TRAINING DOMESTIC DOGS (CANIS LUPUS FAMILIARIS) ON A NOVEL ODOR-DETECTION TASK IN DISCRETE TRIALS

By

NATHANIEL JAMES HALL

A THESIS PRESENTED TO THE GRADUATE SCHOOL
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To my loving wife and family

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Nathaniel James Hall

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Dogs can be trained to reliably detect a wide variety of important odors. Little is known, however, about the rate at which dogs can learn to detect an odor, the variables that influence this rate, and how this rate may vary across individual dogs. In two experiments, we developed a discrete-trials procedure to assess the rate at which previously untrained dogs acquire an odor-detection task. In Experiment 1, 20 dogs were trained to indicate the presence of a novel odor significantly above chance within 24 trials, with two dogs meeting an individual criterion for performing significantly above chance. Experiment 2 compared performance on a visual task (black vs. white) to an odor-detection task and assessed whether placing accessible food directly in the target bin and inaccessible food in the non-target bin enhanced discrimination training, compared to a procedure in which the experimenter delivered food shortly after responding. Dogs learned faster on the odor task when the experimenter delivered food, compared to when food was placed directly in the target bin. When the experimenter delivered food, dogs performed better on the odor task than the visual task. Performance on the visual task was unaffected by how food was delivered. Individual

differences were observed in the rate of acquisition of the odor task when the experimenter delivered food. This discrete-trials procedure shows promise in the selection of dogs likely to perform well on an odor-detection task and to evaluate experimental variables that may influence the rate dogs learn an odor detection.

CHAPTER 1
INTRODUCTION

Dogs are accurate and reliable biosensors, making them a useful detector technology (Furton & Myers, 2001). Domestic dogs can detect a wide variety of odors including explosives (for a review see Goldblatt, Gazit & Terkel, 2009), narcotics (Dean, 1972), tortoises (Cablk, Sagebiel, Heaton & Valentin, 2008), cows in estrus (Fischer-Tenhagen, Wetterholm, Tenhagen & Heuwieser, 2011; Kiddy, Mitchell, Bolt & Hawk, 1978), prostate cancer in humans (Cornu, Cancel-Tassin, Ondet, Giardet & Cussenot, 2011), bladder cancer (Willis et al., 2004), and numerous other volatile stimuli. Dogs can detect a target odor even in the presence of higher concentrations of extraneous odors (Waggoner et al., 1998), and can be trained to simultaneously detect multiple target odors (Williams & Johnston, 2002). In addition, dogs can detect odors in concentrations of tens of parts per billion for chemicals such as nitroglycerin (Johnston, 1999).

Despite dogs' keen sensitivity to odorants, little is know about the variables that influence how quickly dogs first learn to "alert" an observer by emitting an indicative response to the presence of to a novel odor. Traditionally, dogs require extensive and intensive training to reach certification standards in odor detection. Sinn, Gosling & Hilliard (2010) reported that the 341st Training Squadron at Lackland Air Force Base, Texas, trains specially selected dogs for an average of 100 days (SD = 34 days) before deeming them ready for certification testing. Cornu et al. (2011) trained one dog for five days a week for 16 months before the dog accurately identified samples of urine from individuals with prostate cancer. These important odor discriminations require extended periods of training, and make an analysis of the potential variables that influence the rate at which a dog learns an odor detection, in general, difficult to isolate.

Some researchers have utilized other, potentially more salient, odors, to train odor-detection in dogs in relatively few trials. Williams and Johnston (2002) trained dogs to alert to ten different odors, one at a time, with the first discrimination requiring, on average, 28 trials. Williams and Johnston also found the number of trials required to reach criterion decreased as additional odor detections were trained. Fischer-Tenhagen et al. (2011) trained dogs to discriminate bovine estrus vaginal samples from diestrus samples within 52 reinforced trials. Importantly though, the dogs in both of these studies were *not* naïve to odor detection. These dogs were first trained to alert on another "training" or "pre-training" odor before learning the target discrimination. Performance and training data during the first discrimination, however, were not reported, as the training of the alerting response is confounded with the training of the odor detection. Thus, the rate at which naïve dogs can be systematically trained to alert to a novel odor, for the *first* time, has not previously been reported.

Not all dogs that enter detection-training programs successfully complete their training, making individual differences in acquisition an important area of interest for the effectiveness of these programs. Sinn, Gosling & Hilliard (2010) reported that 20.9% of dogs selected for the 341st Training Squadron never met certification criterion for either odor detection or patrol training. Similarly, the Transportation Security Administration (TSA) reported that approximately 50% of the puppies raised for odor detection are successfully trained (TSA, 2011). To maximize the percentage of dogs meeting certification, dogs are typically given a battery of tests aimed at identifying those most likely to succeed as detector dogs. Sinn, Gosling & Hilliard evaluated the selection test used by the 341st Training Squadron, which includes measures of dogs' responsiveness to static objects, thrown objects, different environments, and many other conditions. Sinn, Gosling, and Hilliard found that higher scores on the selection test increased the odds the dog would achieve certification as a patrol dog (a non-odor detection dog) or a dual-certified dog (patrol and odor certified); however, higher scores did not increase the odds of a dog being certified in odor-detection. Maejima et al. (2006) analyzed seven subjectively evaluated behavioral traits such as "general activity" and "concentration" as potential predictors of success in a narcotics detection program. After performing a principle component analysis, the seven behavioral traits were reduced to "desire to work" and "distractibility." "Desire to work," but not "distractibility," increased the odds, although marginally, of a successful outcome (odds ratio: 1.144; 95% CI: 1.085-1.206).

Notably, neither of the aforementioned selection tests assessed the dog's performance on an odor-detection task. A brief odor-detection task in a controlled environment using salient odors might provide a more valid assessment of a dog's likelihood to succeed as an odor detector than the presently deployed aptitude tests.

The purpose of the present study was to develop a rapid systematic training procedure for odor discrimination in dogs. In order to ensure the most objective record of each dog's progress through the task, discrete trials were utilized. In a discrete-trials procedure, every presentation of the training stimuli is programmed as a trial and the subject's response to the stimuli is recorded. The explicit and detailed record of each animal's progress afforded by the discrete-trials procedure ensures that the rate at which each animal acquires the task is assessed, which in turn, makes possible the identification of variables that influence performance. In Experiment 1, we investigated whether dogs could be trained to alert to a novel odor within 24 scheduled trials, and if we could identify variations in performance across dogs. In Experiment 2, we explored variations in the procedure of Experiment 1 as variables influencing performance and attempted to identify consistent high-performing dogs to further identify individual differences in performance across dogs.

CHAPTER 2
EXPERIMENT 1

The purpose of Experiment 1 was to develop a discrete trials procedure to train dogs to alert to a novel odor. We sought to identify individual differences in performance and assess whether dogs can be trained to perform significantly above chance within 24 scheduled trials.

Methods

Subjects

Twenty-five pet dogs were selected for this study, of which, twenty completed Session 1 and sixteen completed Session 2. None of the subjects were working detector dogs or had any previous training to be odor-detecting dogs. All dogs were tested in a familiar environment.

Materials

Dogs were trained with discrete trials in a two-choice procedure to root in anise scented pine shavings in Sterilite™ plastic bins (Sterilite Corporation, Townsend, MA). All training, including the training of the alerting response, was done within scheduled trials of the experiment. Large dogs were trained to root in large bins (40 cm by 35 cm by 16.5 cm), whereas small dogs were trained to root in smaller (30 cm by 36 cm by 15 cm) bins. The rooting response was chosen as the alerting behavior because an observer could objectively score rooting, dogs were able to sniff both choices directly at the source before a response was made, and limited training for an alerting behavior was required (Figure 2-1).

