Learning and Motivation 44 (2013) 218–228

Contents lists available at ScienceDirect

Learning and Motivation

journal homepage: www.elsevier.com/locate/l&m

Training domestic dogs (*Canis lupus familiaris*) on a novel discrete trials odor-detection task

Nathaniel J. Hall *, David W. Smith, Clive D.L. Wynne

Department of Psychology, University of Florida, United States

ARTICLE INFO

Article history:
Received 30 October 2012
Received in revised form 20 February 2013
Available online 15 May 2013

Keywords:
Olfaction
Detection
Domestic dogs
Training
Discrete-trials

ABSTRACT

Dogs can be trained to reliably detect a wide variety of odors. Little scientific research, however, has been published on the rate at which dogs can learn to detect an odor, the variables influencing this rate, and how this rate may vary across dogs. In two experiments, we developed a procedure that allows the study of individual differences in the acquisition of an odor detection task in dogs. We demonstrate that differential reinforcement can be used to train a rooting response in a bin under the control of a novel odorant in discrete trials. In initial testing, we showed that as a group, twenty dogs performed significantly above chance within 24 trials, with two dogs meeting an individual criterion for above chance performance. In a follow-up experiment, we compared burying accessible food inside the target bin (with inaccessible food in the non-target bin) to the experimenter delivering food by hand following correct responses. We assessed the effect of this procedural variation on both an odor discrimination and a visual discrimination. Dogs learned faster on the odor task when the experimenter delivered food, compared to when food was placed directly in the bins. Performance on the visual task was lower than on the odor task and was unaffected by how food was delivered. Our discrete-trials procedure with experimenter-delivered food may be a useful method to study rapid acquisition of an odor-detection in dogs.

Dogs are accurate and reliable biosensors, making them a useful detector technology (Furton & Myers, 2001). Domestic dogs can be trained to 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; Hawk, Conley, & Kiddy, 1984), prostate cancer in humans (Cornu, Cancel-Tassin, Ondet, Giardet, & Cussenot, 2011), bladder cancer (Willis et al., 2004), and numerous other volatile stimuli. Dogs can even detect a target odor in the presence of higher concentrations of extraneous odors (Waggoner et al., 1998).

Despite dogs' keen sensitivity to odorants, little has been published in the scientific literature about the variables that influence how quickly dogs first learn to "alert" an observer with an indicative response to the presence of an odor. In practice, dogs require extensive and intensive training to reach certification standards in odor detection. Sinn, Gosling, and 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 five days a week for 16 months before it accurately identified samples of urine from individuals with prostate cancer. Thus, odor discriminations appear to require extended periods of training. This makes it difficult to isolate the variables that may influence the rate at which a dog learns an odor detection.

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 et al. (2010) reported that 20.9% of

* Corresponding author at: Department of Psychology, University of Florida, Gainesville, FL 32611, United States.
E-mail address: njhall1@ufl.edu (N.J. Hall).

0023-9690/$ – see front matter
http://dx.doi.org/10.1016/j.lmot.2013.02.004

dogs selected for the 341st Training Squadron never met certification criterion for either odor detection or patrol training. Similarly, the United States 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 et al. evaluated the selection test used by the 341st Training Squadron and 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 improve the odds of a dog being certified in odor-detection. Maejima et al. (2007) 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, only “Desire to work,” but not “distractibility,” increased the odds of a successful outcome (though even this improvement was only marginal: 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 procedure that allows rapid assessment (within one or a few sessions) of a dog’s performance on an olfactory discrimination may be a useful addition to the battery of selection tests for dogs intended for odor-detection training.

Prior research has demonstrated that dogs can quickly acquire an olfactory discrimination. 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 for acquisition. 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” odor before learning the target discrimination. These authors did not report performance and training data during the first discrimination; instead, the number of trials required for an olfactory discrimination to transfer to new odors was measured. Developing a procedure that identifies how many trials the *first* discrimination requires would be useful in identifying important individual differences in overall training time and would also indicate when dogs first begin to attend to the odor stimuli. Standardizing an initial training procedure using discrete trial training would be valuable when trying to assess factors that may influence acquisition of olfactory discrimination in dogs. These factors could include breed differences or whether properties of the odors themselves may be important.

