations’ (MO) for clarification purposes and to more accurately reflect the processes underlying the general conceptual framework (Laraway et al., 2003). Within behavior analysis, the term *motivation* generally refers to an organism’s drive to behave toward a particular goal. The concept of the MO is related to the broader view of behavior in that MOs influence how an organism will respond under a particular set of conditions. More specifically, MOs are defined as environmental conditions or preparations that alter the reinforcing or punishing efficacy of stimuli, as well as the likelihood that a behavior resulting in those stimuli will be emitted. Laraway et al. (2003) suggested two major classifications of the effects of MOs—*behavior-altering* and *value-altering*. The *behavior-altering* effect of MOs refers to their ability to either evoke or suppress behavior that has in the past led to a relevant consequence. For instance, if a rat has been trained to press a lever for food reinforcement, food deprivation will serve to evoke lever pressing. Simultaneously, responses that have historically resulted in the removal of food will be suppressed. *Value-altering* effects are comparable
in that they affect an organism’s behavior, though as a result of a change in the value of a relevant consequence. In the example of the food-deprived rat, implementing food deprivation has altered the value of food as a reinforcer. These two processes of altering the probability of behavior, as well as the value of relevant stimuli as consequences, combine to form what has been termed motivation.

In order to better understand the role MOs serve in controlling behavior, it is useful to examine the effects of whether systematically manipulating motivation on tasks with known behavioral outcomes could influence performance. Given that altered stimulus control is responsible for changes in responding on tasks of generalization and discrimination, if stimulus control could be influenced by MOs, than perhaps stimulus discriminations could be improved upon by manipulating the relevant MO. To this end, an examination of the relationship between motivation and stimulus control may prove to be a useful endeavor. Lotfizadeh, Edwards, Redner, and Poling (2012) conducted a literature review of publications that investigated the effects of manipulating MOs on subsequent stimulus control. Although discrepancies in results between studies were noted, many studies demonstrated that altering MOs, primarily through food and water deprivation, influenced the extent to which organisms would respond in the presence of a range of exteroceptive stimuli, as well as their response strength in the presence of those stimuli (Lotfizadeh et al., 2012).

Lotfizadeh et al. (2014) conducted an experiment further exploring the influence of MOs on stimulus control within a drug discrimination paradigm. By training rats using a variation on a classic drug discrimination procedure, researchers were able to assess whether stimulus control, with regard to interoceptive drug stimuli, was affected by food
deprivation. Lotfizadeh et al. (2014) found that increasing, rather than decreasing, food deprivation relative to baseline conditions negatively affected rats’ drug-appropriate lever responses. Though novel with regard to the use of that particular procedure, this phenomenon has previously been observed in other types of procedures outside of the context of drug discrimination.

Observance of the effects of motivation on generalization and discrimination occurred nearly six decades prior to the aforementioned research. Thomas and King (1959) produced similar deprivation-dependent effects while examining the performance of pigeons maintained at differing free-feeding bodyweight percentages. Mean number of responses emitted under a variable-interval schedule indicated that mean responses, during varying untrained stimulus conditions presented under extinction, varied as a function of the degree of physical similarity between the conditioned stimulus and the unfamiliar stimuli (i.e., stimulus generalization). Additionally, the shape of the curve generated by plotting the mean responses by each stimulus condition shifted as a function of the level of free-feeding bodyweights. Specifically, the Gaussian-nature of the resulting generalization curves flattened and diminished as the percentage of free-feeding bodyweights decreased. These findings further demonstrate that manipulation of MOs can affect stimulus control with regard to a wide range of stimuli dependent upon the method of preparation.

Delayed-Matching-to-Sample

The delayed-matching-to-sample (DMTS) procedure lends itself to examining the contributing variables to stimulus control, a concept that plays a key role in what has
been commonly termed short-term, or working memory (Wenger & Wright, 1990). More specifically, the DMTS procedure assesses the extent to which external sample stimuli exert control over choice of comparison stimuli after various delays. Increasing the delay between the termination of the sample stimulus and the onset of the comparison stimuli is the primary manipulation when assessing stimulus control and effects on short-term memory using this paradigm.

In a typical DMTS procedure, a sample stimulus is presented (e.g., either a red or green illuminated key) that requires a specified response criteria be fulfilled (often referred to as an observing response). Following fulfillment of this requirement, two comparison stimuli, one matching and one non-matching, are presented. Reinforcement is delivered contingent upon a response to the stimulus corresponding to the sample, while a time-out period typically follows any incorrect responses. Increasing the delay between the termination of the sample stimulus and the onset of the comparison stimuli results in declining accuracy in selecting the correct corresponding stimulus. However useful, some limitations of the DMTS procedure exist, including the presence of floor and ceiling effects. A number of variations on a typical DMTS procedure exist, including positional tasks as well as those with adjusting delays. A titrating-delayed-matching-to-sample (TDMTS) procedure, which has existed for some time (see Cumming & Berryman, 1965), may avoid the previously mentioned limitations with more commonly used DMTS variants (Kangas, Vaidya, & Branch, 2010; Porritt & Poling, 2008; Wenger & Wright, 1990). The primary advantage of utilizing a titrating procedure is that the delay can be lengthened or shortened by a given unit of time based upon the current performance of the subject. Consequently, the more accurately a subject responds to the comparison
stimuli, the longer the delay becomes between the sample and comparison stimuli, making it possible to locate the maximum delay at which responding is reliably accurate. Through the use of a TDMTS procedure, it is possible to repeatedly assess the maximum delay at which subjects can respond accurately and no floor or ceiling effect is necessarily imposed. Therefore, by utilizing a TDMTS procedure to repeatedly measure stimulus control, it is possible to gain further insight into the effects of motivation on stimulus control and short-term memory.

