Behavioural Processes 162 (2019) 64–71

Contents lists available at ScienceDirect

Behavioural Processes

journal homepage: www.elsevier.com/locate/behavproc

# Behavioral persistence is associated with poorer olfactory discrimination learning in domestic dogs

S. Dalal, N.J. Hall*

*Department of Animal and Food Science, Texas Tech University, USA*

ARTICLE INFO

*Keywords:*
Canine behavior
Persistence
Extinction
Odor detection
Odor discrimination
Working dogs

ABSTRACT

Domestic dogs are trained for a wide variety of jobs; however, half of dogs that enter working dog training organizations never become certified. The aim of this study was to identify whether a basic measure of behavioral persistence was associated with sixteen dogs' performance on an odor discrimination learning task. Further, we evaluated whether dogs that adopted more of a win-stay or win-shift strategy during discrimination learning was associated with greater persistence. Lastly, we tested if measures of a standardized canine behavior questionnaire (the CBARQ) predicted discrimination learning. We found greater persistence during extinction was associated with poorer discrimination learning. Further, dogs that employed more of a win-stay strategy (compared to win-shift) during the discrimination learning phase showed greater persistence in the persistence task and poorer performance on the odor discrimination task. Lastly, the CBARQ measure of trainability showed a trend association with odor discrimination performance, but no other behavioral characteristics were related. Overall, high levels of behavioral persistence is detrimental to olfactory discrimination learning.

## 1. Introduction

Behavioral persistence is the maintenance of a behavior in the presence of behavioral disruptors such as extinction, satiation, or alternative sources of reinforcement. Behavioral persistence can be measured in the laboratory a few different ways, including resistance to extinction (RTE), in which the subject is trained to engage in a target behavior for a reward that is later discontinued, and responding during the extinction phase is measured (Bai et al., 2016; Nevin and Grace, 2000; Thrailkill et al., 2016; Welker and McAuley, 1978). There is an interesting degree of variability in behavioral persistence across individuals, which has previously been associated with important behavioral phenotypes such as the presence of stereotypy (Campbell et al., 2013, 2013; Garner and Mason, 2002; Tanimura et al., 2008; Vickery' and Mason, 2003) and discrimination learning performance (Tanimura et al., 2008).

Higher levels of persistence has previously been associated with behavioral inflexibility and poorer discrimination learning (Frith and Done, 1983; Tanimura et al., 2008). In a rodent model, rodents that respond longer during extinction had poorer performance on a procedural learning task (Tanimura et al., 2008). Further, human patients with schizophrenia had a harder time switching their responses on a switch over task and had a persistent nature in their pattern of responding, suggesting greater levels of persistence might inhibit performance on certain tasks (Frith and Done, 1983).

Persistence appears to be related to a generalized behavioral inflexibility in which responding to changes in surrounding environmental contingencies is slow (Lewis and Kim, 2009). This is thought to manifest in some animals as stereotypic behavior (Garner et al., 2003a, 2003b; Pomerantz et al., 2012). Animals with a high level of responding in extinction may suggest a general difficulty in response inhibition, leading to high levels of inappropriate behavior, such as stereotypic behavior (Protopopova et al., 2014). These persistent stereotypic behaviors have some identified neurological correlates in the basal ganglia (Bechard, 2012; Sandson and Albert, 1984). Together, these results suggest that behavioral persistence may be associated with general difficulties in response inhibition and may lead to difficulties in situations in which an animal needs to adapt to changing contingencies.

Further, persistence may manifest in behavioral differences in normal behavior as well. Previous research has investigated animals' preferences to return to a previously rewarded location (win-stay) or investigate a new location after reward (win-shift). Rats and bees a more likely to engage in a win-shift strategy, suggesting preference for not returning to the same location as previously rewarded (Demas and Brown, 1995; Olton and Schlosberg, 1978) although pigeons have been shown to have a win-stay bias (Randall and Zentall, 1997). Although

* Corresponding author at: Department of Animal and Food Science, 1308 Indiana Ave, Texas Tech University Lubbock Tx, 79409, USA.
*E-mail address:* Nathaniel.j.hall@ttu.edu (N.J. Hall).

https://doi.org/10.1016/j.beproc.2019.01.010
Received 4 October 2018; Received in revised form 8 January 2019; Accepted 25 January 2019
Available online 28 January 2019

species differences may exist, it is unclear whether individual differences in strategy, such as responding persistently to a previously rewarded location, within species, may be associated with behavioral persistence on an RTE task. Thus, it would be of interest to investigate whether win-stay/win-shift patterns in discrimination learning maybe associated with behavioral persistence.

Identifying key behavioral phenotypes that may manifest in differences in reward learning is critical for applications with working dogs. Working dogs are crucial for many situations including law enforcement and homeland security and are required to learn new tasks quickly and be adaptable to changing circumstances (Cablk and Heaton, 2006; Helton, 2009; Hutson et al., 1997; Nussear et al., 2019). Further, dogs can be trained to perform a wide variety of tasks, with detection capabilities being a critical skill (Furton and Myers, 2001; Lazarowski and Dorman, 2014). Identifying the most optimal dogs, especially for odor detection tasks, is challenging (Maejima et al., 2007). Only 63% of detection dogs in training complete their programs and certify (Sinn et al., 2010). Examining behavioral characteristics of dogs that are predictive of odor detection success would be quite useful (Jamieson et al., 2017; Porritt et al., 2015). Therefore, it would be beneficial to determine whether behavioral persistence may be a simple measure that could identify dogs with difficulties in discrimination learning, specifically odor discrimination learning.

Given that high persistence is associated with poorer performances in learning tasks in rodents (Tanimura et al., 2008), we hypothesized that dogs with greater persistence would perform poorer on odor discrimination training that required dogs to respond to the presence of an odor in one of two bins. Thus, the aim of this study was to evaluate whether measures of persistence on an RTE task were predictive of performance on a standardized odor discrimination task. Further, we explored whether persistence was associated with differing reward-learning strategies, such as a win-shift or win-stay strategy during discrimination learning.

