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ORIGINAL PAPER

Using differential reinforcement and extinction to increase specificity in cheetah scat detection dogs

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Abstract

Detection dogs are trained using limited samples and then expected to generalize this ability to recognize wild samples while maintaining specificity to a target category. Such specificity is critical because dogs are often used to locate targets that are difficult to visually identify. Little is known about how to regain target specificity when false alerts become frequent or established. This case study assessed the training of two conservation dogs that alerted to off-target caracal (*Caracal caracal*) and leopard (*Panthera pardus*) scat samples during training to detect cheetah (*Acinonyx jubatus*) scat. The dogs were trained using an extinction-based differential reinforcement protocol consisting of the non delivery of reinforcement to reduce false alerts to caracal and leopard scats while maintaining sensitivity to cheetah scats. All training was conducted in situ in Samburu County, Kenya, by local handlers under the guidance of trainers. Sessions were filmed and coded for false alerts, true alerts, and where possible, misses and correct dismissals. Within four training sessions, both dogs exhibited an extinction burst demonstrated by an increase and then decrease in both the number and duration of false alerts. They continued to make fewer false alerts for the remainder of the training program. These results demonstrate the ability to reduce false alerts in operational detection dogs via extinction coupled with systematic reinforcement of desired behaviors. This case study highlights the importance of record-keeping and handling protocols for training samples. To our knowledge, this study represents the first publication on an extinction protocol to reduce false alerts in detection dogs.

Keywords Detection dogs · Conservation dogs · Extinction · Sensitivity · Specificity

Introduction

Conservation detection dogs are trained to detect and locate odors related to a specific conservation objective. They work similarly to bomb, drug, or search and rescue dogs but rather than search for accelerants, drugs, or missing people, they search for targets related to ecological research or conservation biology. To date, conservation detection dogs have been used to locate 408 animal, 42 plant, 26 fungi and six bacteria species (Grimm-Seyfarth et al. 2021). Past targets of the team members involved in this publication highlight the potential target diversity of conservation detection dogs: bird and bat carcasses on wind farms, zebra mussels (*Dreissena polymorpha*) on boats, scat from 11 species including margay (*Panthera wiedii*) and Alexander Archipelago Wolf (*Canis lupus ligoni*), invasive contexts for the plant Dyer's woad (*Isatis tinctoria*), and black-footed ferret (*Mustela nigripes*) presence. Many of these conservation targets are difficult for humans to locate or identify, but dogs can detect these data while remaining non-invasive, effective, and efficient (Grimm-Seyfarth et al. 2021). To find these targets, dogs learn to associate the detection of a target odor with a reward, such as their favorite food or toy.

Action for Cheetahs in Kenya (ACK) is part of a nonprofit organization that uses conservation detection dogs to locate wild cheetah (*Acinonyx jubatus*) scat in both

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anthropogenic landscapes and wildlife areas. The collected scats are often sent to the laboratory for subsequent analysis related to individual- and population-level cheetah health and prey selection (Mutoro et al. 2022). It can be difficult for humans to distinguish cheetah scat from that of other sympatric predators, as demonstrated by Mutoro et al. (2022) who found that only 27 of 262 (10.3%) putative cheetah scats collected during human-only searches came from cheetahs. Since organizations and researchers generally pay laboratories for each sample, it is costly and inefficient to analyze samples that are not from the target species (DeMatteo et al. 2018). To help combat these inefficiencies, ACK employs two conservation detection dogs. The dogs were previously trained to find cheetah scat and sit in order to communicate to their handler that they found a target. During training sessions, other non-target odors are sometimes presented. Similar "non-target" odors, such as scat from other felids or carnivores, are presented in order to train dogs to discriminate and ensure they continue to only alert to the "target" cheetah scat. Similar, but non-target, odors include scat from leopard (*Panthera pardus*), lion (*Panthera leo*), and caracal (*Caracal caracal*). During practice searches in 2021, Action for Cheetahs staff observed that both dogs were alerting to some of these non-target scats. It is unknown exactly when or how this began, but they were likely rewarded for alerting to these non-target scats at some point in the past. Due to staff turnover, training records that may have shed further light on the origins of this problem were unable to be located.

Extinction is a learning process in which a learned behavior diminishes through the absence of anticipated reinforcement (Dunsmoor et al. 2015). Extinction protocols are difficult, if not impossible, to implement if the trainer does not control the reinforcer. Ignoring a dog who is barking at squirrels will not cause the behavior to decrease over time, because the reinforcer for that behavior was never human attention (Pryor 1999). When undergoing extinction, it is common for the learner to exhibit an extinction burst, in which the intensity, duration, and/or number of attempts of the behavior being extinguished increases before decreasing (Katz and Lattal 2021; Muething et al. 2024). To minimize undesired side effects of extinction, it is often combined with differential reinforcement which occurs when the consequences for two responses are not equal, such as reinforcing a learner's behavior in one situation while withholding reinforcement in another. (Rasmussen et al. 2023). Over time, this discrimination training results in the learner developing distinct responses to different stimuli, which is critical in training dogs to differentiate between odors. In odor discrimination tasks, a detection dog is trained to distinguish between target odors (such as those associated with endangered species, invasive plants, or contraband) and non-target odors (irrelevant or distracting scents). By employing differential reinforcement, trainers can shape the dog's behavior to respond specifically to the target odor while ignoring non-target odors. Alerts to non-target odors undergo extinction when reinforcement is no longer provided, while alerts to target odors continue to be reinforced.