In perhaps one of the only published works on the effects of MOs on DMTS, Cumming and Berryman (1965) briefly detailed an attempt at examining the role that motivation plays in responding. Three birds with an extensive history of DMTS responding were tested under two separate conditions, and the accuracy of their performance was then examined. For the first set of conditions, the birds were reduced to 80% of their free-feeding bodyweight and subsequently tested for four sessions until responding indicated that they were satiated. The second set of conditions also required that the birds be maintained at 80% of their free-feeding weight, with the addition of the access to 10% of their body weight in food for two hours prior to the session. Birds were also exposed to this set of conditions for four sessions, and were allowed to respond until satiation was observed. Accuracy data were then compared from the early and late trials of the satiation sessions to overall session accuracy for the pre-fed satiation sessions. Results showed that across varying delays (0-24s), the effects of altering motivation was mixed, though there was more accurate performance across birds at longer delays when birds were fed prior to sessions. Though performance was examined at differing delay intervals, the breadth of delay values tested was relatively small, with the majority of the
delays ranging from 0-10s, with the exception of the maximum delay value of 24s. Indeed, it has been demonstrated that birds can accurately discriminate over relatively large delay intervals and the interval at which performance remains accurate is dependent upon the subject and training procedure (Poling, Temple, & Foster, 1996). Furthermore, delay intervals were presented in randomized order, such that from trial to trial one subject could experience a range of delays, independent of the previous trial’s performance.

Though few studies have examined the role of motivation within an experimental context (Cumming & Berryman, 1965; Li, Garner, Wessinger, & McMillan 1995; Lotfizadeh et al., 2012; Lotfizadeh et al., 2014; Thomas & King, 1959), the results of such research suggest that manipulating motivation relative to training conditions can have an effect on performance. However, what remains unclear is how differing aspects of performance (i.e., response rate, accuracy, latency, topography) are affected by these manipulations.

Models of Cognitive Impairment and Enhancement

Cognitive Impairment

In order to compare any potential effects that altering MOs may have on stimulus control, a negative control is a useful tool that is available to researchers. A negative control condition is employed in a variety of experimental arenas, notably in the biomedical sciences, in order to aid researchers in drawing conclusions about a given treatment effect. Rather than a certain number of subjects serving as a no-treatment or control group, researchers can use a treatment that is known to produce effects opposite
to those anticipated by modifying the particular variable of interest. Given the findings of Lotfizadeh et al. (2014) regarding improvements/decreases in performance, the use of a compound that is known to produce impairments in performance on DMTS tasks could aid in comparing and contrasting the effects of increasing or decreasing motivation relative to baseline conditions.

Scopolamine is a popular compound used as a negative control when assessing memory, and a widely used model of cognitive impairment in non-humans. Scopolamine administration has a lengthy history in experimental work as a model for cognitive impairment, due to the changes caused in behavior as a result of altered neurotransmission (for an excellent review, see Klinkenberg & Blokland, 2010). Scopolamine acts as a competitive antagonist at muscarinic acetylcholine (ACh) receptors, effectively preventing the cascade of intracellular communications which occur via the G protein second messenger system. Though clinically implicated in the treatment of motion sickness (transdermal patch) and postoperative nausea, other types of ACh antagonists are marketed to the general public with a variety of over-the-counter uses (e.g., atropine, dimenhydrinate (Dramamine®), and diphenhydramine (Benadryl®)).

Scopolamine not only serves as a treatment for some conditions, but its administration is also used to model a number of different conditions, namely Alzheimer’s-related dementia (Buccafusco, 2009) and schizophrenia (Shekhar et al., 2008). However, the effects of scopolamine are not simply restricted to performance on tasks related to cognition. Drug interactions, and especially high doses of scopolamine, have also been shown to induce hallucinations (MacEwan, Remick, & Noone, 1985; Warburton, Wesnes, Edwards, & Larrad, 1985) as well as impair locomotor activity.
(Klinkenberg & Blokland, 2010). Additionally, a number of other physiological effects of scopolamine administration (e.g., tachycardia, mydriasis, blurred vision, reduced salivation) have been repeatedly noted in the literature, and are often undesired side effects of the drug treatment itself (Klinkenberg & Blokland, 2010).