Lastly, identifying whether any measurable canine behavioral characteristics can predict detection learning could have significant impact on identifying optimal dogs for working dog programs. The Canine Behavioral Assessment and Research Questionaire (CBARQ) assesses a variety of behaviors, specifically behaviors related to trainability, aggression, hyperactivity and more (Hsu and Serpell, 2003; van den Berg et al., 2010). The CBARQ does appear to distinguish between pet and working dogs on subscales such as trainability, aggression (towards dogs and people), and measures of fear (Hare et al., 2018). It remains unclear, however, whether these subscales might have predictive abilities for detection learning, or might reflect differences that occur during training.

To evaluate these questions, 16 dogs were trained on an odor discrimination task. Half of the dogs were tested first on the RTE task while the other half were tested first on the odor discrimination task. Handlers rated the dogs on the CBARQ blind to the dogs' performance on the odor discrimination task. We then evaluated whether RTE or CBARQ subscales were associated with overall odor discrimination performance.

## 2. Methods

### 2.1. Subjects

Sixteen dogs at a University facility participated in this study. Ages ranged from 1 to 6 years and all sixteen dogs originated from a local animal source (see Table 1). One dog, however, failed to complete training for the RTE task, and was therefore removed from the study, leaving 15 dogs for analysis.

### 2.2. Procedure

Each dog was trained on two tasks: a resistance to extinction task (RTE) and an odor discrimination task. Half of the dogs were trained with the RTE task first and half were trained in reverse order. Further, the caretakers of these dogs were asked to take a Canine Behavioral Assessment & Research Questionnaire (CBARQ) to identify predictors of performance on the odor discrimination training and evaluate inter-observer agreement among caretakers. These caretakers worked with the dogs on a regular basis with training, enrichment, and overall care. Only those caretakers who worked with dogs longer than 1 month were asked to complete the CBARQ.

**Table 1**
Dog information. Age is a best estimate in years when unknown. Weight is given in kg.

| Dog | Estimated Age | Weight | Sex |
|---|---|---|---|
| Comet | 2 | 21.8 | Male |
| Elliott | 3 | 30.9 | Male |
| Maggie | 3 | 21.8 | Female |
| Norman | 2 | 20.9 | Male |
| Ryan | 2 | 18.6 | Male |
| Sam | 3 | 18.2 | Male |
| Seth | 3 | 18.6 | Male |
| Zeus | 3 | 22.3 | Male |
| Rogue | 1 | 29.1 | Male |
| Norma | 4 | 19.1 | Female |
| Gracie | 1 | 15.9 | Female |
| Elga | 1 | 20 | Female |
| Dasher | 6 | 26.8 | Male |
| Axel | 1 | 30.5 | Male |
| Athena | 1 | 31.8 | Female |
| Tank | 5 | 21.4 | Male |

### 2.3. Measures and tasks

#### 2.3.1. CBARQ

The Canine Behavioral Assessment and Research Questionnaire (CBARQ) is a widely used survey tool to evaluate problem behaviors in dogs (Hsu and Serpell, 2003). Briefly, the instrument asks owners to report on aggression, trainability deficits and distractibility. The CBARQ contains approximately 100 questions and asks the owner to reflect on how their dog reacts to common everyday scenarios. The survey includes questions on various incidences of dog aggression towards children, strangers, other animals, food, toys, touch, scolding, and staring. Further questions ask about level of obedience, distraction, engagement, fear, anxiety, separation, excitability, attachment, attention, and miscellaneous characteristics that are typical of some dogs. The caretakers ranked each dog on a scale of 1–5 and indicated the level of their behavior for questions that ask about obedience, self-control, learning, interacting with others, and excitability. Finally, the survey covered questions on typical stereotypic behaviors such as light-chasing, tail-chasing, walking in circles, staring, wandering and also included questions about problems with memory. The CBARQ yields several summary scales: stranger-directed aggression, owner-directed aggression, stranger-directed fear, nonsocial fear, dog-directed fear or aggression, separation-related behavior, attachment or attention-seeking behavior, trainability, chasing, excitability, and touch sensitivity (Hsu and Serpell, 2003).

The survey was taken by twelve different caretakers, but not all caretakers met an interaction criterion with every dog. Caretakers provided ratings only for dogs with which they met the interaction criterion of working with the dog several times a week for at least a month. Each dog had a minimum of 6 caretakers provide a rating up to a maximum of 12 caretakers providing ratings for an individual dog. Caretakers had significant direct experience with the dogs. Caretakers were responsible for walking dogs, supervising play groups, training the dogs, socializing dogs and cleaning.

#### 2.3.2. RTE

All sixteen dogs were tested on a resistance to extinction device modified from a manual task (Protopopova et al., 2014). This task was used to measure persistence in each dog by recording the number of responses made under extinction. Each dog was trained to press a lever on a Fixed Ratio 1 (FR1) schedule. After making ten independent lever presses, the dog was tested in two resistance to extinction (RTE) sessions. Sessions were composed of ten warmup trials (reinforced), thirty acquisition trials (reinforced), followed by extinction. The warmup trials were done to ensure that the dog was appropriately trained and motivated to press the lever. If the dogs did not complete the warm up trials, the dog would not move on to acquisition. This did not happen for any dog. Otherwise, there was no difference between the warmup trials and the acquisition trials. Extinction continued until no responses were recorded for two minutes. Each dog took different amounts of time to be fully trained on the device and make ten independent lever presses, but testing started identically for all dogs after the first ten independent presses. Dogs were able to press the lever with their nose or paw and the treats used for each dog varied on the dog's preference and what they would consistently work for during initial training.

#### 2.3.3. Apparatus

The resistance to extinction device was comprised of a lever and a feeder that backed data up automatically to a computer. The lever was 13 cm long extending from the device made of polypropylene, and 43 cm from the ground. The feeder dispensed treats below the lever. This was done through an opening 15 cm from the ground to the left of the lever. The apparatus itself was 60 cm tall (see Fig. 1). A lever press was detected by an electronic microswitch which initiated the computer to make a "beep" and signal to the feeder (SuperFeeder™) to release a treat and record the time of the lever press (see Fig. 1). From the timestamped record, we scored the number of presses made in extinction, the time taken to reach the two-minutes with no responses in extinction, and the time taken to complete the 30 acquisition trials.