A suitable procedure has been developed in mice. Mihalick, Langlois, Krienke, and Dube (2000) trained mice in three to five sessions on an odor detection task using differential reinforcement for digging in sand with a specified scent. In this procedure, modified from Berger-Sweeney, Libbey, Arters, Junagadhwalla, and Hohmann (1998), the experimenter buried small pieces of chocolate in two containers of differentially scented sand. If the mouse dug in the S^+ scented container, it was allowed to obtain the chocolate. If the mouse dug in the S^- container, the experimenter removed both containers. Mice quickly learned the task, and the procedure was then used in a second experiment in an attempt to identify differences in odor discrimination in a mutant strain of mice.

The purpose of the present study is to develop a rapid and systematic discrete-trials training procedure for odor discrimination in dogs. Such a procedure could be used later to identify variables influencing odor-detection acquisition. We aimed to utilize differential reinforcement to obtain odorant stimulus control of a rooting response in a limited set of trials.

In Experiment 1, we investigated whether dogs could be trained to alert to a novel odor within 24 scheduled trials, whether responding can be maintained with experimenter-delivered food instead of burying food in the stimulus containers, and whether dogs’ performances varied allowing for selection of better performing dogs. In Experiment 2, we explored the effects of variations in the procedure of Experiment 1 and attempted to identify consistent high-performing dogs across multiple sessions.

Experiment 1

The purpose of Experiment 1 was to utilize differential reinforcement to train odor detection in dogs naïve to the entire task using only discrete trials to assess the acquisition of stimulus control of the odorant. We sought to assess whether dogs can be trained to perform significantly above chance within 24 scheduled trials. The procedure of Mihalick et al. (2000) was modified to include trials in which an experimenter delivered food and included an additional control for experimenter effects.

Methods

Subjects

Twenty-five pet dogs were selected for this study, of which twenty completed Session 1 and sixteen completed Session 2 (see Table 1 for subject information). None of the subjects was a working detector dog or had any previous training to be an odor-detecting dog. All dogs were tested in a familiar indoor 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 (dogs taller than 45 cm) were trained to root in large bins (40 cm × 35 cm × 16.5 cm), whereas small dogs (dogs 45 cm or smaller) were trained to root in smaller bins

Table 1
Subject Information for Experiment 1. Table outlines breed and age (in years) information and also indicates if the subject met the individual criterion of 18 or more correct in a single session.

Subject	Breed	Age	Met individual criterion in Session 1?
Drake	Bichon Yorkshire Terrier Mix	7	Yes
Bellini	Brittany Spaniel	8	Yes
Aegis	Belgian Malonois	5	No
Lilly	Beagle	1	No
Sea Sea	Beagle	2	No
Marlin	Labrador Golden Mix	1	No
Maxwell	Labrador Retriever	4	No
Milly	Labrador Retriever	1	No
Starbucks	Miniature Pincher	10	No
Clea	Australian Shepard Mix	1	No
Fin	Terrier Mix	2.5	No
Bayou	Australian Shepard Catahoula Mix	9	No
Lada	Pitbull	8	No
Buck	Border Collie	9	No
Fin	Catahoula Mix	4	No
Noah	Border Collie	11	No
Rasberry	Border Collie	3	No
Sweat Heart	German Shepard	3	No
Chloe	Yorkshire Terrier Poodle Mix	2	No
Lexi	Australian Shepard Border Collie Mix	5	No

(30 cm × 36 cm × 15 cm) allowing small dogs to more easily access the inside of the 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 (Fig. 1A). Rooting was scored when a dog pushed and buried its nose into the pine, moved left or right, and clearly moved the pine around. This definition was utilized to allow dogs to stick their nose into the pine to sample directly at the source without this behavior being considered a response. Thus, sampling and responding was independent.