Though scopolamine administration may have been a historically popular model of cognitive impairment, there are a number of notable limitations associated with its use that have garnered the attention of researchers. At the neuronal level, scopolamine acts as a nonspecific ACh antagonist, though it is believed that its action is primarily mediated by the M1 and M5 muscarinic receptor subtypes (Klinkenberg & Blokland, 2010). As a result of having multiple sites of action, scopolamine has been associated with a number of undesired side effects (e.g., pupil dilation, reduced salivation, or constipation). Additionally, particularly high doses have been shown to also block nicotinic receptors (Klinkenberg & Blokland, 2010). Currently, more research is being conducted on related compounds that target other specific receptor subtypes. Through the use of specific receptor-targeting compounds, it is possible to circumvent some of the other issues commonly associated with scopolamine administration. Though scopolamine administration is effective in disrupting multiple aspects of performance, it is clear that newer, site-specific drugs have clear advantages to their use.

Cognitive Enhancement

Constructing a model of cognitive impairment is useful if one wishes to study the changes that can accompany cognitive decline. However, arguably the main importance of such as model is dependent upon being able to have compounds with which one can
potentially reverse or attenuate such deficits. Nicotine is one such drug that has been studied extensively by behavioral pharmacologists and scientists at large as having potential nootropic properties. Though renowned for being a key contributing factor in tobacco dependence, nicotine has been demonstrated to improve performance on a variety of tasks in both humans (Mumenthaler et al. 2003) and nonhumans (Buccafusco & Jackson, 1991). Similar to that of scopolamine, nicotine’s primary mechanism of action involves similar, but opposite actions at ACh receptors, through acting as a nicotinic acetylcholine receptor agonist. With a growing population of aging adults, potential pharmacological remedies have seen an increase in the time and resources being allotted to studying such compounds. Through the use of both modeling a cognitive impairment and administration of a putative nootropic (i.e., nicotine), results can help to provide evidence for, or against, the potential therapeutic value for such a drug.

While MOs and their effects on stimulus control have been studied using other behavioral paradigms (Gaiardi, Bartoletti, Bacchi, Gubellini, & Babbini, 1987; Li et al., 1995; Lotfizadeh et al., 2012; Massey & McMillan, 1987; Thomas & King, 1959), the influences of motivation under DMTS procedures and their variations have not yet been fully explored. It has been previously demonstrated that manipulating food deprivation prior to tasks assessing stimulus discrimination has an effect on generalization gradients (Thomas & King, 1959). However, what is not known is how such variables may influence stimulus control on other behavioral tasks. The purpose of the present study was to investigate the effects of altering the motivation of pigeons responding for food under a TDMTS procedure. The effects of this manipulation were then compared to those of administering scopolamine, a drug known to disrupt short-term memory and impact
stimulus control. Though some limitations associated with scopolamine have already been noted, its use in the present study was deliberate with regard to its known effects on learning and performance. Additionally, deprivation-dependent effects of nicotine, alone and in combination with scopolamine, were examined. The use of both food deprivation and pharmacological manipulations, in combination, allows for comparisons to be made between the previously demonstrated disruptive effects of scopolamine on DMTS responding and any observed in the presence of varying food deprivation conditions. Results were expected to provide useful information about the effects of motivation on stimulus control and memory, and about the sensitivity of responding under TDMTS procedures to variables known to disrupt performance under typical DMTS procedures.

**METHOD**

**Subjects**

Four female White Carneau pigeons (17761, 17443, 18921, and 3375) (Palmetto Pigeon Plant, Sumter, SC) were used for the current experiment. Birds had previously served as experimental subjects in non-pharmacologically-based behavioral research, and had an extensive history with responding via key-pecks. Due to mechanical failure, one bird (3375) participated in the deprivation-only condition and was excluded thereafter. Six experimental sessions were conducted per week (Monday-Saturday) at approximately the same time each day during the light cycle. Subjects were individually housed with *ad libitum* access to water and health grit. Subjects were food deprived for 22 hr (*moderate deprivation*) prior to training sessions and for 11 (*low deprivation*), 22, or 44 (*high deprivation*) hours prior to test sessions. Subjects were housed and maintained in
accordance with the *Guide for the Care and Use of Laboratory Animals* (National Research Council, 2011).

**Apparatus**

Experimental sessions were conducted using commercial three-key operant chambers measuring approximately 30 cm by 24 cm by 29.5 cm (Med Associates, St. Albans, VT). Chambers were housed within sound-attenuating cubicles, each equipped with an exhaust fan providing ventilation and masking noise. All keys were functional throughout the duration of the study and were capable of being illuminated red, green, or white. The center of each 2-cm diameter key was located 21.5 cm from the floor panel. The center key was 5.5 cm from each side key. Reinforcement consisted of 3s access to a solenoid-operated hopper filled with mixed grain that was raised into an aperture centered on the base of the work panel. The food hopper was only briefly illuminated during reinforcement. General illumination was provided, except during reinforcer delivery, by a 28 V light opposite the food hopper, located 28 cm above the floor panel. A personal computer operating MED-PC IV®, in conjunction with a Med-Associates interface (Med Associates, Inc., St. Albans, VT), recorded data and controlled all experimental events.