#### 2.3.4. Odor discrimination task

The odor training task was used to measure all dogs' performances on a more complicated olfactory discrimination task. Dogs were trained using a standardized discrete trials odor discrimination procedure (Hall et al., 2015). Dogs were trained to make a rooting response in a bin of pine shaving (Pets Pick™) containing an almond odorant and refrain from responding to an identical bin without almond odorant. Dogs were trained in five sessions of forty-two trials which were composed of six pre-training trials, thirty discrimination trials, and six control trials (described in detail below). Every session started with pre-training trials and control trials were interspersed after every six discrimination trials. In addition, a subset of discrimination trials were conducted double-blind (described in detail under controls).

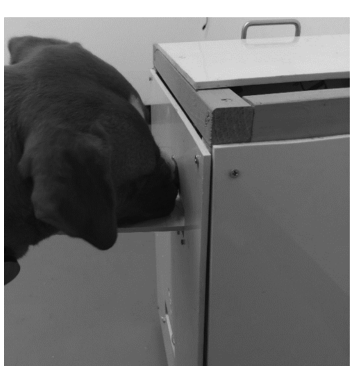

**Fig. 1.** RTE Task. Dog presses lever with nose to earn a treat from opening below lever.

#### 2.3.5. Pre-training

Pre-training trials served to train an initial rooting response for each dog and comprised a total of six trials at the beginning of each session. During pre-training a single bin that included 1 mL of almond extract (Watkins™ Almond Extract) on a cotton pad covered by pine shavings was prepared. For the first two trials, a treat was placed on top of the pine and the bin was placed down on the ground for the dog to eat the treat and smell the almond odorant. Once the dog grabbed the treat, an additional treat was provided by hand from E1. For the next two trials, the treat was buried in the pine approximately 2 cm deep to encourage the dog to dig in the pine. Once the dog began digging E1 gave another treat by hand. For the final two trials, no food was placed in the bin, but once the dog began to dig in the bin, E1 gave a treat by hand.

#### 2.3.6. Discrimination trials

Two more bins, separate from pre-training, were used for the discrimination trials. The S- bin contained 1 mL of distilled water on a cotton pad while the S + bin had 1 mL of almond extract on its cotton pad.

For each trial, the bins were kept 0.5 m apart from one another while a handler kept the dog at least two meters away from the bins. During each trial, the position of the target (odor) bin was switched pseudo-randomly such that the target bin was not on the same side for more than three trials in a row. Once the bins were positioned correctly for the trial, E1 called the dog forward and looked down at the ground (not at either bin). E2, who was blind as to which bin was correct, would then watch the dog and call out the number of the bin the dog was rooting through. If the dog was rooting in the correct bin E1 would say "good dog" and reward the dog with a treat for rooting through the correct bin. If the dog chose incorrectly, both bins were picked up without consequence. If the dog did not make a choice within thirty seconds, the trial was re-presented. If the dog failed to make a choice again within 30 s, a "no choice" was recorded and scored as incorrect.

There were a few conditions for conducting additional pre-training trials. If the dog responded incorrectly for three trials in a row, two pre-training trials were administered. Additionally, if the dog made no response on two trials in a row, two pre-training trials were administered. If the dog did not respond for four rounds of pre-training (food freely available in the bin), they were considered unmotivated and failed the session for that day. This occurred on 8 out of 75 sessions. If a dog completed at least 10 trials, percent correct was determined based on the number of trials completed. If fewer than 10 trials were completed, the session was scored as missing (this occurred for three sessions). One additional session was scored missing due to a dog developing an illness before the final session, and was therefore not tested. In addition, if the dog developed a side bias during training, defined as four trials to the same side, with the last trial being incorrect, a correction trial was implemented (but not scored) where the dog would be encouraged to walk up to both bins and E1 would pick up the incorrect bin forcing the dog to respond to the alternative side and receive a treat.

#### 2.3.7. Controls

Experimenter bias was evaluated using no odor controls and double-blind trials. Two additional bins were control bins which contained 1 mL of distilled water. One bin was a priori assigned as the 'correct bin' although no odor was present. These trials were conducted identically to discrimination trials. If un-intentional cuing was controlling performance, we expected dogs to maintain an above chance performance in the absence of odors. Chance performance was indicative that dogs were following only odor cues. In addition, for two of the five training sessions ten trials were conducted double blind with the help of a third experimenter. The third experimenter arranged the bins and placed them in E1's hands to put down to start a trial. E3 then moved out of the room and around a corner. E2 then indicated verbally the bin the dog was responding in and E3 responded from the other room as to whether the dog was correct or incorrect.

**Table 2**
Definitions of measures from resistance to extinction and odor discrimination training.

| Measure | Definition |
|---|---|
| Resistance to Extinction Mean | Mean number of responses made during extinction across both sessions |
| Acquisition Rate | Mean number of responses made per minute during the acquisition phase |
| Extinction Time | Mean total time from the start of extinction to the timeout criterion of extinction was met (2 min without a response). |
| Extinction Rate | Mean number of responses made per minute during the extinction phase |
| Odor Max | Maximum accuracy reached across the five days of odor discrimination training. |