This case study follows the troubleshooting and training to systematically use an extinction-based differential reinforcement protocol to reduce false alerts on non-target odors in two conservation detection dogs. The goal of the training was to ultimately progress from reduced false alerts in a tightly controlled training scenario to larger and more realistic training scenarios, including those in which ACK handlers were naive to the location and identity of each scat. Below, we outline the methodological approach to an extinction-based differential reinforcement protocol and report progress made by each of the two dogs to reduce false alerts. This study highlights the necessity of training records, observation, and flexibility when working with the dynamic biological systems known as detection dogs.

Methods

Subjects

Two detection dogs owned and trained by ACK were selected for this study. They included Madi, a six-year-old male Border Collie-Rottweiler mix with roughly five years of experience as a cheetah scat detection dog and Persi, a three-year-old female Belgian Malinois with over two years of training completed. She had not yet been deployed in an operational capacity, largely due to the COVID-19 pandemic, but she had significant field trial experience. Over the years, the dogs had been exposed to a variety of handlers, trainers, and training approaches. Both dogs were trained to sit and stare at a target scat when found.

During this study, the ACK staff included two novice dog handlers, hereafter 'handlers'. Both were in their first professional role as dog handlers and trainers with less than six months of experience in this position. ACK staff were the primary trainers and data collectors. As external consultants, the K9 Conservationists team members designed the extinction-based differential reinforcement protocol, hid the scats, and coded the videos. This team included three trainers, hereafter 'trainers', each with at least two years of experience training detection dogs and with at least five years of experience professionally training dogs for a variety of applications.

History-taking

Since subjects of this study were operational working dogs with extensive learning histories, it was necessary to conduct investigations into the dogs' learning histories prior to the creation of any training protocol. This is considered best practice in the dog training industry to avoid the implementation of a training protocol that does not address the complexities of individual learning histories or environmental influences. It also aided in hypothesis formation and led the team to attempt an extinction-based differential reinforcement protocol rather than other potential training approaches, such as administering an aversive stimulus or ending training sessions for an incorrect response. These approaches had potential for unintended behavioral consequences such as fear or breakdown in the trainer-canine bond. This process involved interviews with staff and a review of training records. Some training record notebooks had been lost due to staff turnover or contained incomplete notes. Similarly, some organizational knowledge regarding the starting date of the off-target alerts was lost due to staff turnover. The dogs had been making off-target alerts for at least three months.

Following the Humane Hierarchy (Friedman 2009; but see also Fernandez 2024), it was confirmed that the dogs were not suffering from any health concerns that may impact their ability to perform the task, such as a respiratory illness that reduced their olfactory sensitivity, prior to conducting any training.

Before the start of this study, the ACK team handled off-target alerts in training with verbal redirection ("No, search on"), given in a neutral tone of voice. The goal of this approach was to function as a no-reward marker, which communicates to the dog that a behavior will not be reinforced, and reduces false alerts. If the dog made a subsequent off-target alert, the training session was paused and the dog was returned to the kennel for a minimum of two minutes before resuming the session. Over several months of this approach, the number of false alerts per session had not noticeably decreased. This suggests that the negative punishment did not have the intended effect. The no-reward marker may have functioned as information to the dogs to seek a second scat rather than teaching them to discriminate between species. When presented with two scats, the dogs learned that performing their trained alert behavior was the most expedient way to receive reinforcement. It is also possible that the no-reward marker worked as a cue to keep searching, which on its own can be reinforcing for some dogs. This could create a behavior chain that included alerting to any scats because both toy play and continued searching were reinforcing. Further in-person training with consultant Dr. Leopold Slotta-Bachmayr prior to the commencement of this study resulted in a promising reduction in false alerts in the training center in Nairobi, but this success did not generalize across a range of stimuli such as different trainers, handlers, and location when the team relocated to the field station in Samburu (Slotta-Bachmayr 2024, personal communication). For a more thorough explanation of operant generalization across a range of stimuli, see Rasmussen et al. (2022). The dogs had a strong learning history of sitting and staring at their targets due to extensive training adapted from explosives detection dog protocols. The bulk of their recent training had focused on alert training, including the duration and precision of the dogs' positioning.