**Procedure**

Prior to implementing experimental procedures, all research personnel were trained in accordance with guidelines established by the Collaborative Institutional Training Initiative (University of Miami, Miami, FL) as well as those by the Institutional Animal Care and Use Committee of Western Michigan University.
Autoshaping

Birds were shaped to key peck using forward-pairing autoshaping techniques (Brown & Jenkins, 1968; Picker, Blakely, & Poling, 1986). After a pseudorandomly determined intertrial interval (ITI) had elapsed, one of three response keys was illuminated one of three colors (red, green, or white) for 6s. If a response was made on the key while it was illuminated, the key light was extinguished and the hopper was raised for 3s. If a response was not made before the 6s key illumination elapsed, the key light was extinguished and the hopper was raised for 3s. Sessions concluded after the passage of 30 minutes or 30 reinforcers were delivered, whichever occurred first. ITIs were based upon the progression outlined by Fleshler and Hoffman (1962). Birds progressed onto the TDMTS phase of the experiment once key pecking was reliably established under the autoshaping procedure for at least two sessions, or after attempts at hand shaping had reliably established key pecking responses.

Phase I

Training

Experimental training sessions were conducted six days per week and closely resembled the methods employed by Poling et al. (1996). Training sessions were conducted while the pigeons were 22 hr (moderate) food-deprived. Training consisted of the presentation of either a red or green sample stimulus on the center response key. Subjects were required to peck the key five times (FR 5) in order to terminate the sample stimulus and initiate the onset of two comparison stimuli. Initially, comparison stimuli were immediately displayed on both the right and left response keys, with one matching-
and one non-matching stimulus being presented simultaneously. Upon pecking the key displaying the stimulus corresponding to the sample stimulus, all lights in the chamber were extinguished, and food was delivered through an aperture located in the center of the front panel. Upon completing three consecutive correct matching responses, a 0.5 s delay was implemented between the termination of the sample stimulus and the onset of the comparison stimuli. Any correct responses made following the initial three-consecutive responses resulted in an additional 0.5 s delay to the presentation of the comparison stimuli. Incorrect responses produced a timeout condition, where all of the lights on the response panel were darkened for 3s, with no programmed consequences for responding during the duration of the timeout. Incorrect responses temporarily halted the increasing delay between sample and comparison stimuli until an additional three consecutive correct responses occurred, at which point the delay progressively increased as previously described. Each additional incorrect response decreased the delay to the comparison stimuli by 0.5 s increments. Training sessions were terminated after 60 reinforcers were delivered or 60 minutes elapsed, whichever occurred first.

Testing

Testing commenced once stable responding was observed, as defined by the following criteria: 1) four out of five consecutive sessions ≥ 75% overall session accuracy, 2) the final two out of five consecutive sessions above ≥ 75% overall accuracy, and 3) no significant visible trending in maximum delay values obtained prior to test sessions. Test sessions were conducted the day following fulfillment of these criteria under one of three food deprivation conditions according to a balanced Latin square design sequence: 1) 11 hr (low deprivation), 2) 22 hr (moderate deprivation), or 3) 44 hr
If a day off fell between any of these five sessions, a re-training session was scheduled before a test session was conducted.

Phase II

Training

Training procedures were similar to those outlined in phase I. Subjects were required to reach the aforementioned stability criteria before beginning a BVDBVD testing sequence in which B was a baseline (no injection) session, V was a vehicle (sterile 0.9% saline solution) injection session, and D was a drug treatment (0.0075, 0.03, or 0.1 mg/kg scopolamine) injection session. Given that there was no significant trending in overall session accuracy between successive baseline days in this sequence, testing continued in this manner until there was a day off, before beginning another testing sequence. If any of the sessions in the sequence were separated by a day off, another baseline session was required to assess for stability before continuing with the testing sequence.

Testing

During scopolamine/deprivation combination phases (phases II and III), either vehicle or .03 mg/kg of scopolamine was administered via intramuscular (IM) injection 15 min prior to experimental sessions. This dose was chosen based on previous research indicating it to be a low but sufficient dose to disrupt stimulus control and short-term memory (Dews, 1955; Evenden, 1986; Santi, Bogles, & Petelka, 1988; Savage, Stanchfield, & Overmier, 1994; Teale & Evans, 1982; Wenger, Hudzik, & Wright, 1993). Given instances where responding was either unaffected or completely inhibited, drug
doses were adjusted accordingly until response impairments were observed. Pigeon 17761 failed to display impairments in accuracy of responding ($M = -4.8\%$) at the original intended dose (0.03 mg/kg), so a larger, additional dose (0.10 mg/kg) was employed for that bird. Similarly, 17443’s responding was completely suppressed after administration of the 0.03 mg/kg dose, so a smaller, additional dose (0.0075 mg/kg) was examined for deprivation-dependent effects. Data collection procedures were identical under both testing and training sessions. All sessions were terminated after either 60 reinforcingers were delivered or 60 minutes elapsed, whichever occurred first.

Phase III

Training

Training procedures were similar to those outlined in phases I and II. Subjects were required to reach the aforementioned stability criteria before beginning a BVDBVD testing sequence in which B was a baseline (no injection) session, V was a vehicle (sterile 0.9% saline solution) injection session, and D was a drug treatment (scopolamine and nicotine) injection session.