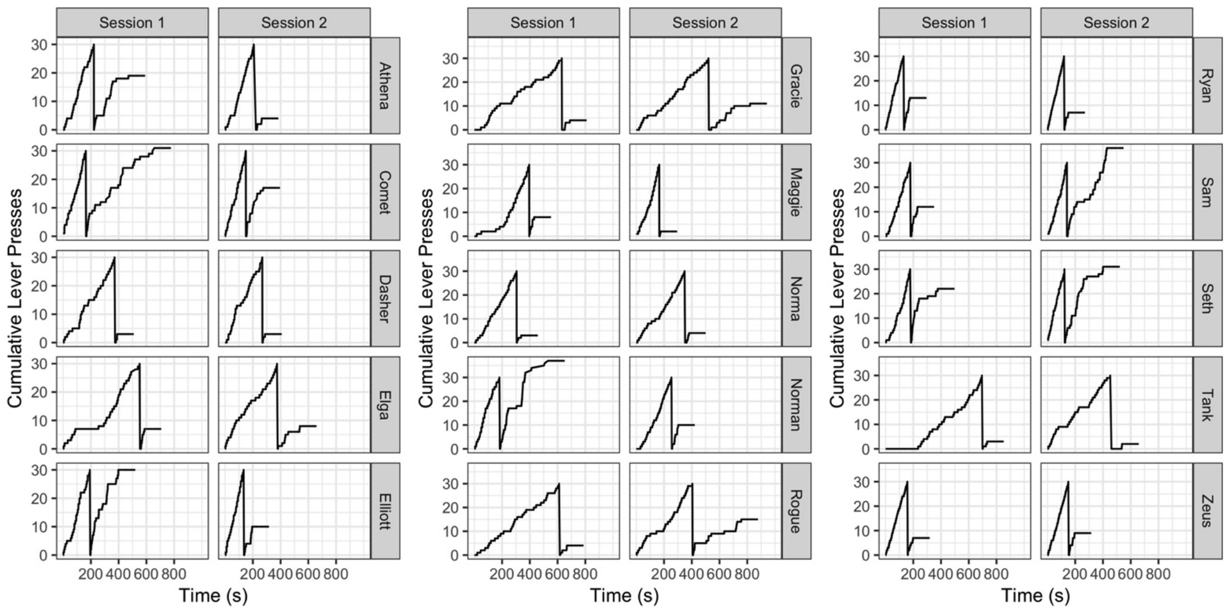


**Fig. 2.** Cumulative record from Resistance to Extinction. Shows the cumulative number of responses made as a function of trial time for each dog for session 1 and session 2 for each dog (labeled to the right). First line indicates the acquisition phase. The line was re-set to zero at the start of the extinction phase.

### *2.3.8. Ethical statement*

All procedures with animals were approved by the University Animal Care and Use Committee (Protocol # 16065-07). Procedures for the caretaker survey were approved as an exempt protocol by the Institutional Review Board (Protocol # 2017-827)

## *2.4. Statistical analysis*

From the cumulative records of the acquisition and extinction phases and odor discrimination training phase, we extracted several parameters (defined in Table 2) using a custom R script (R Core Team, 2013). The dependent variables were the maximum performance reached for a single discrimination session and overall mean accuracy during the odor discrimination training. The maximum was selected to represent the optimal performance that was reached within 5 days, whereas the mean reflected overall performance including early sessions in which performance was expected to be poor.

To summarize the various measures extracted from the RTE task (see Table 2), a principal component analysis (PCA) was conducted to reduce the number of dimensions. This was done, because the four measures of extinction responding are likely to be highly correlated and could not each be added together into a regression model to predict odor detection performance. Thus, the PCA was used to summarize the measures of the RTE task optimally while producing uncorrelated components that could be used for the regression analysis. The RTE task was satisfactorily summarized with a single component (details provided in results). We then conducted a linear regression in which the principal component predicted the maximum accuracy reached during the odor discrimination task (odor max) and mean performance during the odor discrimination task (odor mean). We included sex and weight as a covariate, but did not include age or breed as these variables had significant uncertainty.

To analyze the results of the CBARQ, we computed each of the recommended subscales (Hsu and Serpell, 2003) for each dog for each caretaker. To analyze agreement between caretakers, we computed the Inter-class Correlation for each subscale across all handlers that rated that dog. We also analyzed whether the mean CBARQ measures predicted the maximum accuracy reached for the odor discrimination task (odor max), by linear regression. Due to the exploratory nature of this analysis, and the potential correlations between subscales of the CBARQ influencing a multiple regression, we ran independent regression for each subscale as a predictor of Odor Max. No p-value corrections were made to maintain power of this exploratory analysis.

Lastly, to evaluate whether a win-shift or win-stay strategy during the discrimination task was associated with behavioral persistence and odor discrimination performance, we calculated a mean proportion of trials in which a win-stay strategy was employed during the discrimination task. Following every rewarded response on the two-choice task, we scored whether dogs returned to the same location (win-stay) or shifted to the alternative location (win-shift) on the very next trial. We computed this for each session and took the mean across all sessions for each dog. For one dog, however, only the summary data were preserved for 3 of the sessions. For this dog, we used the average of the two sessions for which trial-by-trial data was available. Overall, we evaluated the proportion of trials in which a win-stay strategy was utilized as a predictor of behavioral persistence and odor discrimination performance.

**Table 3**
Principal Component Loadings. Shows the loadings of each measure onto the retained principal component.

| Measure | PC1 |
|---|---|
| Resistance to Extinction Mean | −0.40 |
| Acquisition Rate | −0.46 |
| Extinction Time | −0.57 |
| Extinction Rate | −0.55 |

**Table 4**
Average Inter-class correlations for random raters for each CBARQ subscale.

| Scale | Average ICC for Random Raters | p-val |
|---|---|---|
| Excitability | 0.45 | 0.02 |
| Touch Sensitivity | 0.66 | < 0.001 |
| Stranger Aggression | 0.79 | < 0.001 |
| Owner Aggression | 0.90 | < 0.001 |
| Stranger Fear | 0.86 | < 0.001 |
| Non-social Fear | 0.79 | < 0.001 |
| Dog Aggression | 0.92 | < 0.001 |
| Separation | 0.68 | < 0.001 |
| Attachment | 0.70 | < 0.001 |
| Trainability | 0.71 | < 0.001 |
| Chasing | 0.87 | < 0.001 |

## 3. Results

Fig. 2 shows the cumulative record of lever pressing for each session for each dog. The first line indicates the acquisition phase. The cumulative record was re-set to zero for the extinction phase. The flat period of extinction indicates the 2 min. of no response required to terminate the extinction session. Overall, significant variability in persistence was observed between dogs (e.g. Comet Session 1 and 2 vs. Dasher session 1 and 2).