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 because 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

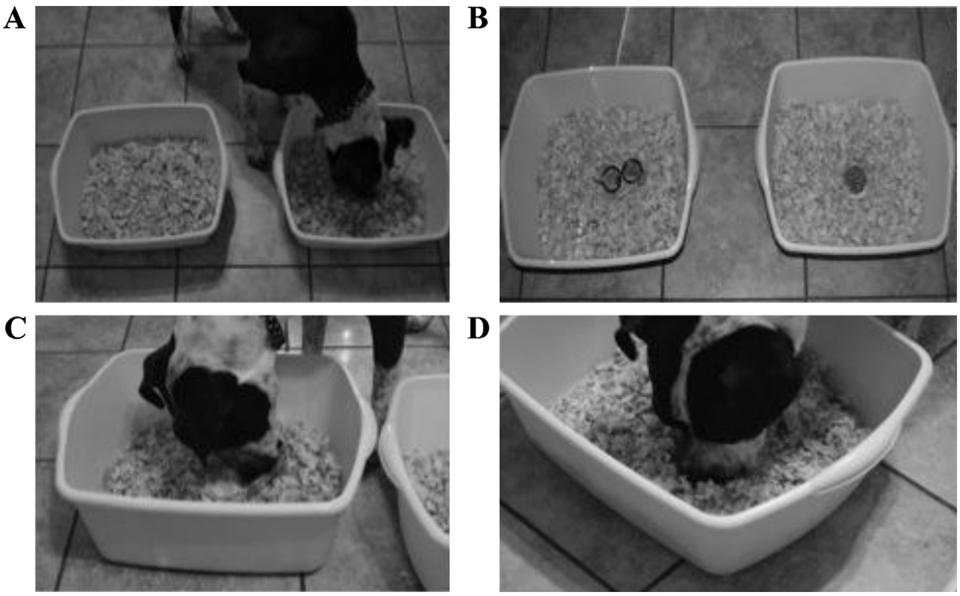

Fig. 1. Layout of Experiment 1 showing experimental bins and a dog responding. (A) Dog making a choice by rooting in one container. (B) Left bin is the food accessible bin with the target odor and an open tea ball with treat, right bin is the food inaccessible bin without the target odor and a closed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

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 Fig. 1A). The subject was held at least 1 m back from the bins and 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. Unlike Mihalick et al. (2000), in which the experimenter reported all responses, an independent observer, who did not know which bin held the target odor, stood 1-m back at the starting location and observed the dog's response. After each trial, the observer would call the dog back. In addition, a second independent observer scored responses for 285 trials from video. Of those trials, the second observer agreed with the scoring of the first observer in 97.5% of cases.

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 in which 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 allow the dog to eat the treat.

Food-buried trials. These trials were modeled after the procedure of Mihalick et al. (2000) in which food was buried in two containers and subjects were only allowed access to the food in the S^+ container on trials in which the S^+ container was selected. In our procedure, the S^+ bin was an anise-scented bin with buried food (S^+), whereas the S^- bin was identical except that it lacked the target odor. Like Mihalick et al., access to the food in the S^- bin was prevented by removing the bins prior to the dog accessing the food on incorrect trials. However, we also made the food physically inaccessible in the S^- bin by placing the food in a closed tea ball (inaccessible food; see Fig. 1B) to prevent accidental reinforcement. Food in the S^+ bin was placed in an open tea ball (accessible food). The tea ball was utilized to physically prevent access to food while equating food odor across the bins, making the anise odor, and not food odor, the only predictor of food.

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 observer, unaware which bin held the target odor, 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 (Fig. 1C). 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 min, both bins were picked up and a 'no choice' was recorded and coded as an incorrect response.

Experimenter-delivered food trials. In addition to the food-buried trials modeled after Mihalick et al. (2000), we conducted trials in which no food was buried. 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 elicit rooting. Experimenter-delivered food trials and food-buried trials only differed in how food was delivered. The S^+ bin contained an anise-scented cotton round buried 2.5 cm in the pine, whereas 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.

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 (Fig. 1D). 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 min, 'no choice' was recorded.

Control trials. Control trials were conducted to test whether the dogs were utilizing unintentional odor or visual 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 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.