Testing

During drug combination phases, vehicle (sterile 0.9% saline solution) or a scopolamine-nicotine combination dose (0.0075, 0.03, or 0.1 mg/kg and 1.0 mg/kg, respectively) was administered via IM injection. Due to differing pharmacokinetic properties of the two compounds used, each compound was administered separately, using differing pretreatment intervals (15 min and 5 min for scopolamine and nicotine, respectively). Scopolamine was administered into either the left or right pectoral muscle.
15 min prior to experimental sessions while nicotine was administered into the alternating pectoral muscle 5 min prior to experimental sessions. Both of these doses were chosen based on previous research (Chadman & Woods, 2004; Dews, 1955; Evenden, 1986; Kangas & Branch, 2012; Lemmonds & Wenger, 2003; Lemmonds, Williams, & Wenger, 2002; Santi, Bogles, & Petelka, 1988; Savage, Stanchfield, & Overmier, 1994; Teale & Evans, 1982; Wenger et al., 1993). Data collection procedures were identical under both testing and training sessions. All sessions were terminated after either 60 reinforcers were delivered or 60 minutes elapsed, whichever occurred first.

Phase IV

Training

Training procedures were similar to those outlined in phases II and III. Subjects were required to reach the aforementioned stability criteria before beginning a BVDBVD testing sequence in which B was a baseline (no injection) session, V was a vehicle (sterile 0.9% saline solution) injection session, and D was a drug treatment (1.0 mg/kg nicotine) injection session.

Testing

During nicotine/deprivation combination phases, vehicle (sterile 0.9% saline solution) or nicotine (1.0 mg/kg) was administered via IM injection. Nicotine was injected alternatingly into the left or right pectoral muscle 5 min prior to experimental sessions. This dose was chosen based on previous research (Chadman & Woods, 2004; Kangas & Branch, 2012; Lemmonds & Wenger, 2003; Lemmonds, Williams, & Wenger, 2002) indicating it to be a safe, but relatively high dose. Data collection procedures were
identical under both testing and training sessions. All sessions were terminated after either 60 reinforcers were delivered or 60 minutes elapsed, whichever occurred first.

Pharmacological preparation.

Bacteriostatic 0.9% sodium chloride solution was used to dissolve both the scopolamine hydrochloride and (-)-nicotine hydrogen tartrate (Sigma-Aldrich, St. Louis, MO). Trained research personnel administered IM injections at a volume of 1.0 ml/kg. Doses were calculated based upon the weight of the salt.

RESULTS

Phase I

Figure 1 depicts the mean percent correct responses (accuracy) across deprivation conditions for each bird. For all three birds, the moderate deprivation condition produced the highest level of accuracy averaged across testing sessions ($M = 87.7\% ; SD = 6$). In comparison, both low and high deprivation conditions produced lower percentages of sample-appropriate responses, with all three birds responding less accurately under the high deprivation condition ($M = 76\% ; SD = 4.6$) than under the low deprivation condition ($M = 84.6\% ; SD = 6$).
Figure 1. Mean percent accuracy averaged across three separate exposures to each deprivation condition for three separate birds.

Response rates increased as a function of level of deprivation, with the low deprivation condition producing lower response rates than those observed during the moderate or high deprivation condition. Figure 2 displays means for overall session response rates for both exposures at each deprivation level, in addition to those obtained for baseline and vehicle sessions.

Figure 2. Mean responses per minute averaged across three exposures for each deprivation condition for three separate birds.
Figure 3 displays averages of the maximum delay reached within a session for each deprivation condition. Maximum delay reached within a session varied much more than did either other measure of performance (rate and accuracy), with two of the birds (17443 and 18921) displaying overall deprivation-dependent increases in maximum delay and the other displaying deprivation-dependent decreases in maximum delay (17761). Maximum delay reached values for 17761 were 5.2 ($SD = 1.5$) for the 11 hr condition, 7 ($SD = 1.5$) for the 22 hr condition, and 7.8 ($SD = 3.9$) for the 44 hr condition. Maximum delay reached for 17443 was 14.7 ($SD = 4.4$) for the 11 hr condition, 15.8 ($SD = 4$) for the 22 hr condition, and 9.3 ($SD = 4$) for the 44 hr condition. Maximum delay reached for 18921 was 10 ($SD = 2.6$) for the 11 hr condition, 7.8 ($SD = 0.6$) for the 22 hr condition, and 9.3 ($SD = 2.8$) for the 44 hr condition.

![Figure 3](image)

*Figure 3.* Mean maximum delay reached displayed for each subject at all three deprivation levels

Phase II

Acute administration of scopolamine (0.03 mg/kg) consistently decreased overall session accuracy for all birds ($M = -17.9\%$) from baseline. The overall means for each
deprivation condition (11 = 62%, 22 = 71.2%, and 44 = 64.3%) did differ systematically across conditions, with the highest percentage of accuracy occurring at the training deprivation condition (22 hr). Figure 4 depicts mean (±S.E.M.) percent accuracy across deprivation conditions for all three birds. For two birds (17443 and 18921), overall session accuracy was impacted in a similar deprivation-dependent manner as observed in phase I, with the high deprivation condition producing greater impairments in performance than the low deprivation condition. The moderate deprivation condition was consistent in producing the greatest overall session performance across all three birds. There were no systematic differences in performance between baseline and control injection procedures.