To analyze the RTE session, the RTE parameters defined in Table 2 were extracted. A principal component analysis was performed. A single component explained 73% of the variance, which was retained. The loadings are shown in Table 3 and indicate that all four measures load together consistently. The negative loadings indicate that higher PC1 scores reflect less resistance to extinction. We then conducted a linear regression in which the principal component score, weight, and sex were predictors of the maximum performance reached on the odor discrimination (see Fig. 3). The principal component score was significantly associated with the maximum odor detection performance ($t$ = 4.54, $p$ < 0.001). Sex, however, was unrelated to detection performance ($t$ = 0.81, $p$ = 0.43) as well as canine body weight ($t$ = 0.19, $p$ = 0.85). Similarly, the resistance to extinction principal component score was associated with the mean performance on the odor discrimination training (see Fig. 3; $t$=4.24, $p$ = 0.001), but sex and weight was unrelated to performance (t=1.61, $p$ = 0.14; t=1.16, $p$ = 0.27).

Next, we evaluated whether the CBARQ produced consistent results across caretakers. First, we computed the eleven subscales of the instrument (Excitability, Touch Sensitivity, Stranger Aggression, Owner Aggression, Stranger Fear, Nonsocial Fear, Dog Aggression, Separation, Attachment, Trainability, Chasing) for each dog and handler completing the survey. Each dog had a minimum of 6 handlers and a maximum of 12 handlers to score the dog's behavior. Table 4 shows the average ICC for each subscale for random raters. Overall, agreement ranged from poor (Excitability: 0.45) to excellent (Dog Aggression: 0.92). Most subscales, however, were acceptable (˜0.70).

We evaluated whether any of the subscales were associated with maximum performance reached on the odor discrimination task. Excitability, touch sensitivity, dog aggression, stranger aggression, owner aggression, stranger fear, non-social fear, separation, attachment and chasing were unrelated to odor discrimination performance (all p > 0.10). One variable, trainability, showed a near statistically significant relationship (estimate = 0.072, se = 0.034, $t$ = 2.08, p = 0.057) indicating that increases in handler rated trainability was associated with greater performance on the odor discrimination task. When accounting for the dog's performance on the resistance to extinction task using the principal component as a predictor in the linear model, trainability no longer remained significant (estimate = 0.03,

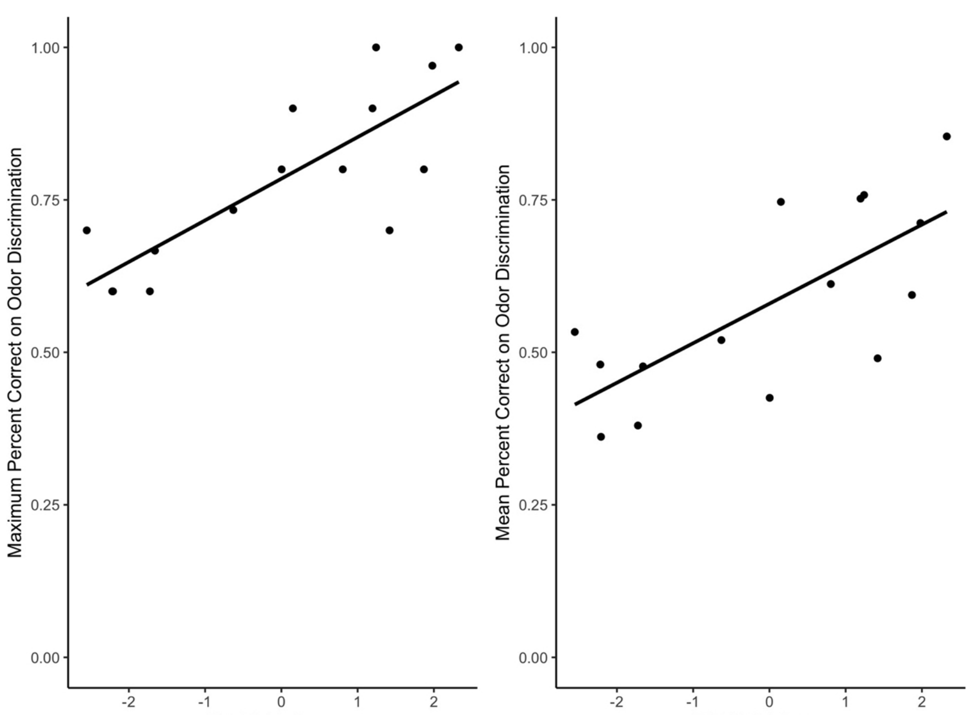


**Fig. 3.** Relationship between principal component of resistance to extinction and maximum performance on the odor detection task (left) and mean performance on the odor detection task (right). Line shows the best fit regression.