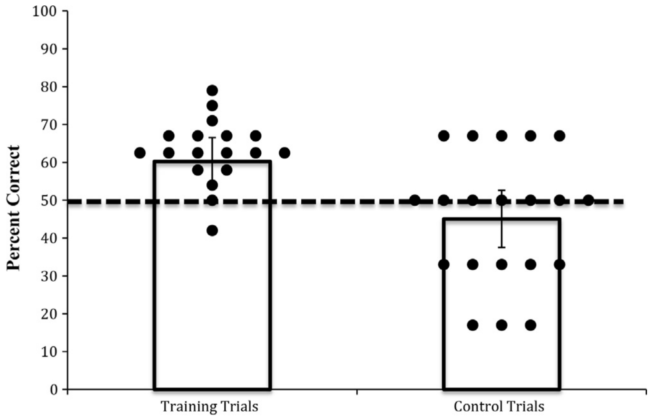

Fig. 2. Dog performance on Session 1 of Experiment 1. Each dot shows the performance of an individual dog and the height of the bar shows the mean. Each dog's performance is shown for training trials (food-buried and experimenter-delivered) and control trials. Error bars show the 95% CI. The dotted line indicates chance performance.

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 in which no food was buried.

For all trial types, the location of the target (S^+) bin was pseudo-randomly determined so that it was not at the same location for more than two trials in succession. If the dog made an incorrect choice and the previous four choices had also been to the same location, a 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 they failed 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. 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%; see Fig. 2). Most dogs performed slightly above chance (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.

The dogs' overall percent correct across the 24 training trials in Session 1 was significantly above chance (see Fig. 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, $t = -.29$, $df = 19$, $p > .8$). This indicates that the control of the odorant can be maintained in the absence of the buried food. On control trials, performance remained at chance (one sample t-test, $t = -1.7$, $df = 19$, $p > .05$).

Performance in Session 2 was highly similar to performance in Session 1 (see Fig. 3); the average percent correct did not change from Session 1 to Session 2 (Session 1, 60.7% correct; Session 2, 60.7% correct), and remained above chance (one

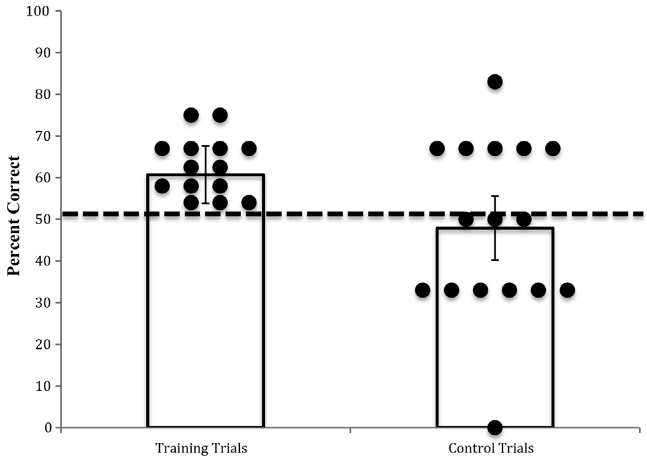

Fig. 3. Dog performance on Session 2 of Experiment 1. Each dot shows the performance of an individual dog and the height of the bar shows the mean. Each dog's performance is shown for the training trials (food-buried and experimenter-delivered) and control trials. Error bars show the 95% CI. The dotted line indicates chance performance.

sample t-test, $t = 4.21$, $df = 15$, $p < .05$). 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%. However, no statistically significant differences were observed between experimenter-delivered food trials and food-buried trials on a paired t-test ($t = -1.78$, $df = 15$, $p > .05$). Performance on control trials remained at chance (Fig. 3).

Using this discrete-trials procedure, dogs, on average across the group, 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 with dogs in which the alerting response to an odor had been trained prior to experimental training.

No significant differences were observed between food-buried trials and experimenter-delivered food trials, indicating that, as a group, the dogs continued to respond above chance when no food was buried in the containers. Given this result, food-buried trials may not be necessary to train the odor detection. The physical proximity of the food and target odor in food-buried trials, however, may enhance 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 increased 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. In addition, the food odor in both containers may increase the irrelevant background odor (e.g. "noise") and reduce the salience of the target odor.

Lastly, the marginally higher than chance (60.7%) performance indicates that dogs may not have received a sufficient number of trials or that the odorant was not a very salient stimulus. Dogs may have been attending to irrelevant unprogrammed visual cues from the bins instead of the odorant. If the odorant was a salient stimulus, and dogs were attending to the odor of the bins and not minor differences in their visual appearance, we would expect dogs to perform better on the odor-detection task than on a simple visual discrimination using the same procedure. Experiment 2 was designed to improve the procedure of Experiment 1 and answer some of the procedural questions raised.