The bins were filled to a depth of approximately 8 cm with PetsPick™ pine shavings (American Wood Fibers, Columbia, MD). Pine shavings were placed in the bins at least one hour prior to testing to allow their natural odor to dissipate. The target odor was anise extract. Anise extract was selected as the target as it was likely a novel odor to all household dogs, safe, readily available, and is utilized as a target odor by the National Association for Canine Scent Work (NACS, 2011). The target odor was prepared by placing 1 ml of McCormick ™ (McCormick & Company, Inc., Sparks, MD) pure anise extract on 100% cotton rounds using a measuring syringe. The scented cotton rounds were buried in the target containers approximately 2.5 cm deep.

Before each trial, the two bins were placed at locations marked with masking tape 0.25 m apart (see Figure 2-1). The subject was held at least 1 m back from the bins, and was released at the beginning of each trial. Before the dog was released, the experimenter stepped at least 1 m away from the bins and looked straight down at the ground. An observer, naive to which bin was correct, stood 1-m back at the starting location and observed the dog’s response. After each trial, the naive observer would call the dog back.

Procedure

Alert training: dogs were first tested for motivation and were trained to root (“alert”) in the pine. For alert-training trials, only one bin, the anise-scented bin, was utilized. A treat was placed in an open tea ball, which was placed on top of the pine shavings and the anise scented cotton round. An open tea ball was used during alert-training trials to keep the presence of the tea ball consistent with later food-buried trials (described below). Two alert-training trials were conducted where the treat was visible and on top of the pine shavings. The dog was allowed to freely approach and consume the visible treat. If the dog did not consume the treat during these two trials, the experimenter would hand the treat to the dog. If the dog still did not consume the treat after two attempts, the treat type was changed. Most dogs readily consumed commercial dog treats or cheese. If, upon changing the treat, the dog still did not take any of the available food, testing was terminated for that dog. Only one dog failed to take any treats during this training. Dogs completing the first two trials were given three trials in which the tea ball, the treat, and the anise cotton round were buried in the pine shavings. Dogs were required to root to obtain the accessible food. Once the dog found the treat the experimenter would say “good dog” and allowed the dog to eat the treat. All dogs completing the first two trials completed the following three trials.

Food-buried trials: for food-buried trials, dogs were presented with two bins; an anise-scented bin with buried accessible food (S^+), and an identical bin without anise, but with buried inaccessible food (S^-). The purpose of food-buried trials was to pair accessible food with the target odorant while strengthening the dog’s rooting response in the pine. Food was placed in an open tea ball in the S^+ bin (accessible), and food was placed in a closed tea ball in the S^- bin (inaccessible; Figure 2-1). The tea ball was utilized to bury identical pieces of food in the S^+ and S^- bins, making the anise odor, and not food odor, the only predictor of food. If food had been buried in only one bin, it would have been unclear if the dog was learning to detect food-odor or the target odor. Pilot studies also indicated that if a whole piece of food was buried in the S^+ bin, and an identical amount of food cut sufficiently small, so as to be inaccessible in the pine, was buried in the S^- bin, at least one dog could discriminate the difference in the food presentation. Thus, the tea ball was required to equate food odor between the S^+ and the S^- bins.

Before the start of each discrimination trial, the experimenter prepared the S^+ bin by burying the anise-scented cotton round and the open tea ball with a piece of food 2.5 cm deep in the pine shavings. The S^- bin was prepared by burying an unscented cotton round and a tea ball closed with a treat 2.5 cm deep in the pine shavings. When the dog was at the start location the experimenter placed the bins at the marked locations, stepped 1 m back, and looked at the ground. Dogs were free to respond in any way. The naive observer watched the dog, and waited for the dog to root in either bin. Once the dog rooted in a bin, the observer would call out “choice,” indicating to the experimenter to look up. If the experimenter observed the dog in the S^+ container, the experimenter would say “good dog” as the dog obtained the accessible food (Figure 2-1). If the dog was rooting in the S^- bin, the experimenter picked up both bins, and began preparing for the next trial. If the dog had not made a choice after 1 minute, both bins were picked up and a ‘no choice’ was recorded and coded as an incorrect response.

Experimenter-delivered food trials**:** experimenter-delivered food trials and food-buried trials differed in that for the experimenter-delivered food trials, no food was buried and the experimenter delivered the reinforcer after the dog made a choice. The S^+ bin contained an anise-scented cotton round buried 2.5 cm in the pine, while the S^- bin contained an unscented cotton round buried in the pine. Different sets of identical bins were utilized for food-buried trials and experimenter-delivered food trials to limit food cross-contamination. The purpose of experimenter-delivered food trials was to assess whether the dogs could also be trained to alert (i.e. root) in the bin with the target odor in the absence of any food odor that may prompt rooting.

Before each trial, the experimenter prepared the bins by burying the appropriate cotton round in the pine. The experimenter placed the bins at the marked location, stepped 1 m back, and looked straight at the ground. The naive observer watched the dog and called out “choice” once the dog rooted in either container (Figure 2-1). The experimenter then looked up, to see the bin the dog had chosen. If the dog was rooting in the S^+ bin, the experimenter would say “good dog” and deliver a treat by hand. If the dog was rooting in the S^- bin, the experimenter picked up both bins and prepared for the next trial. If no response was made within 1 minute, a ‘no choice’ was recorded.

Control trials: control trials were conducted to test whether the dogs were utilizing unintentional cues in addition to, or instead of, the anise odor to identify the S^+ bin. The only difference between control trials and food-buried trials was that neither bin contained an anise-scented cotton round. For the S^+ bin, the experimenter buried an open tea ball with a treat and an unscented cotton round 2.5 cm in the pine. For the S^- bin, the experimenter buried a closed tea ball with a treat inside and an unscented cotton round 2.5 cm in the pine. Thus, we expected an above chance performance on control trials if dogs were discriminating between an open and closed tea ball, or if the experimenter was unintentionally cueing the dog. We expected dogs’ performance to be at chance, if the dogs were using only the anise odor to identify the S^+ bin. A total of six control trials were run for each dog, unless the dog chose correctly on five of the six control trials. If the dog chose correctly on five of six control trials, two to three additional trials were completed for that dog.

Programmed trial order: dogs were given 12 food-buried trials, 12 experimenter-delivered food trials, and six control trials per session. These trials were divided into five blocks of five trials (four training trials and one control). The initial block contained four food-buried trials and one control trial. Food-buried trials were subsequently decreased to two trials across the following three blocks and were faded out entirely for the last block. No experimenter-delivered food trials were given in the first block, they were increased to two trials per block in blocks 2, 3 and 4, and block 5 consisted of all experimenter-delivered food trials. The trials were structured in different blocks to initially strengthen the rooting response with food-buried trials, and to slowly fade in experimenter-delivered food trials where no food was buried.

For all trial types, the location of the target (S^+) bin was pseudorandomly determined so that the S^+ bin was not at the same location for more than two trials in a row. If the dog made an incorrect choice and the previous four choices had also been to the same location, a forced correction trial was run by repeating the same trial after the non-target (S^-) bin was picked up and made unavailable. If the dog made three incorrect choices in a row or two no-choices in a row, two alert-training trials with the food on top of the pine shavings were run to insure motivation. If the dog did not consume the food during both of these trials, testing was terminated for that dog. Testing was terminated for four dogs after failing to take freely available, visible, food.

Session 2

Sixteen of the original twenty dogs were available to be retested for a second session. Dogs were re-tested between 1 and 28 days after the first session (average of 11 days). All procedures were identical to those of Session 1.

Statistical Analyses

Performance on food-buried and experimenter-delivered food trials was analyzed both separately and in combination. One sample t-tests were used to compare the group performance on each trial type and the overall average to chance. A two-tailed binomial test was used to identify the criterion for an individual's performance that was significantly above chance on the combined score (18 out of 24, 75%, $p < .023$). Paired t-tests were used to compare the differences between food-buried trials and experimenter-delivered food trials. Pearson's product-moment correlation assessed the correlation between Session 1 and Session 2. A linear regression assessed the effect of the number of hours since the dog had last eaten before testing and the subject's age on performance. All statistical tests were run using R™ or Graphpad Prism™.