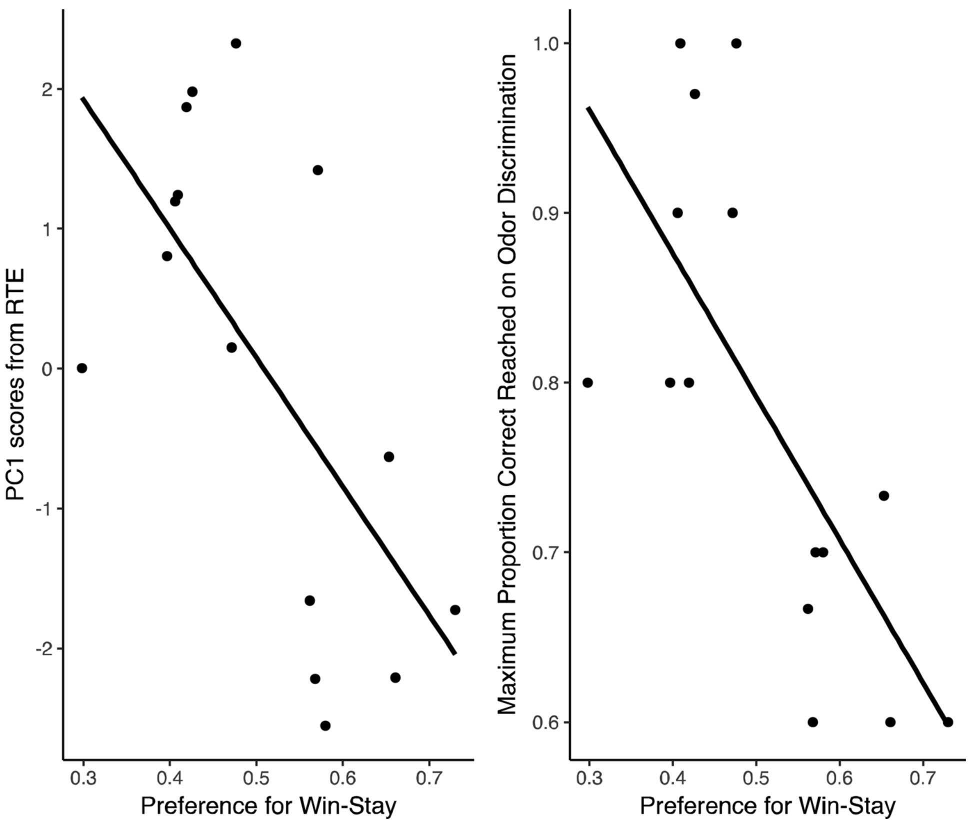


**Fig. 4.** Relationship between principal component of resistance to extinction and proportion of trials following a reward the dog approached the same side (left) and (right) the relationship between the maximum performance on the odor detection task and the proportion of trials following a reward the dog approached the same side (win-stay). Line shows the best fit regression.

se = 0.024, $t$ = 1.29, $p$ = 0.22), but the principal component remained a highly significant predictor (estimate = 0.10, se = 0.024, $t$ = 4.27, $p$ < 0.01).

Next, we evaluated whether the dogs' strategy during discrimination sessions was biased more towards a win-stay or win-shift approach and whether this was related with persistence and odor discrimination performance. To calculate the preference for a win-stay approach, we evaluated after each correct trial, the proportion of subsequent trials the dog approached the same side. Preference for a win-stay approach was associated with higher overall behavioral persistence (lower PC1 scores; est = −9.21, se = 3.00, t = −3.08, p < 0.01). Further, a more win-stay approach was associated with lower maximum performance reached on the odor discrimination task (see Fig. 4, est = −0.84, se = 0.23, t = −3.61, p < 0.01 Interestingly, this does not appear to simply reflect preference for returning to the same side. When simply evaluating the proportion of trials dogs responded to the same side as the previous trial, regardless of whether it followed a correct or incorrect response, there was no relationship between side preference and persistence (est = −6.85, se = 5.40, t = −1.27, p = 0.23).

### 3.1. Controls

To confirm dogs were following the odor cue and not unintentional cues, we evaluated dog's performance on two types of control trials. First, we evaluated dogs' performance on trials in which no odor was presented, but one container was a priori assigned as correct. If dogs were following odor cues, we expected dogs to perform at or below chance given that dogs may not respond if the odor is removed. Overall performance on these trials was 37% (chance = 50%), indicating that dogs were following the odor cue. In addition, dogs were given double blind trials across two sessions (580 trials in total; one dog did not receive double blind trials due to a scheduling conflict and one dog was ill during the final double-blind session and received only one session). If dogs were following unintentional cues by the experimenter, we would expect performance to drop on trials in which all experimenters were blind to the correct bin. Overall performance was similar on double blind trials to the overall mean for the session in which the double-blind trials were conducted (62% vs 64%). A linear mixed effect model in which performance was predicted as a function of double-blind or non-double-blind trials (including a random effect for each subject) was conducted. There was no difference between regular and double-blind trials with respect to performance (estimate = 0.02, se = 0.04, df = 42, $t$ = 0.52, $p$ = 0.61), indicating dogs were not utilizing unintentional experimenter cues.

## 4. Discussion

Dogs with higher persistence performed poorer on the odor discrimination training, as predicted. This suggests that high levels of persistence can lead to difficulties in learning for more complex discrimination tasks in dogs, and is similar to that seen in other species (Frith and Done, 1983; Tanimura et al., 2008). Sex and body weight had no effect on odor discrimination performance. In addition, control trial performance was below chance and performance on double-blind trails was identical to single-blind trials indicating dogs were not following unintentional cues from the experimenters and that dogs were utilizing the odor stimuli.

The direct relationship between extinction responding and discrimination learning is not entirely unexpected. Discrimination itself is an important component in extinction, in which the change in contingency must be detected and discriminated from the contingency previously in effect (for a review see Nevin and Grace, 2000). The partial reinforcement extinction effect (PREE) is an example of this (Nevin, 1988; Nevin and Grace, 2000). Although richer schedules of reinforcement are generally associated with greater resistance to extinction, partial reinforcement schedules lead to greater resistance to extinction compared to continuous schedules (Nevin, 1988; Nevin and Grace, 2000d). This is thought, in part, to be related to discrimination between continuous schedules and extinction being better than between intermittent and extinction schedules. Thus, extinction responding involves discrimination processes, and the present study finds that extinction responding is further related to discrimination processes outside the extinction context, to performance on a separate odor discrimination task.

Interestingly, we also noted that higher rates of win-stay responses during the odor discrimination phase was associated with greater persistence on the RTE task and consequently poorer performance on the odor discrimination task. Perhaps less persistent individuals maybe more likely to adopt a shifting strategy and may be more sensitive to reward changes. Unfortunately, this experiment was not directly designed to address these questions, and should be interpreted cautiously. An interesting future direction of this research is to see whether measures of behavioral persistence, as measured in a resistance to extinction task, is associated with strategy differences under a more naturalistic foraging paradigm.

Inter-observer agreement on CBARQ subscales showed moderate to good agreement when caretakers were rating the dog. This varied based on the subscale indicating some characteristics were more difficult for caretakers to evaluate consistently, such as excitability. This may suggest that excitability maybe a more fluid state and is perhaps influenced by the handler's behavior as well (e.g. some handlers may be more excited and enthusiastic leading to dog excitement). The CBARQ analysis showed no correlation between ten of the eleven subscales with odor discrimination success. The subscale of trainability, however, showed trend significance as a predictor for greater performance on the odor discrimination training. This suggests that handler reported answers to the CBARQ trainability may provide some clues as to odor discrimination success. However, the PC1 scores from the persistence task were a stronger predictor of performance on the odor discrimination task. Previous research has shown that the CBARQ does successfully discriminate between Search and Rescue Dogs from Pet dogs on a variety of scales, of which Trainability is one (Hare et al., 2018). Our analysis was focused to initial detection learning and therefore was looking at a more focused aspect of detection dog work, which may explain the differences in results. In addition, our samples size was significantly smaller, making it more difficult to detect smaller effect sizes.