Experiment 2

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 acquisition as a function of trial type. Lastly, dogs were simultaneously trained on a visual discrimination task (white bin vs. black bin) using an alternating conditions design to find out whether dogs attended similarly to the odorant and the visual stimuli of the bin.

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

Table 2
Subject Information for Experiment 2. Table gives the breed, age (in years), and group assignment information for each dog. The table also indicates if the dog met the 83% correct criterion in the last session in the odor discrimination and visual discrimination.

Subject	Breed	Group	Age	83% in the last odor session?	83% in the last visual session?
Casidy	American Bull Dog Mix	Food-buried	2	Yes	No
Eriyx	German Shepard	Food-buried	2	No	Yes
Mousse	Labrador Retriever	Food-buried	4	No	No
Attina	Hound Mix	Food-buried	1	No	No
Percy	Staffordshire Terrier Mix	Food-buried	1	No	No
Cosita	Red-boned Coon hound	Food-buried	0.5	No	No
Ti	Labrador Retriever	Food-buried	4.5	No	No
Bella	German Shepard	Food-buried	3	No	No
Kona	Shepard Mix	Food-buried	1	No	No
Wallie	Spaniel Mix	Food-buried	2	No	No
Otis	Shetland Sheepdog	Food-buried	4	No	No
Mitch	Basset hound	Food-buried	4	No	No
Yeska	German Shepard	Experimenter-delivered	2	Yes	No
Abbey	Golden Retriever	Experimenter-delivered	1	Yes	Yes
Cooper	Staffordshire Terrier	Experimenter-delivered	3	Yes	No
Chloe	Jack Russell	Experimenter-delivered	6	Yes	No
Pretzel	Boston Terrier	Experimenter-delivered	4	Yes	No
Carbon	Australian Shepherd Mix	Experimenter-delivered	4	Yes	No
Happy	Maltese	Experimenter-delivered	5	No	Yes
Roman	Dachshund mix	Experimenter-delivered	1	No	No
Yancey	Great Dane	Experimenter-delivered	3	No	No
Lucy	Great Dane	Experimenter-delivered	5	No	No
Kush	Pitt Bull Mix	Experimenter-delivered	3	No	No
Beau	Pitt Bull Mix	Experimenter-delivered	1.5	No	No

(experimenter-delivered group). All dogs were trained on both the odor-detection task from Experiment 1 and a black from white visual-discrimination task (see Table 2 for subject information). Dogs were tested in a familiar indoor environment.

Materials

Dogs were trained to detect anise scented cotton rounds using tan-colored (30 cm × 36 cm × 15 cm) 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 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. Each session consisted of alert-training trials, 24 training trials, and six 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 a control trial interspersed every four 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 for each dog.

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 (both outside and in). 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 observer saw the dog rooting in a container (the observer was unaware which bin was the target), 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 allow 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 s, the bins were picked up and re-presented. If the dog did not make a choice in the following 30 s, "no choice" was recorded and scored as incorrect. A second independent observer scored dogs' choices in a subset of trials (420) from video and agreed with the primary observer 97.6% of the time (410 agreements). All other procedures (e.g. correction trials) were the same as Experiment 1.

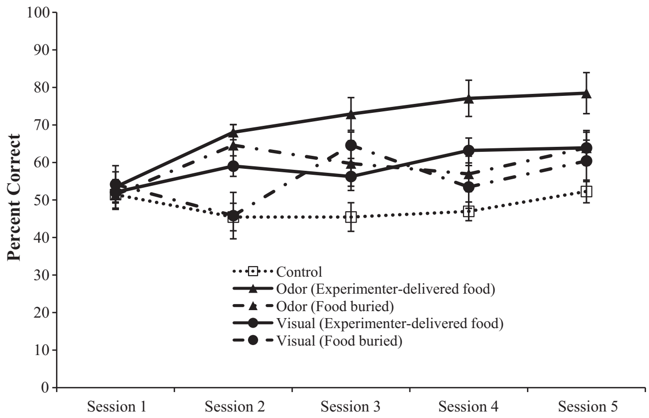

Fig. 4. Average performance across all five sessions of Experiment 2. Solid lines indicate the dogs in the experimenter-delivered food group, dashed lines the food-buried group, and the dotted line indicates performance on control trials. Triangles indicate performance on the odor-detection task and circles indicate performance on the visual task. Error bars indicate the standard error.