Materials and study area

Most training took place at two different areas in the ACK field station in Meibae Community Conservancy, Samburu, Kenya (0.98333, 37.31667). Area 1 was an open sandy location bordered by shrubs, approximately $200m^2$, with cut-off 2L soda bottles partially buried in the sand. Trial scats would be placed inside of the 2L soda bottles or on the ground within the search area. Area 2 was roughly $500m^2$ with shrubs, two roughly perpendicular 30-cm deep gullies, rocks, and other vegetative matter sparsely mixed throughout the area. In both areas, rocks, shrubs, vegetative matter, and other camp materials were occasionally used to visually obscure scats.

To address the sample contamination concern, we started by disposing of all old samples and containers. New samples were donated by local wildlife rehabilitation centers and orphanages. In initial trials, the dogs did not show any undesired responses to lion, domestic cat, goat, domestic dog, or sheep feces and these species were excluded from training. The dogs performed off-target alerts to leopard and caracal scats in initial trials, so further training focused on these species.

All new samples were air-dried outdoors in designated on- and off-target areas separated by at least 10 m. They were then placed in new labeled containers and stored with at least 3 barriers between on- and off-target samples (e.g., sample CH1-A inside of a plastic bag inside a plastic container for individual CH1 inside of a larger plastic container for all cheetah samples). Plastic bags and new plastic storage containers continued to be used despite permeability and odor concerns (see Goss 2019) with plastic due to the lack of availability of glass or mylar containers in rural Kenya. Samples included 9 unique cheetah scats and 10 unique off-target scats. All samples were handled with gloves and were discarded after 3 months of use or if contamination was suspected. Best practices support discarding and replacing samples more frequently, but this was not practical due to the limited availability of species-confirmed scat. A reference sheet marked the scat identification code, species, individual, age, sex, source, date collected, and any notes regarding the sample.

At the start of each training session, a single off-target species scat (leopard or caracal) and cheetah scat were selected. Rather than using random samples, the trainer selected samples to ensure training included a balanced range of species, individuals, sexes, and sources.

Extinction-based differential reinforcement training protocol

The dogs were trained one at a time in sessions consisting of one or more trials with the following procedure:

1. The trainer set up a video recording using a mobile phone and tripod. The camera was set up to show the trainer, handler, dog, and search area with a buffer.
2. The trainer said out loud the date, time of day, samples used, dog and handler.
3. The trainer then placed out one cheetah scat sample and one off-target scat sample (leopard or caracal).
4. The handler walked the dog on-leash to an X in the sand.
5. The handler cued the dog to search. The handler remained on the X with their hands behind their back to reduce potential cueing. The trainer remained just outside of the search area. The handlers were instructed not to move or speak until the trainer clicked the clicker. Handlers were warned of the concept of an extinction burst; that the intensity, duration, or number of false alerts would likely increase before decreasing (Katz and Lattal 2021; Muething et al. 2024).
6. The dog searched the area. In the event of an off-target alert, both handler and trainer were to stay quiet and stationary until the dog dismissed the off-target scat and made a correct alert.
7. When the dog made a correct alert, the trainer used a handheld clicker to mark the moment that the dog performed its alert (sitting and staring at the target scat), and then the dog returned to the handler for toy play.
8. The trial ended and the handler removed the dog for continued reinforcement while the search area was reset, or the session was ended. Resetting the area included moving both scats to new locations so that the dog was not memorizing the location of the target, and so that sometimes the dog encountered non-target odor first, and sometimes target odor first.
9. At the end of a session, the dog was given a brief walking cool-down and then returned to their kennel with water available.

Training averaged 4.84 trials per session (range 1–8, with 51 sessions total). Session length was determined based on trainer assessment of the dog's energy, focus, stress level, and learning objectives. For example, dogs were given shorter sessions on hotter days or days that they had additional agility or obedience training sessions. Training took place mostly in search area 2. Search area 1 was used only for the first two sessions. Training was then moved to search area 2 in order to allow for a more realistic and complex search area, such as rocks and shrubs to hide the targets.

The handler and the trainer were not consistently blinded in training sessions. In testing, blinding or double-blinding is imperative to reduce the chance of "Clever Hans" effects (Pfungst and Rahn 1911). However, in realistic training scenarios, the handler often knows the target's location to set up a search strategy appropriate for the level of expertise of the dog and to facilitate timely markers and reinforcement delivery. It was important that our training strategy remain practical for the ACK team in our absence and be repeatable for single-person detection dog outfits in the future, and therefore we chose not to blind the handler in early training. However, as training progressed to larger linear searches the handler searched blind while the trainer followed (i.e., single-blind approach). Linear searches consisted of walking the dogs in a straight line along a feature such as a road or trail, allowing the dog to search on- or off-leash. This is the main search strategy employed by Action for Cheetahs in Kenya. Linear searches were conducted off-leash with the handler following at least 2 m behind the dog, except for June 9 trials where leash handling was introduced.