Figure 4. Mean (±SEM) percent accuracy across baseline (B), vehicle (V), and the three test deprivation conditions (11, 22, and 44 h) for scopolamine

17761 had averages of 54% (SD = 35.4) for the 11 hr condition, 72.5% (SD = 7.8) for the 22 hr condition, and 69% (SD = 7.1) for the 44 hr condition. 17443 averaged 74.5% (SD = 14.8) for the 11 hr condition, 85.5% (SD = 0.7) for the 22 hr condition, and 59.5% (SD = 21.9) for the 44 hr condition. 18921 averaged 53% (SD = 0) for the 11 hr condition, 55.5% (SD = 10.6) for the 22 hr condition, and 64.5% (SD = 2.1) for the 44 hr condition.
Figure 5. Mean response rates (±SEM) for scopolamine across deprivation conditions

Figure 5 depicts mean (±S.E.M.) responses per minute for each bird across deprivation conditions. Response rates were highly variable across birds (SD = 5.7). Unlike those observed under the deprivation-only conditions, phase II produced deprivation-dependent decreases in response rates (17443 & 18921), as well as increases (17761), dependent upon subject.

Figure 6. Mean maximum delay reached (±SEM) within a session across deprivation conditions

Maximum delays reached were variable across birds, with consistently lower delays (M = 2.9) reached under each deprivation condition than those observed under baseline (M = 10.3) or vehicle (M = 11.3) conditions. Maximum delay reached for 17761 was 1.8 (SD = 2.5) for the 11 hr condition, 1.8 (SD = 1.8) for the 22 hr condition, and 4 (SD = 0.7) for the 44 hr condition. Maximum delay reached for 17443 was 2.8 (SD = 1.1) for the 11 hr condition, 4.5 (SD = 4.9) for the 22 hr condition, and 2.3 (SD = 3.2) for the 44 hr condition. Maximum delay reached for 18921 was 2 (SD = 0) for the 11 hr condition, 1.8 (SD = 1.8) for the 22 hr condition, and 5 (SD = 1.4) for the 44 hr condition.
Phase III

Acute administration of the scopolamine-nicotine combination (0.03 mg/kg and 1.0 mg/kg, respectively) impaired performance across all three response measures when compared to performance obtained under baseline and vehicle conditions. Figure 7 displays means for overall session accuracy for both exposures at each deprivation level, in addition to those obtained for baseline and vehicle sessions. Due to the lack of responding that occurred during this phase of the experiment for all subjects, mean percent accuracy was unable to be calculated for 17443 at the 0.03 mg/kg scopolamine/1.0 mg/kg nicotine dose, as well as the low and moderate deprivation conditions for 17761 for the 0.03 mg/kg scopolamine/1.0 mg/kg nicotine dose. Mean percent accuracy for 17761 was 67% for the 44 hr condition. Mean percent accuracy for 17443 was 88% ($SD = 0$) for the 11 hr condition, 80.5% ($SD = 10.6$) for the 22 hr condition, and 83% ($SD = 14.1$) for the 44 hr condition. Mean percent accuracy for 18921 was 61.5% ($SD = 6.4$) for the 11 hr condition, 65% ($SD = 0$) for the 22 hr condition, and 64% ($SD = 1.4$) for the 44 hr condition.

![Graphs showing mean percent accuracy across deprivation conditions for 17761, 17443, and 18921.]

Figure 7. Mean percent accuracy ($\pm$SEM) for the scopolamine-nicotine combination across deprivation conditions

Figure 8 displays means for overall session response rates for both exposures at each deprivation level, in addition to those obtained for baseline and vehicle sessions.
Responses per minute increased for two out of three birds (17443 and 18921) under the high deprivation condition, and were either comparable or slightly higher than the moderate deprivation condition.

Figure 8. Mean response rates (±SEM) for the scopolamine-nicotine combination across deprivation conditions

Figure 9 displays means for maximum delay reached within a session for both exposures at each deprivation level, in addition to those obtained for baseline and vehicle sessions. Mean maximum delays for 17761 were 0 (SD = 0) across all deprivation conditions. Mean maximum delays for 17443 were 8.75 (SD = 1.8) for the 11 hr condition, 2.3 (SD = 1.1) for the 22 hr condition, and 5 (SD = 0.7) for the 44 hr condition. Mean maximum delays for 18921 were 6.6 (SD = 2.1) for the 11 hr condition, 7.2 (SD = 2.8) for the 22 hr condition, and 10.3 (SD = 1) for the 44 hr condition.

Figure 9. Mean maximum delay reached (±SEM) for the scopolamine-nicotine combination under each deprivation condition
Phase IV

Acute administration of nicotine prior to sessions had no systematic effects across subjects with regard to overall session accuracy. Nicotine administration neither consistently decreased nor increased accuracy relative to performance during baseline or vehicle conditions (Figure 10). Rate of responding increased slightly as a function of level of deprivation (Figure 11). However, maximum delay reached (Figure 12) showed no consistent effects as a function of deprivation, though delays reached throughout the session were consistently lower than those reached during baseline conditions.