Results and Discussion

Performance varied across dogs, with only two of the twenty dogs meeting the individual criterion for performing significantly above chance in a single session (18 correct out of 24, 75%; Figure 2-1). Most dogs performed slightly above chance (chance is 50%); however, they did not meet the individual criterion. Individual performance on food-buried trials ranged from 25% to 75% correct. Performances on experimenter- delivered food trials ranged from 17% to 83% correct. Performance on control trials varied around chance. Overall, dogs showed a wide range of performances, with some achieving slightly higher levels of performances in experimenter-delivered food trials (Figure 2-2).

When considering the performance of the group, dogs' performance across food-buried and experimenter-delivered food trials, was significantly above chance (Figure 2-2, one sample t test, $t = 4.05$, $df = 19$, $p < .001$). Performance was also significantly above chance when considering food-buried trials alone (one sample t test, $t = 3.22$, $df = 19$, $p < .01$) or experimenter-delivered food trials alone (one sample t test, $t = 2.98$, $df = 19$, $p < .01$), and there was no statistical difference in performance between food-buried trials and experimenter-delivered food trials (paired t test, $t = -.29$, $df = 19$, $p > .8$). On control trials, performance remained at chance (one sample t test, $t = -1.7$, $df = 19$, $p > .05$). Although at the individual level only two of twenty dogs performed significantly above chance, the average performance across dogs indicated that as a group, dogs identified the anise-scented container more often then expected by chance. The group's accuracy, however, never reached very high levels (average 60.7%), indicating that even as a group, the dogs were not selecting the anise-scented container much more than expected by chance alone.

The time since the last feeding (hereafter referred to as food deprivation) was estimated for each subject as the difference (to the nearest half-hour) between the time the owner last reported feeding the dog and the time testing of the dog began. The ages of the dogs were owner reported and recorded to the nearest year. A liner regression model including the hours of food deprivation, age, and an interaction term revealed that the age of the dog had no significant effect on the total score ($p > .57$), but the level of food deprivation had a significant negative effect ($p < .02$: i.e. the more food deprived the poorer the total score, Figure 2-3). No interaction between food deprivation and age was detected ($p > .79$). A reduced model only including food deprivation as a predictor variable showed that food deprivation had a significant -.44 association, $F(1,18) = 24.03$, $p < .001$, with the total score ($R^2 = .57$).

Performance in Session 2 was highly similar to performance in Session 1; the average percent correct in the total score did not change from Session 1 to Session 2 (Session 1, 60.7% correct; Session 2, 60.7% correct). Performance on experimenter-delivered food trials increased from a mean of 60% to a mean of 66%, whereas performance on food-buried trials decreased from a mean of 60% to 54% (Figure 2-4). The group performance on the experimenter-delivered food trials and the combined total score was significantly above chance (one sample t-test, t =4.21, df = 15, p < 05), however, when considering food-buried trials alone, performance was at chance in Session 2 (one sample t-test, t = 1.50, df = 15, p >.05). No statistically significant differences were observed between experimenter-delivered food trials and food-buried trials on a paired t-test (t = -1.78, df = 15, p > .05), however, the data suggest higher performances in experimenter-delivered food trials (Figure 2-4). Performance on control trials remained at chance.

Unlike Session 1 a linear regression analysis revealed no statistically significant effect of food deprivation on performance in Session 2. A Pearson-product moment correlation coefficient of .16 was observed for the correlation between Session 1 and Session 2; however, this was not significantly different from zero (t = .6, df = 14, p < .56).

Using this discrete-trials procedure dogs were detecting a novel target odor significantly above chance within 24 trials. Prior to the scheduled trials, all dogs were naïve to the task, and all training, including the training of the alerting response, occurred in programmed trials. This is an important difference from prior research in which the alerting response to an odor had been trained prior to experimental training.

This procedure identified individual differences in performance across dogs: including two dogs that performed significantly above chance in a single session. Thus, the procedure may be useful in selecting dogs that learn an odor-detection task rapidly.

In addition, the procedure identified that food deprivation may have a significant negative effect on performance; however, this effect was not replicated in Session 2.

The average performance across Sessions 1 and 2 remained stable, however, individual performance in Session 1 did not correlate with performance in Session 2. While the performance of some dogs increased, the performance of other dogs decreased equivalently. The average 11-day gap between Session 1 and Session 2 may have contributed to the lack of a correlation. Repeated testing less than 11 days apart may reveal a stronger test-retest relationship.

No significant differences were observed between food-buried trials and experimenter-delivered food trials, even though the highest performances occurred in experimenter-delivered food trials in both Sessions 1 and 2. Potentially, the physical proximity of the food and target odor in food-buried trials may have enhanced discrimination training, as in these trials the dog received immediate and direct access to food when responding correctly. In the experimenter-delivered food trials, the dog had to wait for the experimenter to deliver the food. The potential increase in the delay to the reinforcer in experimenter-delivered food trials may negatively impact acquisition, as the delay to reinforcement is known to be an important variable for acquisition (for a review, see Tarpy & Sawabini, 1974). Alternatively, performance may be lowered in the food-buried trials, as the odor of the inaccessible food in the S^- bin may elicit rooting behaviors that decrease accuracy.

Lastly, it is important to note that although dogs were performing significantly above chance in both sessions, performance was marginally higher than chance (60.7%). How this accuracy level may compare to the rate dogs learn a non-odor detection task is unclear. Thus, it is unclear if the use of a digging task in pine may facilitate an odor-detection task or inhibit performance.

Figure 2-1. Layout of Experiment 1 showing experimental bins and a dog responding. A: Dog making a choice by rooting in one container. B: Left bin is the food accessible bin with the target odor and an open tea ball with treat, right bin is the food inaccessible bin without the target odor and a closed tea ball with treat. C: Dog sniffing and beginning rooting motion. D: The continuation of image C, showing the dog rooting by thrusting the nose into the pine and moving the pine.

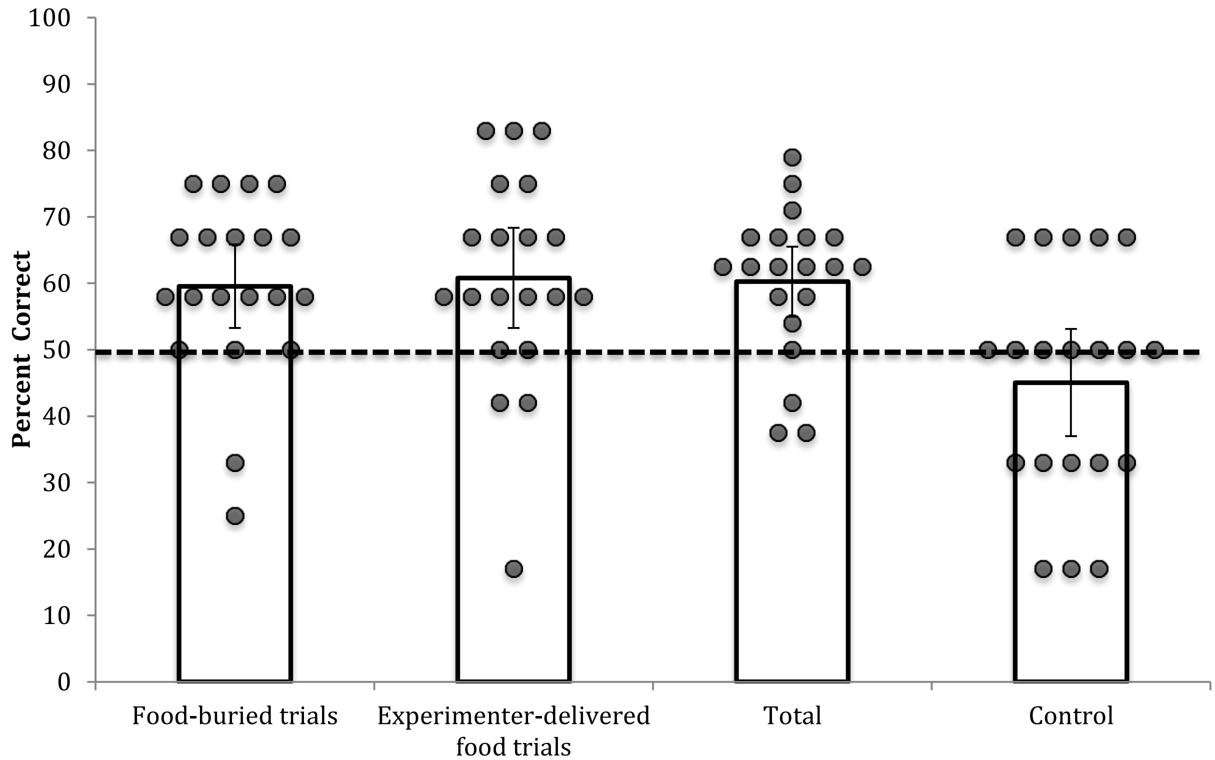

Figure 2-2. Dog performance on Session 1 of Experiment 1. Each dot shows the performance of an individual dog and the height of the bar shows the mean. Each dog's performance is shown across the two trial types, the average combined score, and control trials. Error bars show the 95% CI. The dotted line indicates chance performance. Thus, error bars that do not contain the dotted line show a statistically significant difference from chance on a t-test.