Based on the expert opinion of the trainer, some training trials strayed from this basic setup. This is common in the training of operational dogs outside of the laboratory and reflects the dynamic nature of these protocols.

Persi's modifications primarily addressed her initial response to extinguish all alert behaviors to all species, not just off-target samples. In two early trials, the trainer elected to click (mark) and reward Persi for sniffing the correct scat rather than waiting for a full alert. Following a single trial in which Persi made 8 false alerts and 5 incorrect dismissals, a few trials without an off-target scat available were deemed necessary. The goal for these three trials was to rebuild Persi's speed and confidence in correct alerts. For 3 subsequent trials, trainers provided Persi with a setup where only cheetah scats were present to eliminate the possibility of a false alert.

In one trial Madi attempted to mouth the scat and was verbally corrected (the trainer said "ah-ah" loudly). Additionally, the trainer interrupted one false alert for Madi, which lasted 600 s and Madi was starting to fall asleep. That trial was followed by one successful trial and the session ended early. See the full training records in Supplementary Materials.

Continued training

In the later stages of training, the dogs were also trained in longer linear searches to ensure that differential responding to on- and off-target scats was adequately generalized to realistic search scenarios and risk of spontaneous recovery was mitigated (Broomer and Bouton 2022). These took place around the field station in search areas estimated in minutes walked down a road. Dogs were primarily trained off-leash, though later training introduced leash handling. Scat location in area searches was marked on a handheld GPS unit. The trainer walked to areas other than the scat placement and touched other items such as rocks or branches to reduce the likelihood of the dog tracking the assistant to the scat. Training session videos were recorded using mobile phones for analysis. In other late training sessions, the trainer also placed multiple off-target samples in a single search to determine the dogs' ability to dismiss multiple off-targets before encountering a cheetah sample. The number and extent of these training sessions was limited by the trainers' remaining time in Kenya.

Table 1 Definitions used during video coding

	Cheetah Scat	Off-Target Scat
Dog Alerts	Correct Alert - The dog sits and stares at the cheetah scat.	False Alert - The dog sits at a non-cheetah scat. If the dog takes steps away and then returns, count as a separate false alert. Readjusting a sit, standing and staring, and other interactions with a scat during an alert event all count as one alert until the dog steps away; then count as a separate alert if the dog returns.
Dog Does Not Alert	Miss - The dog sniffs a cheetah scat without alerting. If the dog never checks a scat (runs right past it or never approaches), that is NOT marked as a miss.	Correct Dismissal - The dog sniffs a non-cheetah scat and does not alert. The dog's nose must drop to indicate sniffing; passing by without a sniff is not a dismissal.
False Alert Duration	N/A	Duration - Counted in seconds from when a dog is in a half-sit at the start of an alert to when the dog is in a half-sit at the end of an alert. An alert ends if after standing the dog steps away from the scat. If the dog readjusts its sit or continues to stand at a scat, seconds until the dog actually leaves the scat are counted as one alert.

Video analysis and definitions

The trainers coded all videos of sessions for correct and false alert numbers and duration to prepare for the next training session.

For video coding purposes and analysis, the following definitions were used (Table 1):

Trainers reviewed video, coded results in a spreadsheet, and used timestamps and the definitions above to determine the training program progress and assess the plan for the next day. Only one trainer was present at the field station at a time except during hand-off periods and internet service was unreliable, so videos were only coded by one person. During hand-off periods, trainers coded video together as training. When a response was in doubt, trainers reviewed relevant footage jointly. However, inter-coder reliability was not tested.

Data analysis

The extinction-based differential reinforcement protocol explained above was utilized from May 9 - June 7, 2022. Training with the teams continued after June 7, 2022, however, methods changed in order to progress training, so the analysis is primarily limited to before June 7, 2022. Data were cleaned and processed using R version 4.3.3 (R Core Team 2024). Cleaning included correcting typos and standardizing date formatting. Processing involved using notes and video to remove select trials from the analysis. For example, trials in which no off-target scats were presented were removed from the analysis regarding false alerts because false alerts were not possible. The number of false alerts, misses, and trials were summed per session. The total number of false alerts and misses were compared to determine if an increase, decrease, or no change occurred over time. A link to the repository can be found in Supplementary Materials.

A few trials also included handler errors on the timing or criteria of the click and were removed from the analysis ($n=2$, Madi).

Original data included trials $n=98$ Madi and $n=149$ Persi. Records were removed if true alerts did not contain a value ($n=1$ Madi), no opportunity for a false alert was available ($n=3$ Madi, $n=4$ Persi), or no opportunity for a true alert was available ($n=1$ Madi). Because training sessions could not always be completed on a regular schedule, sessions were converted from date to ordinal numbers.