There were a few important limitations to this study. First, there was significant within-subject variability in our RTE measure between the first and second testing session. At present, the sources of the variability from the first to second session are unclear, but could reflect uncontrolled experimental error or may reflect another process in which participants are learning that the contingencies change during the session and learn to stop responding more quickly at the start of extinction. However, given that the second session did not consistently produce lower rates of responding and that previous studies have observed consistent responding in extinction across repeated sessions (Anger and Anger, 1976; Bai and Podlesnik, 2017; Guilhardi et al., 2006), this suggests that there is likely some uncontrolled error in the task. One such example is when training the dogs on the lever press, dogs required different periods of time to acquire the lever press. Developing a training procedure that provided more measurable consistency across all of the subjects during initial training would be a useful improvement. Furthermore, different treats were utilized based on dog preference. It would be useful in future assessments to attempt to control for treat value across dogs with a pre-study food motivation assessment. Further, future studies should conduct significantly more than two extinction assessments given the observed within-subject variability. This will help provide a more reliable measure of extinction responding for individual dogs and may help identify patterns across repeated tests.

The present findings are relevant to understanding what makes an ideal working dog. High persistence leads to slower learning in complex tasks, suggesting low persistence is ideal for training purposes. However, working animals are required to be persistent for a variety of reasons (Mahoney, 2019). Many searches take a long time, often with little to no reward at the end (Sargisson and Mclean, 2010). Dogs may require a certain aspect of persistence in order to maintain a search with long durations and thin reinforcement schedules (Hall, 2017). It could potentially be beneficial to have a working dog that takes longer to train, but maintains persistence once learned. Alternatively, a dog that is very sensitive to reward contingencies may be easier to train and could be trained to tolerate thinner reinforcement schedules for long duration searches. Thus, this study needs to be extended to a working dog population before clear recommendations can be made as to whether resistance to extinction can be used to select optimal working dogs.

## Acknowledgments

We would like to thank Micah Allen for her work on this project. We also thank everyone in the TTU Canine Olfaction Lab for all of their help with the dogs as well as the Honors College Undergraduate Research Scholars Program supported by the CH and Helen Jones Foundation, Inc. We also thank the Haven Animal Care Services for their support and assistance.

## References

Anger, D., Anger, K., 1976. Behavior changes during repeated eight-day extinctions1. J. Exp. Anal. Behav. 26 (2), 181–190. https://doi.org/10.1901/jeab.1976.26-181.

Bai, J.Y.H., Podlesnik, C.A., 2017. No impact of repeated extinction exposures on operant responding maintained by different reinforcer rates. Behav. Processes 138, 29–33. https://doi.org/10.1016/j.beproc.2017.02.011.

Bai, J., Chan, C.K.J., Elliffe, D., Podlesnik, C., 2016. Stimulus–Reinforcer Relations Established During Training Determine Resistance to Extinction and Relapse via Reinstatement Vol. 106https://doi.org/10.1002/jeab.227.

Bechard, A., 2012. Modeling restricted repetitive behavior in animals. Autism. Access 01 (S1). https://doi.org/10.4172/2165-7890.S1-006.

Cablk, M.E., Heaton, J.S., 2006. Accuracy and reliability of dogs in surveying for Desert Tortoise (Gopherus Agassizii). Ecol. Appl. 16 (5), 1926–1935. https://doi.org/10.1890/1051-0761(2006)016[1926:AARODI]2.0.CO;2.

Campbell, D.L.M., Dallaire, J.A., Mason, G.J., 2013. Environmentally enriched rearing environments reduce repetitive perseveration in caged mink, but increase spontaneous alternation. Behav. Brain Res. 239, 177–187. https://doi.org/10.1016/j.bbr.2012.11.004.

Demas, G.E., Brown, M.F., 1995. Honey bees are predisposed to win-shift but can learn to win-stay. Anim. Behav. 50 (4), 1041–1045. https://doi.org/10.1016/0003-3472(95)80104-9.

Frith, C.D., Done, D.J., 1983. Stereotyped responding by schizophrenic patients on a two-choice guessing task. Psychol. Med. 13 (04), 779. https://doi.org/10.1017/S0033291700051485.

Furton, K.G., Myers, L.J., 2001. The scientific foundation and efficacy of the use of canines as chemical detectors for explosives1Invited paper for the special issue of Talanta 'Methods for Explosive Analysis and Detection'.1. Talanta 54 (3), 487–500. https://doi.org/10.1016/S0039-9140(00)00546-4.

Garner, J.P., Mason, G.J., 2002. Evidence for a relationship between cage stereotypies and behavioural disinhibition in laboratory rodents. Behav. Brain Res. 136 (1), 83–92. https://doi.org/10.1016/S0166-4328(02)00111-0.

Garner, J.P., Mason, G.J., Smith, R., 2003a. Stereotypic route-tracing in experimentally caged songbirds correlates with general behavioural disinhibition. Anim. Behav. 66 (4), 711–727. https://doi.org/10.1006/anbe.2002.2254.

Garner, J.P., Meehan, C.L., Mench, J.A., 2003b. Stereotypies in caged parrots, schizophrenia and autism: evidence for a common mechanism. Behav. Brain Res. 145 (1), 125–134. https://doi.org/10.1016/S0166-4328(03)00115-3.

Guilhardi, P., Yi, L., Church, R.M., 2006. Effects of repeated acquisitions and extinctions on response rate and pattern. J. Exp. Psychol. Anim. Behav. Process. 32 (3), 322–328. https://doi.org/10.1037/0097-7403.32.3.322.

Hall, N.J., 2017. Persistence and resistance to extinction in the domestic dog: basic research and applications to canine training. Behav. Processes 141, 67–74. https://doi.org/10.1016/j.beproc.2017.04.001.

Hall, N.J., Smith, D.W., Wynne, C.D.L., 2015. Pavlovian conditioning enhances resistance to disruption of dogs performing an odor discrimination: conditioning enhanced dogs' resistance. J. Exp. Anal. Behav. 103 (3), 484–497. https://doi.org/10.1002/jeab.151.