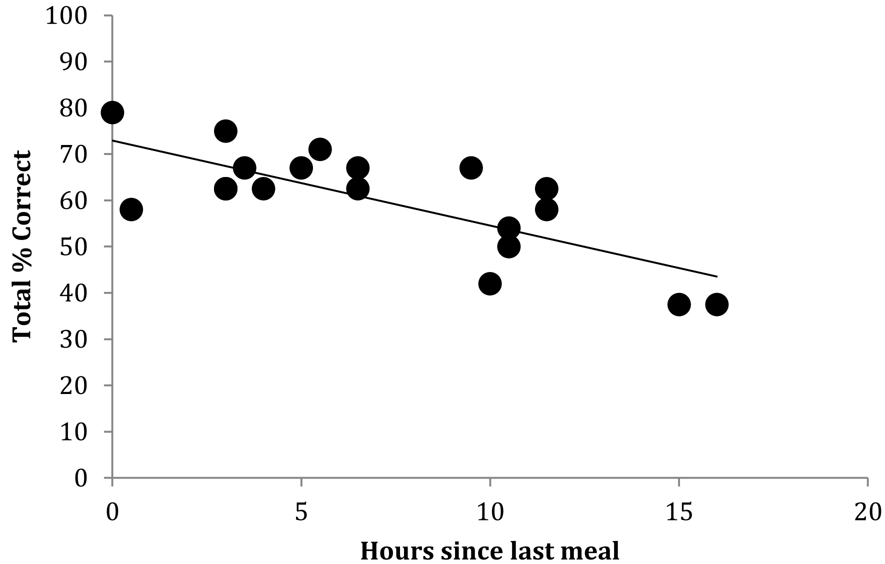

Figure 2-3**.** The effects of food deprivation on performance in Session 1 of Experiment 1. Each dot indicates the total percent correct in Session 1 for each dog as a function of the number of hours of food deprivation.

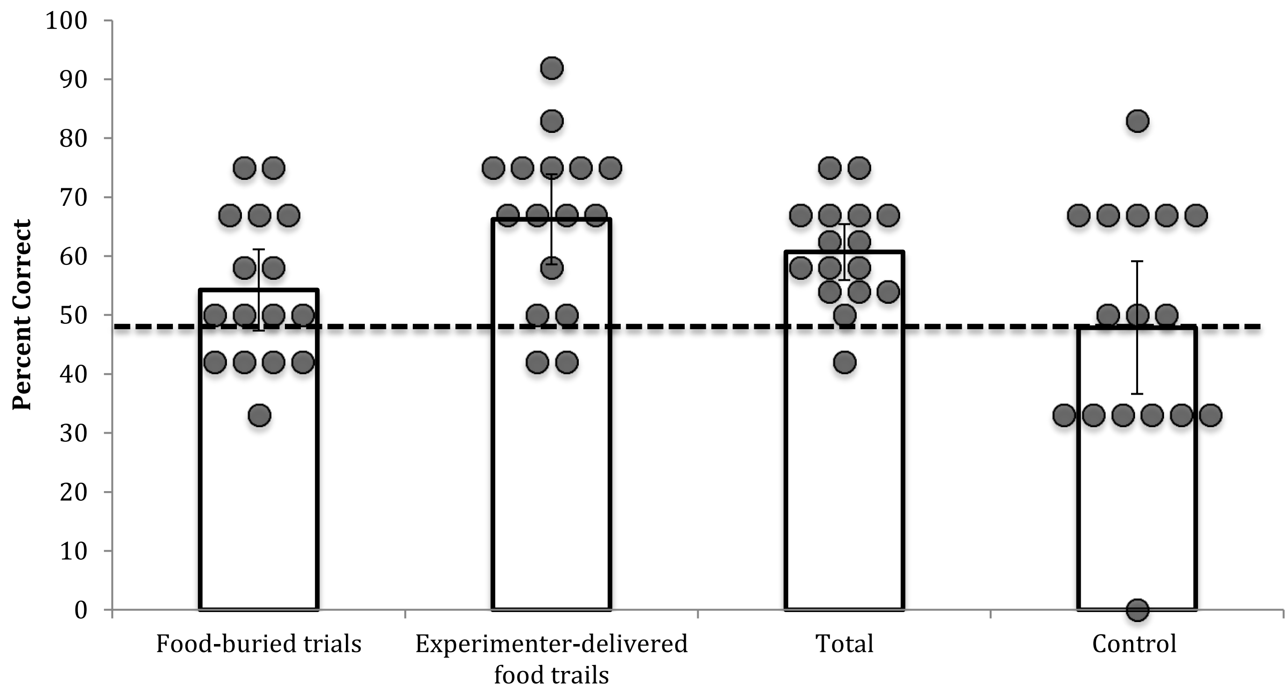

Figure 2-4. Dog performance on Session 2 of Experiment 1. Each dot shows the performance of an individual dog and the height of the bar shows the mean. Each dog's performance is shown across the two trial types, the average combined score, and control trials. Error bars show the 95% CI. The dotted line indicates chance performance. Thus, error bars that do not contain the dotted line show a statistically significant difference from chance on a t-test.

CHAPTER 3
EXPERIMENT 2

We designed Experiment 2 to address the questions raised by Experiment 1. In Experiment 2, dogs were given frequent and repeated testing sessions in an odor-detection task to assess their rates of learning, the level of performance they can quickly achieve, and the stability of the performance of individual dogs. Dogs were given only one trial type (food-buried or experimenter-delivered food) to assess any differences in the trial types. Lastly, dogs were simultaneously trained on a visual discrimination task (white vs. black) using an alternating conditions design to address if the dogs attended to odorant and visual stimuli in the task similarly.

Methods

Subjects

Twenty-six pet dogs naïve to odor-detection training were recruited for participation; however, two dogs would not take free food from the experimenter and were not tested. Of the remaining twenty-four dogs, twelve dogs were trained using only food-buried trials (food buried group) and twelve dogs were trained using only experimenter-delivered food trials (experimenter-delivered group). All dogs were trained on both the odor-detection task from Experiment 1 and a black from white visual-discrimination task. Dogs were tested in a familiar environment.

Materials

Dogs were trained to detect anise scented cotton rounds using tan-colored (30 cm by 36cm by 15cm) Sterilite bins (Sterlite Corporation, Townsend, MA) and were trained on the visual discrimination using black and white Sterilite bins (of the same size) filled with pine shavings as specified in Experiment 1. For the odor-detection training bins, odors were prepared in the same manner as described in Experiment 1. All general layout procedures not explicitly discussed below were held constant from Experiment 1.