Results

Between May 9 and June 7 2022, Persi underwent 15 training sessions, which contained a total of 145 trials, while Madi underwent 12 training sessions, which contained a

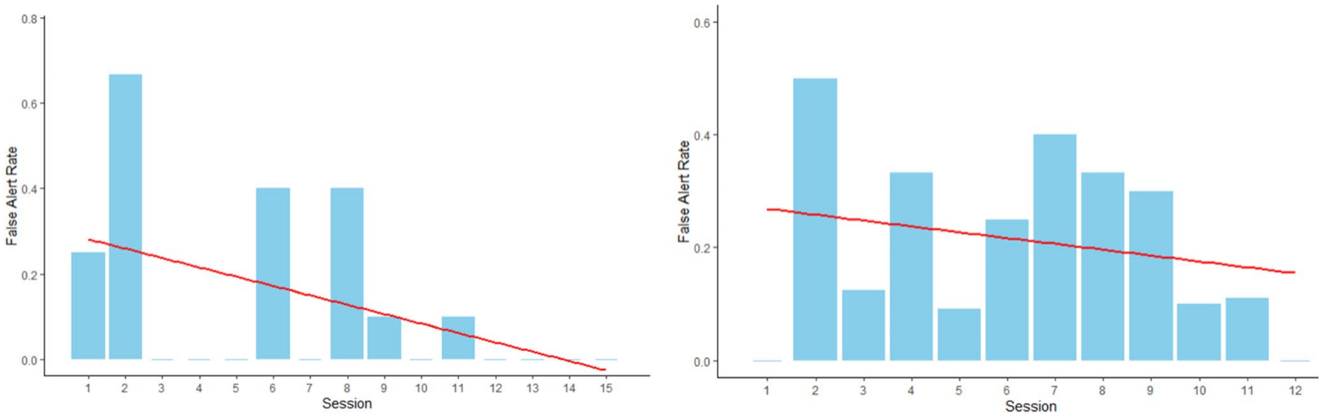

Fig. 1 Persi's (left) and Madi's (right) false alert rate (number of false alerts per number of trials) as a function of session number. Red diagonal line of best fit shows trend over time

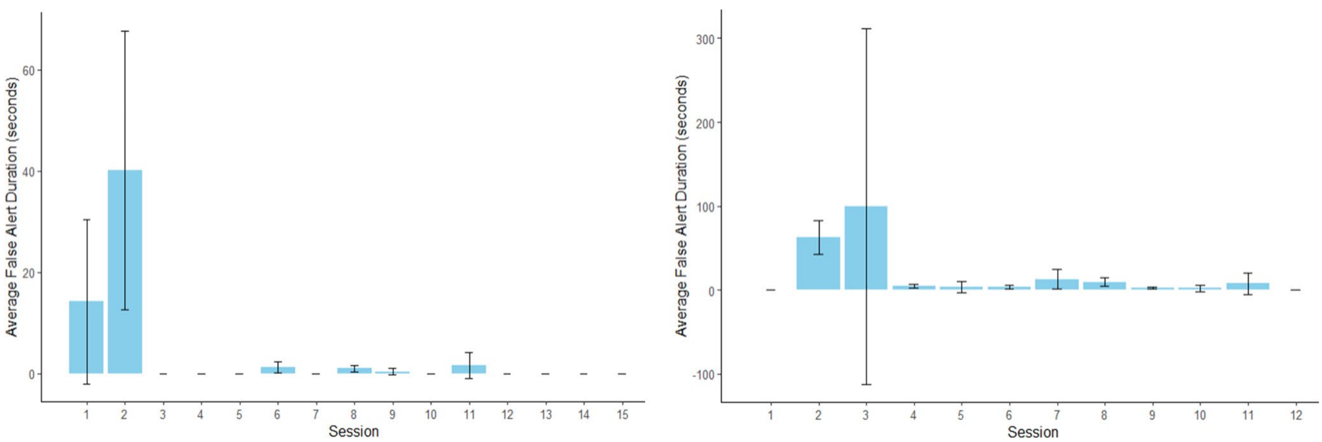

Fig. 2 Persi's (left) and Madi's (right) false alert duration in seconds for each false alert. If a trial contained multiple false alerts, the duration of each false alert is shown individually. If there were no false alerts in a trial, that trial is shown as one record of a duration of 0

total of 93 trials. Both dogs showed decreased numbers and durations of false alerts over time. Training logs prior to the commencement of training were incomplete and primarily consisted of qualitative notes (such as "dogs had good energy and focus in training"). Qualitative interviews with the staff suggested that off-target alerts were a persistent and ongoing problem, but baseline data were unavailable. Time constraints for the trainer team in Kenya did not allow for a quantitative baseline study.

During sessions 1 and 2, Persi's extinction burst was exhibited by multiple false alerts. Her number of false alerts decreased over time, and she had no false alerts after session 11 (Fig. 1). Madi's number of false alerts decreased over time, however he continued to have occasional false alerts (Fig. 1). Although continued sessions with Madi would have been ideal, they were not possible due to trainer's limited time.