Experimenter-delivered food group. Twelve dogs were trained using only experimenter-delivered food trials as in 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 in which 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 treat by hand. If a dog failed to root within 30 s, 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 during 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 distinct from the alert-training trial bins to prevent food-odor contamination.

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. Prior to testing, one bin was assigned as the "correct" bin for all testing, and the other bin was assigned as the "incorrect" bin. A response to the assigned "correct" bin was scored as a correct response and responses to the asigned incorrect bin were scored as incorrect responses.

Statistical analyses

An individual criterion of 10 out of 12 correct in a single session was considered 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 Fig. 4, 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, from 53 to 78%, was shown in the odor-detection task for dogs in the experimenter-delivered food group. 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 over Sessions 1–3, with more gradual changes over Sessions 3–4 and particularly over Sessions 4–5 (see Fig. 4). This deceleration in learning once the group reached approximately 78% accuracy is an artifact arising from a sub-set of dogs that quickly learned the task and performed at a high level of accuracy, while the remaining

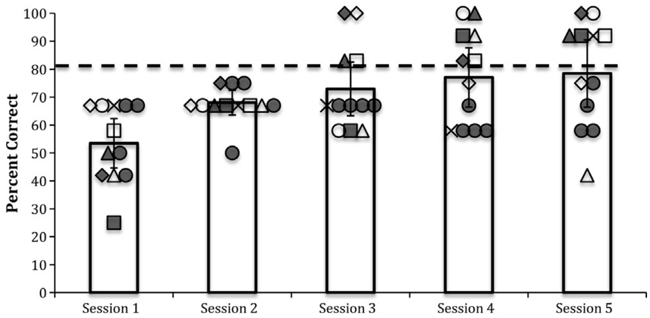

Fig. 5. Acquisition of the odor discrimination for experimenter-delivered food trials in Experiment 2. Each symbol shows the performance of an individual dog. Dogs that met the individual criterion of 83% accuracy (dashed line) in at least one session are plotted with a unique symbol to show performance across sessions. Dogs not achieving this criterion are graphed with filled circles. Bars show the mean and error bars show the 95% CI.

dogs had not yet acquired the task. Fig. 5 shows individual performance 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 (see Fig. 5). By Session 5, six dogs performed with accuracy levels above 92%, whereas the remaining six dogs' performances varied between 40% and 75% accuracy.

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

To assess significant differences between these groups, the slope of acquisition for each dog for both the odor and the visual tasks was computed from a best-fit linear regression line. The individual slopes for each task trial-type combination are shown in Fig. 6. These slopes show that three dogs performed at consistently high levels with slopes greater than .8 (see the open square, filled diamond and filled triangle in Fig. 5 for the performance of these dogs across sessions).

A two-way ANOVA was used to assess the effect of the trial type (food-buried vs. experimenter-delivered) and the task (odor vs. visual) on the acquisition slopes. The 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 significant effects of task, $F(1,22) = 20.1$, $p < .0002$, trial type, $F(1,22) = 6.34$, $p < .02$, and their 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 in 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 learned readily and faster than a visual cue 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. In addition, further testing manipulating the parameters of the odorant and visual stimuli is needed to assess whether dogs attend to odorants more readily than visual stimuli, in general, as is hypothesized for the rat by Slotnick (2001).

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 the 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 both the S^+ and S^- bins, 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. Thus, the buried food in the S^- bin may have elicited incorrect responding, or the food odor may have decreased the salience of the target odor by increasing the background odor.

It still remains possible that pairing food *only* with the target odor may aid training, but 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.