Procedures

All dogs underwent five testing sessions; testing sessions were spaced between one day and seven days apart. The interval between testing sessions was determined by the owner's schedule; however, most dogs received sessions two to four days apart. Given the results of Experiment 1, the level of food deprivation was held similar from Session 1 to Session 5 for each dog. Each session consisted of alert-training trials, 24 training trials, and 6 control trials. Of the training trials, all dogs underwent a block of 12 odor-detection trials and a block of 12 visual discrimination trials with control trials interspersed every 4 trials. The order of the trial blocks (odor discrimination trials or visual discrimination trials) was counterbalanced across dogs and alternated within dogs from session to session. The target for the visual discrimination (white or black) was counterbalanced across dogs but consistent across sessions within dogs.

Food-buried group**:** twelve dogs were trained using only food-buried trials from Experiment 1. Immediately preceding the block of visual or odor discrimination trials, dogs underwent five alert-training trials. Alert-training trials were identical to Experiment 1 for the odor-detection task, but differed for the visual discrimination task, in that, the bin used for training was the colored target bin (without scented cotton rounds) assigned for that dog (white or black).

For the visual discrimination food-buried trials, the procedures of the odor-detection task were followed except that neither bin was scented with a cotton round and one bin was white whereas the other bin was black. For both the visual- and the odor-detection trials, food was placed in an open tea ball in the target container and food was placed in a closed (inaccessible) tea ball in the non-target container. If the naive observer saw the dog rooting in a container, the observer would call ‘choice.’ If the dog was rooting in the target container (anise scented for odor, or the target colored container) the experimenter would say “good dog” and allowed the dog to eat the treat. If the dog was in the incorrect container, the bins were picked up and the dog was called back. If the dog did not make a choice within 30 seconds, the bins were picked up and re-presented. If the dog did not make a choice in the following 30 seconds, “no choice" was recorded and analyzed as incorrect. All other procedures (e.g. correction trials) were the same as Experiment 1.

Experimenter-delivered food group**:** twelve dogs were trained using only experimenter-delivered food trials from Experiment 1. Immediately preceding all blocks of odor-detection training, dogs were given a modified version of the alert-training trials. First, a treat was placed on top of the pine shavings and the anise scented pad for two trials. Subsequently, dogs were given three trials where the treat and the odor scented round were buried. Once the dog began to root and found the treat, the experimenter said “good dog” and delivered an additional treat by hand. After completion of these trials, dogs were given three trials of just the scented bin without buried food. Once the dog rooted in the bin, the experimenter said “good dog” and delivered a teat by hand. If a dog failed to root within 30 sec, the experimenter re-presented the trial. If the dog failed to root during an alert-training trial, up to two additional trials were given. If dogs failed to root by the additional trials, testing was discontinued. No dogs that rooted when food was buried failed to root by the additional alert-training trials. Immediately preceding all blocks of the visual discrimination training, dogs were given the above modified alert-training trials except that for the visual discrimination trials, the training bin was the target colored bin (i.e. it was not scented with anise).

For the visual- and odor-detection trials, no food was buried in the bins. The bins used in subsequent training trials were separate from the alert-training trial bins to prevent food-odor contamination. During training trials, a naive observer called ‘choice’ when the observer noted the dog rooting in a container. If the dog was rooting in the target container, the experimenter said “good dog” and delivered a treat by hand. If the dog was rooting in the non-target container, the containers were picked up and prepared for the next trial.

Control Trials: control trials were the same as control trials in Experiment 1 except that the control trials for the experimenter-delivered food group did not have buried food in tea balls. For this group, control bins were tan-colored and contained only pine shavings.

Statistical Analyses

An individual criterion of 10 out of 12 correct in a single session was considered significantly above chance (83%, binomial test, $p < .04$). Group performances were compared to chance with a one-sample t-test. To assess if acquisition was different across the two trial groups (experimenter-delivered food group and food-buried group) and two task types (odor task and visual task), the cumulative number of correct trials for each session was plotted across the cumulative number of trials for each session, for every dog. For each dog a linear regression line was fit to the data and the rate of acquisition (the slope) was determined. A two-way ANOVA was used to compare the acquisition rate across the four groups and post-hoc comparisons were made using a corrected alpha level of 0.013 for multiple comparisons.

Results and Discussion

Both the food-buried group and the experimenter-delivered food group performed at chance levels during the first 12 trials in both the visual and odor discriminations. As shown in Figure 3-1, by the end of five sessions, both groups were performing significantly above chance on both discriminations (one sample t-test, $p \leq .05$). The largest improvement was shown in the odor-detection task for dogs in the experimenter-delivered food group from 53% to 78% across testing. Dogs in the food-buried group showed much less improvement. Performance on the visual task showed modest improvement for both groups, and performance on control trials showed no signs of improvement and remained at chance across all five sessions.

For the group showing the greatest improvement (experimenter-delivered food on the odor task), a sharp increase in performance was noted from Sessions 1-3 with more gradual changes from Session 3-4 and particularly from Sessions 4-5 (Figure 3-1). This deceleration in learning once the group reached approximately 78% accuracy is an artifact arising from a sub-set of dogs quickly learning the task and performing at high accuracies, while the remaining dogs had not yet acquired the task. Figure 3-2 shows the individual performances across the five sessions for the odor task of the experimenter-delivered food group. By the end of Session 3 (36 odor trials), four dogs met the individual criterion of 83%: two of these dogs were performing at 100% accuracy (Figure 3-2). By Session 5, six dogs performed with accuracy levels above 92%, whereas the remaining six dogs' performances varied between 40- 75% accuracy.

Figure 3-2 also plots the changes in performance across the five sessions for the eight dogs that achieved the individual criterion for a single session in at least one session. Only five of these dogs, however, maintained accuracy above 83% across the last two sessions. Three of these dogs achieved the 92% accuracy across the last two sessions, with one dog achieving 100% accuracy across the last two sessions (Session 4 and 5), one dog achieving 96% accuracy, and one dog achieving 92% accuracy.

Figure 3-3 shows rates of acquisition by graphing the cumulative number of correct trials by the total number of trials, for each task and trial type combination. The odor task of the experimenter-delivered food group shows the highest performance and the highest rate (slope). In addition, Figure 3-3 shows that dogs start off at the same point, indicating that prior to testing, all dogs performed similarly on both tasks. To assess significant differences between these groups, the slope of each dog for both the odor and the visual task was computed from a best-fit linear regression line. The individual slopes for each task trial-type combination are shown in Figure 3-4. The individual slopes show that three dogs perform at consistently high levels with slopes greater than .8 (See the open square, filled diamond and filled triangle in Figure 3-2 to see the performance of these dogs across sessions).

To compare performance across task and trial type, a two-way ANOVA compared the slopes to assess the effect of the trial type (food-buried vs. experimenter-delivered) and the task (odor vs. visual). The goodness of fit of the linear regression line for each task trial-type combination was good and no systematic variation in the residuals was noted (r^2: Odor experimenter-delivered food, .94; Visual experimenter-delivered, .95; Odor food-buried, .93; Visual food-buried, .79). The ANOVA revealed a significant effect of the task, $F(1,22) = 20.1$, $p < .0002$, trial type, $F(1,22) = 6.34$, $p < .02$, and an interaction, $F(1,22) = 5.89$, $p < .02$. A paired t-test revealed that for the experimenter-delivered food group, acquisition was higher for the odor task than the visual task (t =

4.89, df =11, $p < .005$). An unpaired t-test revealed that for the odor task, performance was higher in the experimenter-delivered food group than the food-buried group (t = 3.54, df =22, $p < .002$). When considering the effect of trial type on visual task performance, however, no significant difference was found (unpaired t-test, t = .93, df= 22, $p < .36$). In addition, no statistical difference was noted between the task type (odor vs. visual) for the food-buried group (paired t-test, t= 1.45, df = 11, $p < .17$).

Dogs performed significantly better on the odor task than the visual task, when trained using only experimenter-delivered food trials. This suggests that the procedure is appropriate for studying odor-discrimination learning, as the odor cues provided were readily learned and learned *faster* than visual cues using the same procedure. The alert-training trials and the pine shavings may have prompted sniffing of the odors in the bucket and may have facilitated acquisition of the odor task, however, further testing is needed to elucidate the effects of the pine shavings.