Persi's sessions 1 and 2 included false alerts with high duration, followed by decreased false alert duration (Fig. 3). Despite continuing to have occasional false alerts, Madi's duration decreased over time (Fig. 3).

Persi exhibited a drop in both frequency and duration of false alerts after about 30 false alerts (Fig. 2). After one especially persistent false alert of 600 s (10 min), the duration of Madi's false alerts decreased (Fig. 2).

Persi initially exhibited what could be an increase in misses, but these also decreased over time (Fig. 4). Madi's misses increased slightly over time (Fig. 4).

Discussion

Our study suggests that an extinction-based differential reinforcement protocol can reduce false alerts in detection dogs. Within just four training sessions, both dogs exhibited an extinction burst of increased number or duration of false alerts, followed by a reduction in the number and duration of false alerts. The dogs performed no more false alerts as the search scale increased and handlers began to work blind.

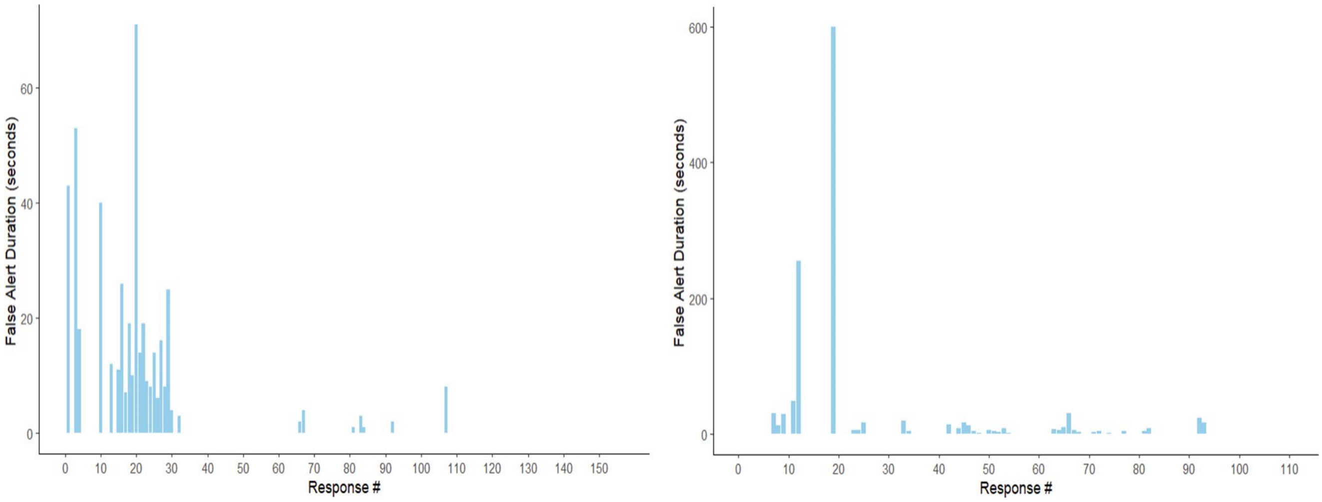

Fig. 3 Persi's (left) and Madi's (right) average duration of false alerts in a session, measured in seconds

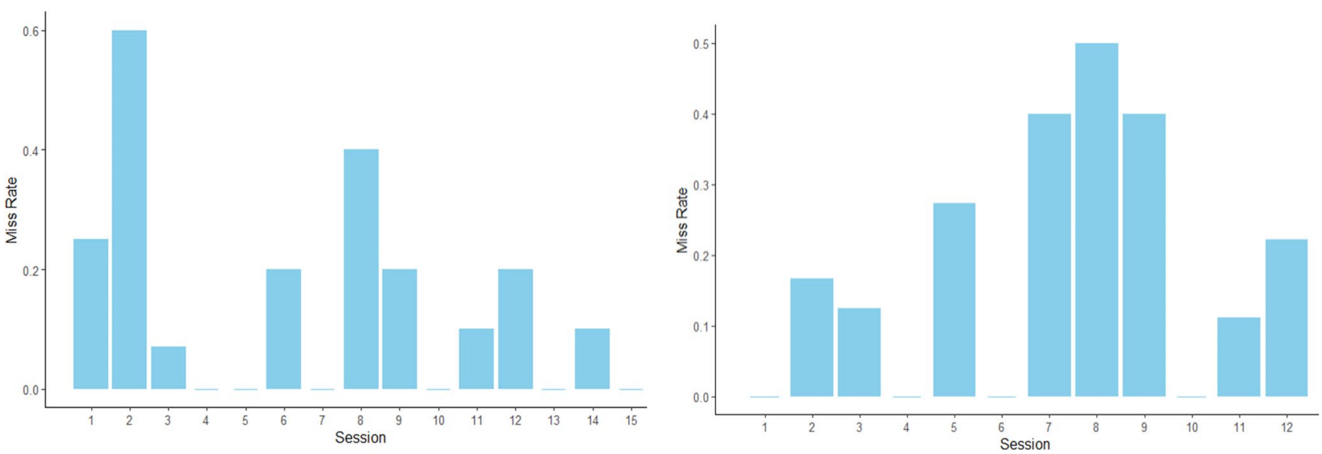

Fig. 4 Persi's (left) and Madi's (right) rate of misses (number of misses per number of trials) across sessions