Hare, E., Kelsey, K.M., Serpell, J.A., Otto, C.M., 2018. Behavior differences between search-and-rescue and pet dogs. Front. Vet. Sci. 5. https://doi.org/10.3389/fvets.2018.00118.

Helton, W.S. (Ed.), 2009. Canine Ergonomics: the Science of Working Dogs. CRC Press/ Taylor & Francis, Boca Raton.

Hsu, Y., Serpell, J.A., 2003. Development and validation of a questionnaire for measuring behavior and temperament traits in pet dogs. J. Am. Vet. Med. Assoc. 223 (9), 1293–1300. https://doi.org/10.2460/javma.2003.223.1293.

Hutson, H.R., Anglin, D., Pineda, G.V., Flynn, C.J., Russell, M.A., McKeith, J.J., 1997. Law enforcement K-9 dog bites: injuries, complications, and trends. Ann. Emerg. Med. 29

(5), 637–642. https://doi.org/10.1016/S0196-0644(97)70253-1.
Jamieson, L.T.J., Baxter, G.S., Murray, P.J., 2017. Identifying suitable detection dogs. Appl. Anim. Behav. Sci. 195, 1–7. https://doi.org/10.1016/j.applanim.2017.06.010.
Lazarowski, L., Dorman, D.C., 2014. Explosives detection by military working dogs: olfactory generalization from components to mixtures. Appl. Anim. Behav. Sci. 151, 84–93. https://doi.org/10.1016/j.applanim.2013.11.010.
Lewis, M., Kim, S.-J., 2009. The pathophysiology of restricted repetitive behavior. J. Neurodev. Disord. 1 (2), 114. https://doi.org/10.1007/s11689-009-9019-6.
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. Appl. Anim. Behav. Sci. 107 (3), 287–298. https://doi.org/10.1016/j.applanim.2006.10.005.
Mahoney, A.M., 2019. Mine Detection Rats: Effects of Repeated Extinction on Detection Rates (n.d.). pp. 68.
Nevin, J., 1988. Behavioral momentum and the partial reinforcement effect. Psychol. Bull. 103 (1), 44–56. https://doi.org/10.1037/0033-2909.103.1.44.
Nevin, J.A., Grace, R.C., 2000. Behavioral momentum and the law of effect. Behav. Brain Sci. 23 (1), 73–90. https://doi.org/10.1017/S0140525X00002405.
Nussear, K.E., Esque, T.C., Heaton, J.S., Cablk, M.E., Valentin, C., Yee, J.L., Medica, P.A., 2019. Are wildlife detector dogs or people better at finding desert tortoises (Gopherus Agassizii)? (n.d.). Herpetol. Conserv. Biol. 13.
Olton, D.S., Schlosberg, P., 1978. Food-searching strategies in young rats: win-shift predominates over win-stay. J. Comp. Physiol. Psychol. 92 (4), 609–618. https://doi.org/10.1037/h0077492.
Pomerantz, O., Paukner, A., Terkel, J., 2012. Some stereotypic behaviors in rhesus macaques (Macaca mulatta) are correlated with both perseveration and the ability to cope with acute stressors. Behav. Brain Res. 230 (1), 274–280. https://doi.org/10.1016/j.bbr.2012.02.019.
Porritt, F., Shapiro, M., Waggoner, P., Mitchell, E., Thomson, T., Nicklin, S., Kacelnik, A., 2015. Performance decline by search dogs in repetitive tasks, and mitigation strategies. Appl. Anim. Behav. Sci. 166, 112–122. https://doi.org/10.1016/j.applanim.2015.02.013.
Protopopova, A., Hall, N.J., Wynne, C.D., 2014. Association between increased behavioral persistence and stereotypy in the pet dog. Behav. Processes 106, 77–81.
R Core Team, 2013. R: a Language and Environment for Statistical Computing.
Randall, C.K., Zentall, T.R., 1997. Win-stay/lose-shift and win-shift/lose-stay learning by pigeons in the absence of overt response mediation. Behav. Processes 41 (3), 227–236. https://doi.org/10.1016/S0376-6357(97)00048-X.
Sandson, J., Albert, M.L., 1984. Varieties of perseveration. Neuropsychologia 22 (6), 715–732. https://doi.org/10.1016/0028-3932(84)90098-8.
Sargisson, R., Mclean, I., 2010. The effect of reinforcement rate variations on hits and false alarms in remote explosive scent tracing with dogs. J. ERW Mine Action 14.
Sinn, D.L., Gosling, S.D., Hilliard, S., 2010. Personality and performance in military working dogs: reliability and predictive validity of behavioral tests. Appl. Anim. Behav. Sci. 127 (1), 51–65. https://doi.org/10.1016/j.applanim.2010.08.007.
Tanimura, Y., Yang, M.C., Lewis, M.H., 2008. Procedural learning and cognitive flexibility in a mouse model of restricted, repetitive behaviour. Behav. Brain Res. 189 (2), 250–256. https://doi.org/10.1016/j.bbr.2008.01.001.
Thrailkill, E.A., Kacelnik, A., Porritt, F., Bouton, M.E., 2016. Increasing the persistence of a heterogeneous behavior chain: studies of extinction in a rat model of search behavior of working dogs. Behav. Processes 129, 44–53. https://doi.org/10.1016/j.beproc.2016.05.009.
van den Berg, S.M., Heuven, H.C.M., van den Berg, L., Duffy, D.L., Serpell, J.A., 2010. Evaluation of the C-BARQ as a measure of stranger-directed aggression in three common dog breeds. Appl. Anim. Behav. Sci. 124 (3), 136–141. https://doi.org/10.1016/j.applanim.2010.02.005.
Vickery', S.S., Mason, G.J., 2003. Behavioral Persistence in Captive Bears: Implications for Reintroduction. pp. 9.
Welker, R.L., McAuley, K., 1978. Reductions in resistance to extinction and spontaneous recovery as a function of changes in transportational and contextual stimuli. Anim. Learn. Behav. 6 (4), 451–457. https://doi.org/10.3758/BF03209643.