Dogs trained with only the experimenter-delivered food trials performed significantly better on the odor task than dogs trained with the food-buried trials. This runs counter to our hypothesis that physical proximity of the target odor and the accessible reinforcer may reduce the delay to the reinforcer and enhance discrimination compared to experimenter-delivered food trials. It is important to note, however, that food was buried in the S^+ bin and the S^- bin, with food only accessible in the S^+ bin. This was done to insure dogs were not simply detecting the smell of food and not the target odor, without requiring additional control trials to test for this possibility. It still remains possible that pairing food *only* with the target odor may aid training, however, the results from this experiment suggest it is unlikely. Burying food during the odor task resulted in a 15% decrement in accuracy, indicating that food odor is a powerful stimulus influencing behavior on this task. Food odor may elicit numerous behaviors that may influence the dog's behavior (as shown by the decrease in performance) or possibly overshadow the target odor itself. These results suggest that training without placing the food in close proximity to the odor may be more efficient. It is interesting to note that there was no difference in performance between the food-buried and the experimenter-delivered food groups for the visual task. The food odor had no impact on performance for the visual task, indicating that other stimuli were more important in this task.

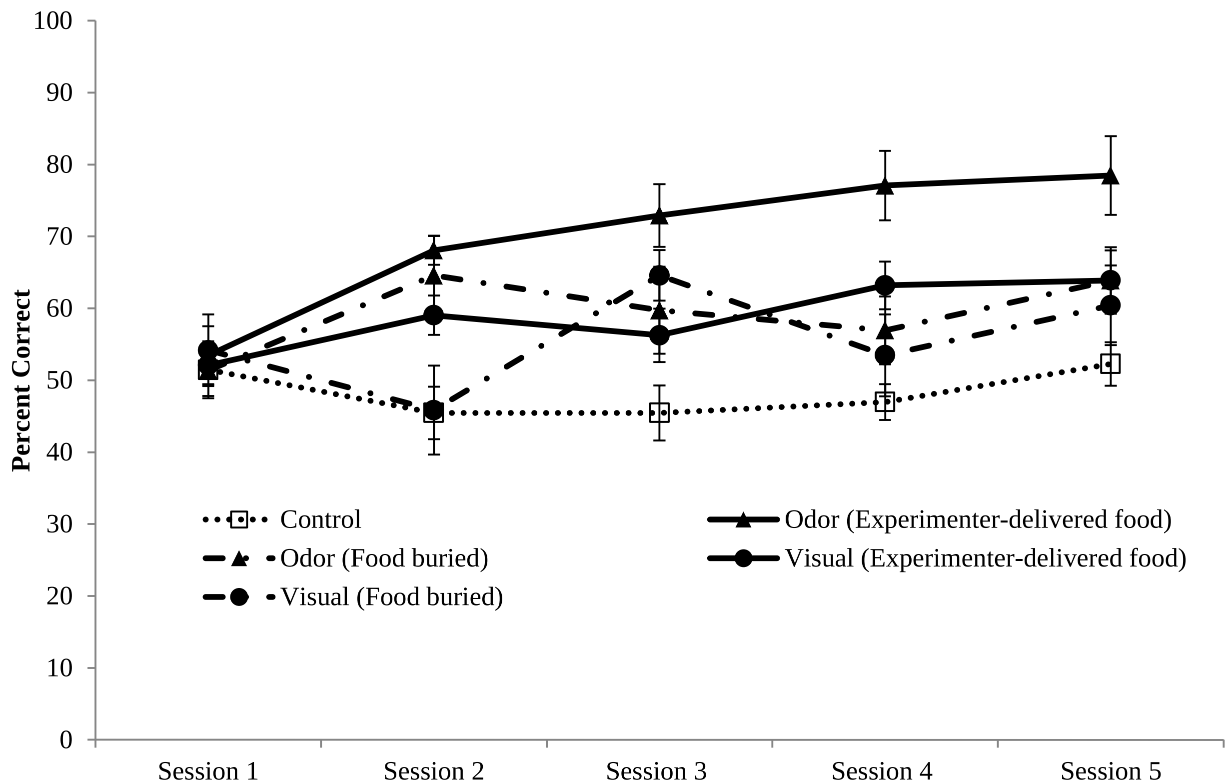

Figure 3-1**.** Average performance across all five sessions of Experiment 2. Solid lines indicate the dogs in the experimenter-delivered food group, dashed lines indicate the food-buried group, and the dotted line indicates performance on control trials. Triangles indicate performance on the odor-detection task and circles indicate performance on the visual task. Error bars indicate the standard error.

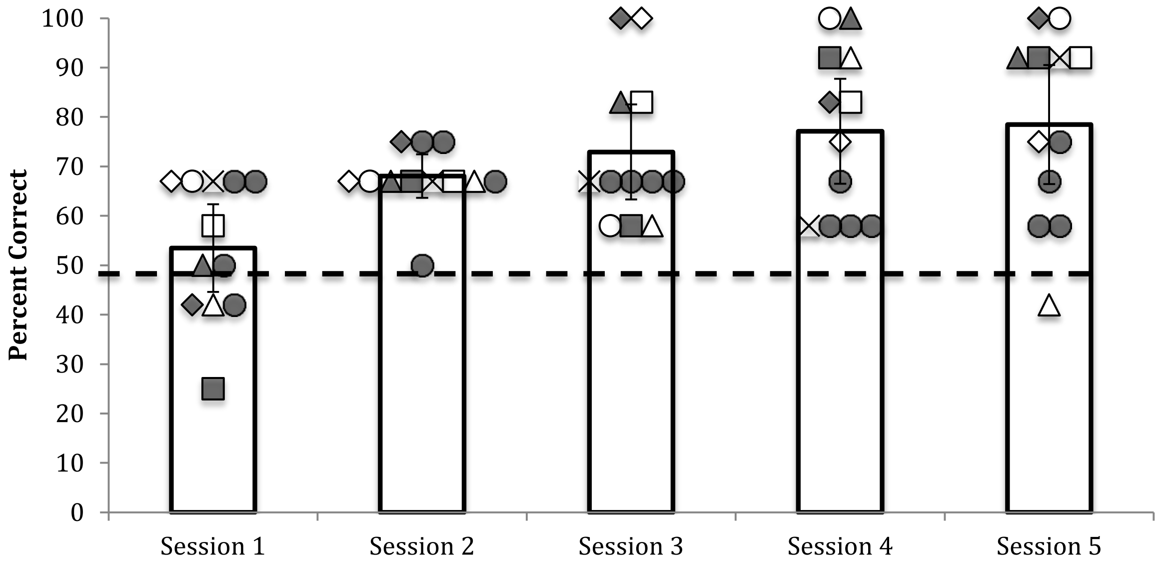

Figure 3-2. Acquisition of the odor discrimination for experimenter-delivered food trials in Experiment 2. Each symbol shows the performance of an individual dog. Dogs that met the individual criterion of 83% accuracy in at least one session are plotted with a unique symbol to show performance across sessions. Dogs not achieving this criterion are graphed with filled circles. Bars show the mean and error bars show the 95% CI.