These further searches were conducted after this discrimination training protocol. They were not considered discrimination training, and are not reflected in the graphs above. The protocol described was carried out by two people within the span of 12 days and 12 sessions totaling 93 trials (Madi) or 15 days and 15 sessions totaling 145 trials (Persi). Ongoing training has been completed in order to ensure operant generalization across stimuli, but that training is beyond the scope of the present extinction-based differential reinforcement protocol (for further training records, see Supplementary Materials).

This training protocol ultimately maintained target species sensitivity, meaning that there was no increase in misses, even with samples that the dogs were exposed to for the first time later in training (Figs. 3 and 4, see Supplementary Materials for sample references). Early in training, Persi demonstrated an increase in misses that was quickly remedied through three trials with only cheetah scat present. This minor adjustment underscores the importance of flexibility and responsiveness in a training protocol for detection dogs; blindly following a progression plan without taking data on the dog's response may create entirely new problems for the team. Maintaining sensitivity was a reason the team opted for an extinction-based differential reinforcement protocol rather than punishment of false alerts. Literature in rats (see Broomer and Bouton 2022) suggests that extinction may progress more slowly than punishment and that extinguished responses are reacquired more quickly. It is therefore tempting to consider a punishment-based approach for dealing with false alerts. However, punishment is generally avoided in detection training due to the risk of reducing sensitivity by creating an aversion to seeking, sniffing, alerting, or otherwise approaching potential targets. For this reason, we did not punish the dogs' responses to caracal or leopard scats. This protocol did not compare extinction-based differential reinforcement to negative punishment or other protocols, and continued research is needed to determine effectiveness of different protocols in different contexts.

It is worth noting that, aside from Madi mouthing one scat in trial 15, neither of the dogs pawed at or mouthed scats as part of their extinction burst (see Supplementary Materials for full training records). Both dogs demonstrated that their first response to a withheld reinforcer was to either alert longer, alert again, or to continue searching. This is likely due to a long history of training the dogs to hold lengthy, precise alerts, as reported by the ACK team. The K9 Conservationists team has observed in student and mentorship groups that detection dogs with different learning histories and personalities may default to disturbing samples much more frequently than Madi and Persi. Dogs demonstrating this response to extinction would benefit from other modifications to this training plan, again underscoring the importance of flexibility and observation when working with detection dogs.

This protocol required significant time and attention to avoid inadvertent reinforcement of an extinction burst or undue frustration, which may not be practical for some practitioners. An errorless learning approach (see Terrace 1963) may be more straightforward for the practitioner and canine. Errorless learning is a teaching method that focuses on minimizing the chances of the learner making errors during the learning process. Extinction can be accompanied by unwanted behaviors, such as vocalizing or pawing at a target out of frustration when an expected reinforcer is not received. Errorless learning avoids this issue by setting up training in a way that the learner is unlikely to be incorrect, thereby teaching new behaviors without introducing the frustration that often accompanies extinction.

The dogs did not respond to training uniformly. Madi's results overall are less clear, as he continued to perform some false alerts throughout the entire training period. Madi is three years older and has three years more experience than Persi. He has worked through many more trainers and training protocols. Given the uncertainty of the duration the dogs were reinforced for non-target alerts, Behavioral Momentum Theory (BMT) suggests that stimuli with higher reinforcement rates are more resistant to extinction and more likely to reoccur after extinction (Podlesnik and Shahan 2009). Each of these factors could potentially contribute to a longer extinction process.

Furthermore, Madi's field deployments involved intermittent reinforcement of cheetah scats which may have delayed the success of our extinction protocol with caracal and leopard scat, as it took more training trials for him to differentiate between intermittent reinforcement and extinction. Madi is described as "lower drive" than Persi, meaning that he is less exclusively focused on his toy or food reinforcement. This may make the withholding of reinforcement less salient to him as part of the extinction-based differential reinforcement protocol. All of these potential explanations would require separate investigations to confirm.

Specificity for conservation detection dogs is key to their utility to locate and identify biological samples. The costs of false alerts include lost time in the field and increased analytical costs due to the processing of off-target samples (DeMatteo et al. 2018). Given the already high cost of the detection dog method and limited conservation dollars, it is imperative that conservation dog trainers and handlers work to maintain target species sensitivity (Grimm-Seyfarth et al. 2021; Waldron et al. 2013). Despite this importance, little has been published on best practices to maintain specificity for detection dogs. To our knowledge, the present study is the first to investigate a protocol to recover specificity after it has been diminished.