Figure 10. Mean percent accuracy (±SEM) for nicotine across each deprivation condition

Acute administration of nicotine (1.0 mg/kg) slightly impaired performance across all three response measures when compared to performance obtained under baseline and vehicle conditions. Figure 10 displays means for overall session accuracy for both exposures at each deprivation level, in addition to those obtained for baseline and vehicle sessions. Mean percent accuracy for 17761 was 80.5% ($SD = 19.1$) for the 11 hr condition, 95.5% ($SD = 6.4$) for the 22 hr condition, and 81% ($SD = 8.5$) for the 44 hr condition. Mean percent accuracy for 17443 was 73% ($SD = 2.8$) for the 11 hr condition, 78% ($SD = 9.9$) for the 22 hr condition, and 84% ($SD = 7.1$) for the 44 hr condition. Mean percent accuracy for 18921 was 77% ($SD = 2.8$) for the 11 hr condition, 74% ($SD = 2.8$) for the 22 hr condition, and 73.5% ($SD = 2.1$) for the 44 hr condition.
Figure 11 displays means for overall session response rates for both exposures at each deprivation level, in addition to those obtained for baseline and vehicle sessions. Responses per minute were inconsistent across birds and deprivation conditions, with 17761 displaying deprivation-dependent increases, 17443 displaying deprivation decreases, and 18921 displaying equally lower response rates under all deprivation conditions than under baseline or vehicle.

Figure 11. Mean response rates (±SEM) for nicotine across deprivation conditions

Figure 12 displays means for maximum delay reached within a session for both exposures at each deprivation level, in addition to those obtained for baseline and vehicle sessions. Mean maximum delays for 17761 were 3 (SD = 4.2) for the 11 hr condition, 3.3 (SD = 1.1) for the 22 hr condition, and 7.5 (SD = 4.9) for the 44 hr condition. Mean maximum delays for 17443 were 9.5 (SD = 7.1) for the 11 hr condition, 8 (SD = 2.8) for the 22 hr condition, and 12.3 (SD = 1.8) for the 44 hr condition. Mean maximum delays for 18921 were 7.8 (SD = 2.5) for the 11 hr condition, 4.3 (SD = 0.4) for the 22 hr condition, and 8.8 (SD = 3.9) for the 44 hr condition.
Figure 12. Mean maximum delay reached (±SEM) for nicotine across each deprivation condition

Data Analysis

The primary dependent variables of interest were: a) response rates, b) maximum delay reached per session, and c) overall session accuracy. Response rates were calculated by dividing the total number of responses by total session duration. All three dependent variables were calculated on a trial-by-trial basis via experimental programming. Following termination of the experimental session, data were also reviewed and recorded by trained research personnel. Due to the nature of the present experimental design, (i.e., small n, lack of counterbalancing with regard to drug conditions) statistical analyses were deemed unjustified. All data were therefore analyzed via visual inspection.

DISCUSSION

The current findings clearly demonstrate that manipulating deprivation has an effect on performance within the TDMTS paradigm, the nature of which is dependent upon whether deprivation is increased or decreased. This is in line with findings of the relatively scant amount of published literature on the subject (Cumming & Berryman, 1965; Li et al., 1995; Lotfizadeh et al., 2012; Lotfizadeh et al., 2014; Thomas & King,
and provides further confirmation that particular aspects of current performance can be influenced by altering motivation.

In the present study, all three birds repeatedly demonstrated a decrease in overall session accuracy when tested at deprivation levels other than that used for training (22 hr). Furthermore, the extent of the decrease in accuracy between the two separate deprivation conditions (11 and 44 hr) depended on the level of deprivation, with the low deprivation condition consistently producing higher levels of overall session accuracy than the high deprivation condition.

Altering motivation, in combination with administering drugs (nicotine, scopolamine, or nicotine/scopolamine) did not produce any substantial differences in performance among the deprivation levels, though there were consistent drug-dependent effects across all of deprivation conditions as a whole. Consistent with previous research (Santi, Bogles, & Petelka, 1988; Savage, Stanchfield, & Overmier, 1994; Wenger et al., 1993), acute administration of scopolamine alone negatively impacted overall session accuracy, response rates, and maximum delays reached within a session. Acute administration of the scopolamine-nicotine combination produced greater perturbations with regard to all three response measures (i.e., accuracy, response rate, maximum delay reached) than did scopolamine or nicotine alone. This is particularly interesting given the implications in the literature (e.g., Buccafusco & Jackson, 1991; Levin, Kaplan, & Boardman, 1997) for nicotine as a cognitive enhancer. However, given the contradicting findings regarding nicotine administration on this particular task (Kangas & Branch, 2012), it seems plausible that the present findings could be accounted for based upon the performance-disrupting effects of scopolamine and nicotine combined.
Rather than nicotine counteracting any performance-disrupting effects of scopolamine, the combination appears to have produced an additive effect on responding. Decreases in all three responses measures across birds were observed during the scopolamine-nicotine combination phase. By examining the effects of nicotine independent of scopolamine, it became clear that although using a relatively high dose of nicotine alone (1.0 mg/kg) did slightly decrease performance along all three response measures from baseline conditions, the effects observed under the scopolamine-nicotine combination condition cannot be accounted for simply by the scopolamine or nicotine data alone.