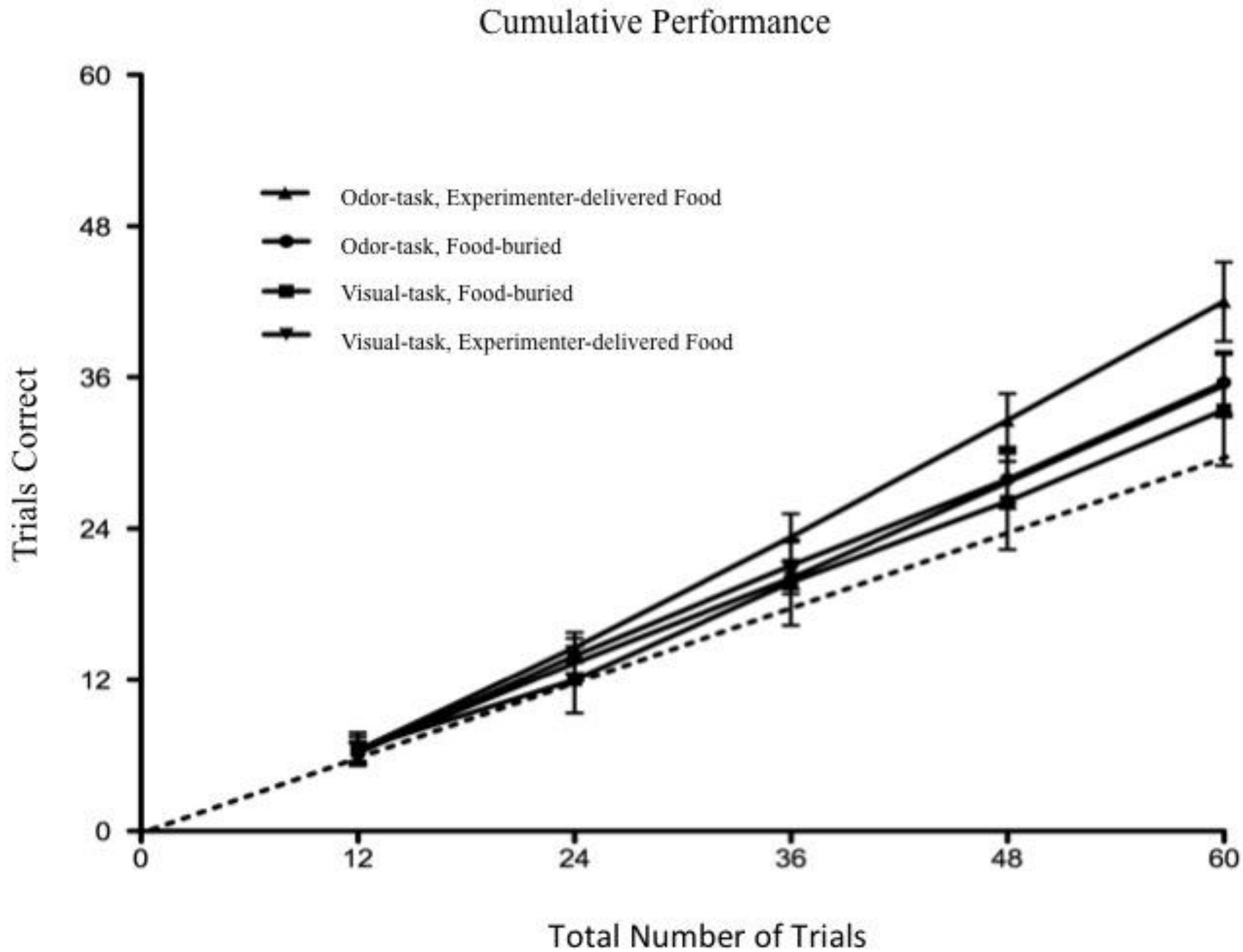

Figure 3-3. Cumulative performance across all trials. The mean and 95% confidence interval for each task and trial type combination is shown. The odor task of the experimenter-delivered food group shows the largest slope and highest performance. Dashed line shows a line with a slope of .5, and would be expected to occur by chance.

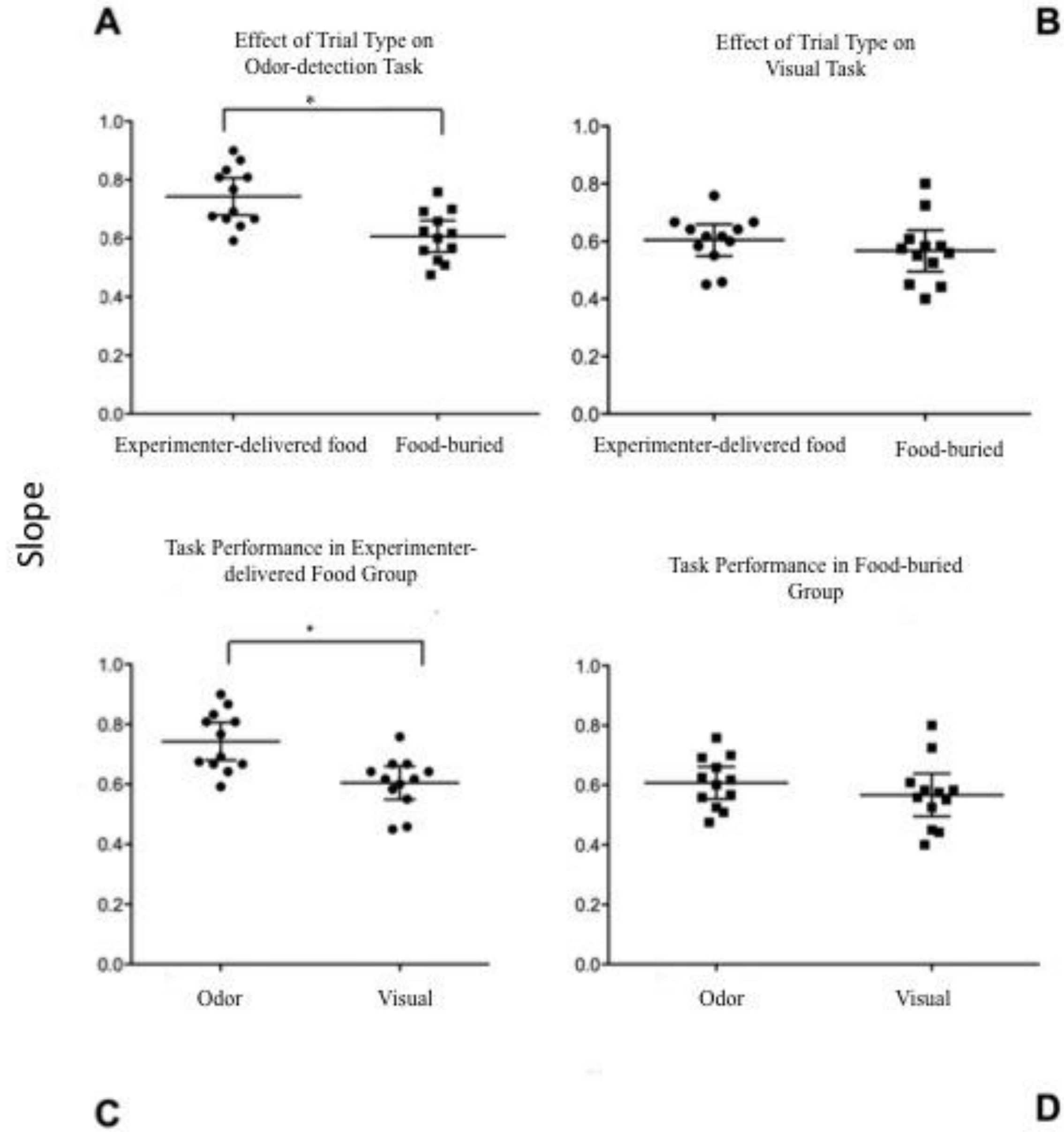

Figure 3-4. Comparisons of trial types and tasks in Experiment 2. Dots indicate dogs in the experimenter-delivered food group. Squares indicate dogs in the food-buried group. Line indicates the mean and error bars show the 95% confidence interval of dogs in each group. * indicates a significant differences with a corrected alpha for multiple comparisons. The first row shows the cross subject comparison and the second row shows within subject comparisons. Panels A & B compare the slopes of experimenter-delivered food group and food-buried group for the odor detection task and the visual task respectively. Panels C & D: compare the slopes of the odor-detection task to the visual task for experimenter-delivered food group and the food-buried group respectively.

CHAPTER 4
GENERAL DISCUSSION

Results from Experiments 1 and 2 show that dogs can be rapidly trained on an odor detection task. All training, including the training of the alerting response, was carried out during experimentally programmed and recorded trials. This allows comparison across dogs and permits evaluation of variables that may influence the rate at which an odor detection is learnt. Experiment 1 demonstrated that dogs can be systematically trained using only discrete trials. Experiment 2 demonstrated the usefulness of the components of this procedure to experimentally evaluate the effects of the different training trials and showed that the rate of acquisition for an odor discrimination was faster than the acquisition of a simple visual discrimination.