There are multiple limitations to this study, such as short study duration, lack of internal validation on video review, the inability to separate learners into control and treatment groups to test different approaches, and the lack of detailed prior records to the dogs' training. We were unable to evaluate the relationship between handler and training success due to scheduling conflicts with handlers and overall sample size, though handlers can have a substantial effect on detection dog performance (Lit et al. 2011; Jamieson et al. 2018). We were also unable to evaluate the effect of different samples, such as sample quality or species, on the dogs' success due to the lack of independence and small sample size. For example, most of Persi's false alerts ($n = 15$ out of 28 false alerts total, 53.6%) occurred using scat CA1 (see Supplementary Materials), but 8 of those false alerts were during a single trial that corresponded to her extinction burst. New samples were introduced over time, and we expect alert frequency and duration to change due to the learning process, so the effect of individual samples cannot be evaluated independently. For example, it is possible for the dogs to learn which specific samples would lead to reinforcement, without learning the broader discrimination goal. Further study with treatment/control groups and longer time scale would be required to investigate whether specific samples were more likely to trigger false alerts than others. We did not investigate the duration of correct alerts. This would be difficult to study without introducing extinction to positive targets, but would provide valuable information. Trainers gradually extend the duration of correct alerts from nearly immediate reinforcement by clicking as the dog's rear legs bent into a sit to alerts of 3–5 s to confirm that the dogs did not abandon correct alerts with minor delays in reinforcement, but this was not measured.

Resistance to extinction is an important goal for many detection dog programs. When preparing detection dogs for field deployments, trainers often shift from continuous to intermittent reinforcement (DeChant 2021). The partial reinforcement extinction effect suggests that this intermittent schedule can enhance resistance to extinction (Thrailkill et al. 2016 and Mackintosh 1974), particularly in operational settings where alerts cannot be immediately confirmed (e.g., a drug dog alerting to a gas cap that requires dismantling to verify the presence of drugs). This approach also helps avoid reinforcing potential false alerts or providing reinforcers in dangerous environments. Hall (2017) recommends aligning training and operational contexts—either by reducing the reinforcement rate during training to match conditions in the field or by increasing the reinforcement rate during operations—to improve performance and generalization. This study emphasizes the importance of careful sample collection, storage, and handling to prevent off-target alerts given the relationship between intermittent reinforcement and resistance to extinction. We recommend thorough training logs and routine testing of dogs with novel samples from both the target species and potentially problematic off-target species. This allows programs to identify and respond to issues regarding specificity before they become exacerbated by resistance to extinction.

Punished and extinguished responses may be equally likely to return following a change of context (Broomer and Bouton 2022). This study concluded after just over one month due to logistical restrictions for the trainers, leaving us unable to confirm that this protocol remained successful over time and context changes. We would expect ongoing training, especially during context changes, to be necessary to maintain target species specificity for these dogs. More research is needed to determine the factors that influence the long-term success of extinction, no-reward markers, errorless learning, or punishment to reduce false alerts.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10071-025-01947-0.

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Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Kayla Fratt, Rachel Hamre, and Heather Nootbaar. The first draft of the manuscript was written by Kayla Fratt and Rachel Hamre and all authors commented on previous versions of the manuscript. Supervision was provided by Mary Wykstra. All authors read and approved the final manuscript.

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Data availability GitHub Repository with data, code, and select training videos at: https://github.com/kfratt/extinction Code and data for Fratt K., Hamre R., Burak M., Mutoro N., Nootbaar H., and Wykstra M., Using Extinction to Reduce False Alerts in Cheetah Scat Detection Dogs.Supplementary Materials Guidedoi_data_clean.csv is the partially cleaned data from our study. This was manually cleaned to remove notes, asterisks, and comments.data_cleaning.R shows the process to clean and standardize the data and create figures. Training VideosSelect videos of the training process can be seen at https://www.youtube.com/playlist?list=PL2f3Dgh0Fg_l9Q0nACphbSajCvMFm1eRG The video titled "May 11 2022 ACK Training Session" is a com plete training session showing handler Edwin working with Persi and Madi while author/trainer Kayla assists.The video titled "Visualizing an Extinction Burst" shows Persi make an off-target alert. The trainer clicks the moment that she sniffs the cheetah scat rather than waiting for a full alert.The video titled "Persi Correct Dismissal" shows Persi correctly dismissing an off-target scat after investigating it, then making a correct alert to the cheetah sample. This video depicts the repetition directly following the video above.

Declarations

Ethical approval Ethical approval was not required.

Consent to participate Consent to participate was not required.

Competing interests Fratt K., Hamre R., and Nootbaar H. are co-founders of an organization that trains conservation detection dogs to assist in research. Mutoro N. and Wykstra M. work at the organization that owns and trained the cheetah scat detection dogs used in this study.

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