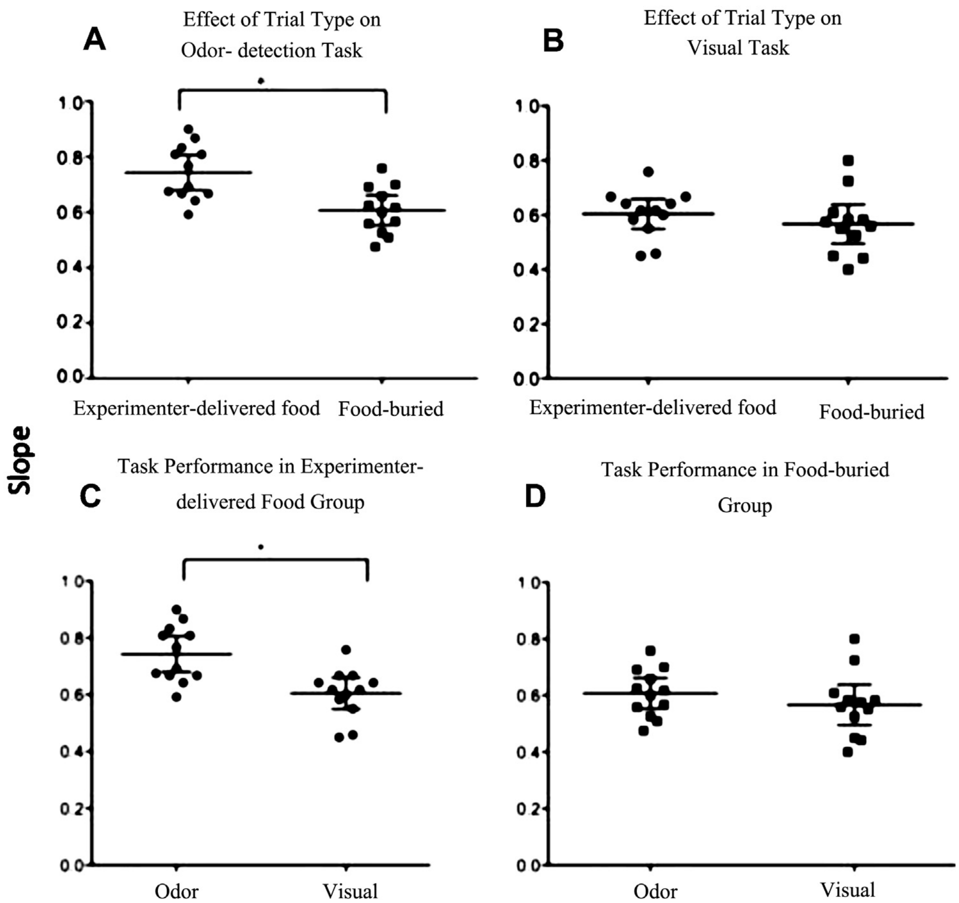

Fig. 6. Comparisons of acquisition slopes for the trial types and tasks in Experiment 2. Dots indicate dogs in the experimenter-delivered food group. Squares indicate dogs in the food-buried group. Line indicates the mean and error bars show the 95% confidence interval of dogs in each group. * indicates 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.

The food odor had no impact on performance for the visual task, indicating that stimuli other than food odor were more important in this task.

General discussion

Experiments 1 and 2 showed that dogs can be trained rapidly on an odor detection task using differential reinforcement. All training, including the training of the alerting response, was carried out during experimentally programmed and recorded trials. This procedure allows assessment of stimulus control, comparison across dogs, and evaluation of variables that may influence the rate at which odor detection is learned. Experiment 1 demonstrated that dogs can be systematically trained using only discrete trials and that performance can be maintained in the absence of buried food, extending the results of Mihalick et al. (2000) to dogs. Experiment 2 further demonstrated the effectiveness of differential reinforcement in the acquisition of an odor-detection, experimentally evaluated 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.

Performance on control trials remained at chance levels across all sessions of Experiments 1 and 2. The control trials may have had a negative impact on the rate of acquisition, because reinforcing a response in the absence of a target odor could reduce dogs' attention to the odor cue. It is important, however, to note the necessity of these trials. Prior work has suggested that dogs can be very sensitive to human cues (e.g. Udell, Giglio, & Wynne, 2008). Thus, it is important to test for the possibility that unintentional cuing may control responding. Control trials were run as probes throughout training to maintain the integrity of all training data by ruling out the possibility that a cue other than the odor may influence responding. To prevent observer bias, observers were kept blind on all trials, as the belief of handlers has been shown to influence the performance of detection teams (Lit, Schweitzer, & Oberbauer, 2011). Interestingly, 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. These dogs quickly returned 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 odor discrimination.