The first session of Experiment 1 demonstrated an unexpected negative correlation between hours of food deprivation and rate of acquisition of the odor discrimination; however, this correlation was not replicated during Session 2 of Experiment 1. One limitation to our analysis of food deprivation is that it was an experimental correlate and not an experimentally manipulated variable. Thus, further studies that experimentally manipulate deprivation are required to establish if the observed correlation is a replicable correlation, and if so, whether the correlation represents a causal relationship.

Performance on control trials remained at chance levels across all sessions of Experiments 1 and 2. The control trials may have negatively impacted the rate of acquisition, because not presenting the target odor and still reinforcing a response may have interfered with acquisition of the discrimination. It is important, however, to note the necessity of these trials. Prior work has shown that dogs' performance on odor-detection tasks can depend on the handler's beliefs about the presence or absence of the odor the dog is detecting (Lit, Schweitzer, & Oberbauer, 2011). Thus, it is important to control for any potential experimenter cueing. Additionally, it was noted that during control trials, the highest performing dogs would sniff both buckets and then refrain from responding. On other control trials, the highest performing dogs would sniff both bins and begin to bark at the experimenter or tip over the bins with their paws. Interestingly, these dogs would quickly return to rooting appropriately and accurately during the subsequent non-control trials. Future studies may utilize control trials to evaluate the effects of the absence of the target odor on behavior during an odor discrimination.

The procedure utilized for the experimenter-delivered food group in Experiment 2 may be useful for identifying individual differences in dogs and selecting for dogs likely to do well in an odor-detection training program. Performance varied in this group with some dogs quickly learning the odor-detection task and performing consistently accurately, whereas other dogs' performances remained at chance or were highly variable. Dogs that achieve a consistently high level of accuracy may be good dogs to select for further odor-detection training.

The procedure of Experiment 2 is rapid, requires few materials, and can be administered by individuals with minimal experimental training. The odor task for the experimenter-delivered food trials only requires 12 trials a session and eight alert-training trials. Each trial timed out at 1-minute, indicating that testing took no longer than 20 minutes per session or 100 minutes in total per dog. In addition, if the goal is only to identify dogs that acquire the task most rapidly, five sessions may not be necessary. Instead, identifying only those dogs reaching 83% accuracy in three or four sessions may be sufficient. The present data suggest, however, that not all dogs reaching the 83% accuracy criterion will maintain this level of performance consistently over time. Further evaluation is required to determine appropriate selection criteria. The slope analysis presented in Figure 3-4 may be one promising method for selecting consistently performing dogs. The three dogs with slopes great than .8 were consistently high performing dogs across all five sessions. Further evaluation, however, is required to evaluate the slope, or the overall performance on this test, as predictors for how successful a dog will be in a professional detector dog training operation. It remains possible that success on this task may not predict success in professional detector-dog training operations.

One important consideration for this procedure is that dogs were trained to detect the presence of an odor from background pine odor. Dogs were trained on this task as detecting the presence of an odor from background odor may be more similar to real-world detection tasks. Alternatively, dogs could be trained to discriminate between two odors, one odor as the S^+ and a different odor as the S^-. Potentially, utilizing a novel odor as the S^-, instead of only background odor, may enhance the discriminability of the target odor and facilitate learning. This hypothesis, however, requires further testing.

Together, the results demonstrate that naïve dogs can be trained to detect a novel odor using only discrete trials in a short period of time. The experimenter-delivered food procedure in Experiment 2 showed that dogs responded more to odor cues than visual cues and that consistently high performing dogs on the odor task can be identified within five short testing sessions. This may be a good way to select promising odor detection dogs. The ultimate utility of this procedure in selecting dogs and in studying the variables controlling odor detection will require further evaluation.

LIST OF REFERENCES

Cablk, M. E., Sagebiel, J. C., Heaton, J. S., & Valentin, C. (2008). Olfaction-based detection distance: a quantitative analysis of how far away dogs recognize tortoise odor and follow it to source. *Sensors*, *8*(4), 2208–2222.

Cornu, J. N., Cancel-Tassin, G., Ondet, V., Girardet, C., & Cussenot, O. (2011). Olfactory detection of prostate cancer by dogs sniffing urine: a step forward in early diagnosis. *European urology*, *59*(2), 197–201.

Dean, E. E. (1972). *Training Dogs for Narcotic Detection*. Retrieved from http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=A0749302

Fischer-Tenhagen, C., Wetterholm, L., Tenhagen, B.-A., & Heuwieser, W. (2011). Training dogs on a scent platform for oestrus detection in cows. *Applied Animal Behaviour Science*, *131*(1-2), 63-70. doi:10.1016/j.applanim.2011.01.006

Furton, K. G., & Myers, L. J. (2001). The scientific foundation and efficacy of the use of canines as chemical detectors for explosives. *Talanta*, *54*(3), 487-500. doi:doi: DOI: 10.1016/S0039-9140(00)00546-4

Goldblatt, A., Gazit, I. & Terkel, J. (2009). Olfaction and explosives detector dogs. In W. Helton, *Canine Ergonomics: The science of working dogs* (pp. 135-175). Boca Raton, FL: CRC Press.

Johnston, J. (1999). Canine detection capabilities: Operational implications of recent R & D findings. *Institute for Biological Detection Systems, Auburn University*, *1*(7).

Lit, L., Schweitzer, J. B., & Oberbauer, A. M. (2011). Handler beliefs affect scent detection dog outcomes. *Animal cognition*, 1–8.

Maejima, M., Inoue-Murayama, M., Tonosaki, K., Matsuura, N., Kato, S., Saito, Y., Weiss, A., et al. (2007). Traits and genotypes may predict the successful training of drug detection dogs. *Applied Animal Behaviour Science*, *107*(3-4), 287–298.

National Association for Canine Scent Work (2011). Target Odors. Retrieved from http://www.funnosework.com/targetodors.html

Sinn, D. L., Gosling, S. D., & Hilliard, S. (2010). Personality and performance in military working dogs: Reliability and predictive validity of behavioral tests. *Applied Animal Behaviour Science*, *127*(1-2), 51–65.

Tarpy, R.M. & Sawabini, F.L. (1974). Reinforcement Delay: a selective review of the last decade. *Psychological Bulletin, 81*(12), 984-997.

Transportation Security Administration (2011). TSA’s Puppy Program. Retrieved from http://www.tsa.gov/lawenforcement/programs/puppy_program.shtm

Waggoner, L. P. (1998). Effects of extraneous odors on canine detection. *Proceedings of SPIE* (pp. 355-362). Presented at the Enforcement and Security Technologies, Boston, MA, USA. doi:10.1117/12.335008

Williams, M., & Johnston, J. M. (2002). Training and maintaining the performance of dogs (Canis familiaris) on an increasing number of odor discriminations in a controlled setting. *Applied Animal Behaviour Science*, *78*(1), 55-65. doi:10.1016/S0168-1591(02)00081-3

Willis, C. M., Church, S. M., Guest, C. M., Cook, W. A., McCarthy, N., Bransbury, A. J., Church, M. R. T., et al. (2004). Olfactory detection of human bladder cancer by dogs: proof of principle study. *BMJ, 329*(7468), 7

BIOGRAPHICAL SKETCH

Nathaniel Hall was born and raised in St. Petersburg, FL, where he attended Boca Ciega High School and graduated from the Medical Magnet Program. Upon graduation, he was admitted to the University of Florida for undergraduate studies. Thanks to the support of the Florida Opportunity Scholarship, he was able to dedicate his time to his studies in Microbiology and Cell Science while developing an interest in behavioral research.

After conducting an undergraduate thesis on the behavior of bats, Nathaniel continued with behavioral research. He graduated in the spring of 2010 with a Bachelor of Science majoring in microbiology and cell science. Nathaniel subsequently entered a doctoral program in Psychology. Nathaniel plans to continue his research and hopes to obtain his PhD in Psychology.