The lack of consistent modulation of drug effects by deprivation level may be due to a variety of factors. Not only do the drugs used in the present study produce well-established effects on appetite and consummatory behavior (Bláha, et al., 1998; Bartholomew Hodges, Jr. et al., 2009), they also may produce central nervous system effects that have the potential to mask drug-independent changes in behavior. For example, scopolamine has been shown to have effects on visual acuity (Robinson, Harbaran, & Riedel, 2004)—a key component to successful performance on DMTS tasks.

When examining drug effects on behavior within the TDMTS paradigm, it appears that, independent of deprivation level, administration of scopolamine alone caused a dose-dependent decrease in stimulus control (i.e., accuracy). The scopolamine-nicotine combination had an additive effect on responding and decreased overall stimulus control. Nicotine alone neither substantially increased nor decreased stimulus control. These effects are based on a measure of overall session accuracy, rather than maximum delay reached within a session, which is typically the dependent measure of interest in
TDMTS procedures (Poling et al., 1996). Even though birds were required to meet stability criteria before testing began, others have demonstrated that performance within DMTS procedures could require an extended period of time to stabilize (Kangas, Berry, & Branch, 2011). Additionally, the main dependent measure within TDMTS procedures (i.e., maximum delay reached within a session) has never been repeatedly examined across relatively long periods of time, as was the case in the present study. Due to the immense variability of maximum delay reached from session-to-session, in combination with fluctuations in performance over time, it was near impossible to discern any consistent trends from one condition to the next.

When viewed from a molar perspective, performance on a TDMTS procedure may not be a good measure of stimulus control, but may instead reflect an optimization of time spent responding versus the overall reinforcement rate. Responding with a high level of accuracy results in an overall greater delay to the same amount of reinforcement (i.e., responding correctly increases the subsequent delay to the next reinforcer), whereas responding alternatingly correctly/incorrectly at a high rate would produce very little delay between responses and reinforcement, though overall accuracy would be much lower. Therefore, overall session accuracy may not be the most adequate measure of responding. For example, because increasing deprivation alone was shown to decrease overall session accuracy, it may in fact decrease a pigeon’s tolerance for withstanding a delay to reinforcement, rather than decreasing the stimulus control over the length of the retention interval.

The experimental design in the present study was counterbalanced with regard to the testing order of deprivation conditions. However, all birds experienced drug
conditions in the same sequence (i.e., scopolamine-only, scopolamine-nicotine combination, and nicotine-only). In order to fully exclude the effects of drug history on performance under these conditions, ideally the order of drug testing conditions should be counterbalanced across birds as well. Due to the fact that performance first had to be impaired by the dose in question, it was required that the scopolamine-only conditions occur prior to the other drug conditions. Once it was demonstrated that the relevant dose impaired performance, the scopolamine-nicotine combination was then used in an attempt to rescue any performance deficits observed under the scopolamine-only condition. Due to the fact that the combination further impaired performance, rather than producing the hypothesized performance-enhancing effects, the effects of acute administration of nicotine alone were examined thereafter.

Conclusion

It has been repeatedly demonstrated that altering motivation can alter performance. However, the degree to which performance is influenced appears to be dependent on the task, as well as the extent to which motivation is altered. More research needs to be conducted on the extent to which motivation influences other aspects of performance. Though a few researchers have examined this topic from a basic research perspective (Thomas & King, 1959; Cumming & Berryman, 1965; Li et al., 1995; Lotfizadeh et al., 2012; Poling, 2012; Lotfizadeh et al., 2014), considerably more work has been done on the applied front (for a review, see Laraway et al., 2014). This probably reflects the fact that simple modifications of motivation (e.g., providing “free” access to reinforcers, as under the so called “non-contingent reinforcement” procedure) can significantly affect target responses in applied settings. The effects of more subtle
alterations in motivation of complex human behaviors have not, however, been reported in the applied literature, perhaps because basic research provides no guidance regarding how such manipulations should be arranged. Be that as it may, if concepts such as motivation are to be used and extrapolated to real world applications, there must be an attempt at systematically evaluating the effects of doing so.
REFERENCES


Appendix A

Institutional Animal Care and Use Committee Approval Letter
Date: November 14, 2013

To: Alan Poling, Principal Investigator

From: Robert Eversole, Chair

Re: IACUC Protocol Number 13-11-01

Your protocol entitled “Effects of Altering Motivation in Pigeons Performing a Titrating-Delayed-Matching-To-Sample Task” has received approval from the Institutional Animal Care and Use Committee. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: November 14, 2014
Appendix B

Cumulative Record—Phase I
Appendix C

Delay Across Session—Phase I
Appendix D

Cumulative Record—Phase II
Appendix E

Delay Across Session—Phase II
Appendix F

Cumulative Record—Phase III
Appendix G

Delay Across Session—Phase III
Appendix H

Cumulative Record—Phase IV
Appendix I

Delay Across Session—Phase IV
17761

![Graph of Delay (s) vs Trial for 17761](image)

17443

![Graph of Delay (s) vs Trial for 17443](image)

18921

![Graph of Delay (s) vs Trial for 18921](image)
Appendix J

Grouped Response Measures Graph
Appendix K

Trials Initiated Graph
Appendix L

Response Latency Graph