The experimenter-delivered food procedure of Experiment 2 is rapid, requires few materials, and can be administered by individuals with minimal training. The odor task for the experimenter-delivered food trials only requires 12 trials per session and eight alert-training trials. Each trial timed out at 1-min, so that testing took no longer than 20 min per session or 100 min in total per dog. Thus, the procedure is brief and could be used as a rapid behavioral assessment of odor detection in dogs. Such an assessment could be used in future research exploring variables that influence acquisition in odor discrimination. In addition, the rapid assessment may be useful as a selection tool for future odor-detection training, although for this purpose the procedure would require further empirical validation.

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 because detecting the presence of a target odor from a background odor may be more similar to real-world detection tasks. Alternatively, dogs could be trained to discriminate between two odors, one as the S^+ and a different odor as the S^-. Potentially utilizing a novel odor as the S^-, instead of using only a 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 the odor cue than the color of the sample bins and that consistently high performing dogs on the odor task can be identified within five short testing sessions. The ultimate utility of this procedure in selecting dogs and in studying the variables controlling odor detection will require further evaluation.

Acknowledgments

We would like to thank all of the owners that permitted our repeated testing of their dogs. We thank Camp Marlin Doggie Day Care for all of their help in recruiting and testing dogs. We would also like to thank Andrew White and Bradleigh Lore for their assistance with this project.

References

Berger-Sweeney, J., Libbey, M., Arters, J., Junagadhwalla, M., & Hohmann, C. F. (1998). Neonatal monoaminergic depletion in mice (*Mus musculus*) improves performance of a novel odor discrimination task. *Behavioral Neuroscience*, *112*, 1318–1326. http://dx.doi.org/10.1037/0735-7044.112.6.1318

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*, 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*, 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*, 63–70. http://dx.doi.org/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*, 487–500.

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

Hawk, H. W., Conley, H. H., & Kiddy, C. A. (1984). Estrus-related odors in milk detected by trained dogs. *Journal of Dairy Science*, *67*, 392–397. http://dx.doi.org/10.3168/jds.S00220302(84)81314-4

Lit, L., Schweitzer, J. B., & Oberbauer, A. M. (2011). Handler beliefs affect scent detection dog outcomes. *Animal Cognition*, *14*, 1–8.

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

Mihalick, S. M., Langlois, J. C., Krienke, J. D., & Dube, W. V. (2000). An olfactory discrimination procedure for mice. *Journal of the Experimental Analysis of Behavior*, *73*, 305–318.

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*, 51–65.

Slotnick, B. (2001). Animal cognition and the rat olfactory system. *Trends in Cognitive Sciences*, *5*, 216–222.

Tarpy, R. M., & Sawabini, F. L. (1974). Reinforcement delay: A selective review of the last decade. *Psychological Bulletin*, *81*, 984–997.

Transportation Security Administration. (2011). *TSA's puppy program*. Retrieved from http://www.tsa.gov/lawenforcement/programs/puppy_program.shtm

Udell, M. A., Giglio, R., & Wynne, R. F. C. D. L. (2008). Domestic dogs (*Canis familiaris*) use human gestures but not nonhuman tokens to find hidden food. *Journal of Comparative Psychology*, *122*, 84–93.

Waggoner, L. P., Jones, M. H., Williams, M., Johnston, J. M., Edge, C. C., & Petrousky, J. A. (1998). Effects of extraneous odors on canine detection. *Proceedings of SPIE*, *3575*, 355–362. http://dx.doi.org/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*, 55–65. http://dx.doi.org/10.1016/S0168-1591(02)00081-3

Willis, C. M., Church, S. M., Guest, C. M., Cook, W. A., McCarthy, N., Bransbury, A. J., et al. (2004). Olfactory detection of human bladder cancer by dogs: Proof of principle study. *BMJ*, *329*, 712.