Learn Behav
DOI 10.3758/s13420-013-0133-7

Effect of odor preexposure on acquisition of an odor discrimination in dogs

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Abstract In two experiments, we investigated the impact of odor preexposure treatments on the acquisition of an olfactory discrimination in dogs. In the first experiment, four groups of dogs were each given five days' odor-exposure treatment prior to discrimination training. Dogs in the exposure group were exposed to anise extract (S+) for 30 min daily. Dogs in the Pavlovian-relevant pairing group received six daily delayed-conditioning trials to the same S+. The Pavlovian-irrelevant pairing group received conditioning trials to almond extract (S′). Dogs in the control group received no pretreatment. All of the dogs were then trained to detect S+ from a background pine odor (an AX-vs.-X discrimination). The Pavlovian-relevant pairing group acquired the odor discrimination significantly faster than all of the other exposure and control groups, and the remaining groups acquired the discrimination at the same rate as the no-exposure control group. In a second experiment, we extended these results to a within-subjects design using an AX-versus-BX discrimination. Six dogs were simultaneously trained on two different odor discriminations, one discrimination in which the S+ was previously Pavlovian conditioned, and one discrimination in which the S+ was novel. All of the dogs learned the odor discrimination with the previously conditioned S+ faster than they learned the novel odor discrimination, replicating the results of Experiment 1, and demonstrating that familiarity in the form of Pavlovian conditioning enhances odor-discrimination training. The potential mechanisms of the facilitated transfer of a Pavlovian conditioned stimulus to discrimination training are discussed.

Keywords Dogs · Canine · Pavlovian conditioning · Classical conditioning · Odor discrimination · Odor detection

Dogs have long been deployed to detect odors of explosives and narcotics (Dean 1972; Goldblatt, Gazit, and Terkel 2009), and more recently they have been used to detect a variety of chemical stimuli, such as those associated with cancer and wildlife (cancer: Cornu, Cancel-Tassin, Ondet, Girardet, and Cussenot 2011; Willis et al. 2004; wildlife: Cablk, Sagebiel, Heaton, and Valentin 2008). These capabilities make suitably trained dogs a valuable chemical detection tool. Despite the importance and usefulness of the canine sense of smell, relatively few scientific studies have investigated the variables that may influence canine odor perception.

In a review of research on canines detecting explosives, Goldblatt et al. (2009) highlighted studies suggesting that repeated exposure to an odor may be a simple way to significantly facilitate detection of that odor. Identifying simple ways to improve canine detection performance could have a significant impact on the costs and effectiveness of these training programs. One important and laborious component of the training process is acquisition of the initial odor discrimination. If preexposure to the target odor facilitated acquisition of the discrimination, then preexposure could be used as a simple technique to reduce training effort for odor-detection dogs.

Basic research in rodents on the effects of preexposure to odors suggests that long-term exposure (24 h a day for months) to an odorant may not enhance acquisition of a discrimination with the exposed odor (Cunzeman and Slotnick 1984; Laing and Panhuber 1980), and may even retard acquisition for some odorants (Cunzeman and Sltonick 1984). In contrast, more recent research has suggested that shorter-term exposures to the S+ and S–, or just the S+, for an hour or two per day for several days can produce

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spontaneous discrimination between the S+ and S– odors, as measured in a habituation/dishabituation task (Escanilla, Mandairon, and Linster 2008; Mandairon, Stack, Kiselycznyk, and Linster 2006a, b). These results suggest that short-term odor exposure may enhance spontaneous odor discriminability, and may therefore facilitate acquisition of the discrimination.

Similar research has evaluated the effects of stimulus preexposure on taste discrimination. In the basic procedure, the experimenter flavors drinking water with either flavor A or B. One group of subjects is then preexposed to flavor B (or flavors A and B), whereas control subjects remain naïve to flavor B. The rodents then receive taste-aversion conditioning trials to flavor A. In a subsequent test session, rodents with preexposure to flavor B show less conditioned suppressed drinking of flavor B than do subjects naïve to flavor B, indicating greater discrimination between flavors A and B (e.g., Honey and Hall 1989). Several subsequent permutations of this experimental procedure have confirmed that flavor preexposure enhances subsequent discrimination of the preexposed flavor from the flavor that was taste-aversion conditioned (e.g., Mackintosh, Kaye, and Bennett 1991; for a review, see Mitchell and Hall 2014).

An alternative to "mere exposure" of an odor for the facilitation of acquisition of a discrimination is Pavlovian conditioning. Pavlovian conditioning may be a simple way to prepare dogs for discrimination training. Prior research has demonstrated that Pavlovian conditioning can facilitate subsequent discrimination performance. In one experimental paradigm, rats received water (an unconditioned stimulus [US]) when exposed to one stimulus (a click or tone; the conditioned stimulus [CS]) and never received water when exposed to a second stimulus (a tone or click; Bower and Grusec 1964). The rats were later trained on a discrimination task in which half of the subjects were trained to lever-press for water in the presence of the previously paired stimulus, and not to lever-press in the presence of the previously unpaired stimulus (consistent group). The other rats were trained in an inconsistent manner (lever-pressing was reinforced in the presence of the *nonpaired* stimulus). Rats in the consistent group learned significantly faster, outperforming the inconsistently trained rats. In a subsequent study, Mellgren and Ost (1969) showed that rats trained consistently outperformed a group of rats without any prior exposure to the stimuli.

Together, the previous studies demonstrate that stimulus preexposure and Pavlovian conditioning may facilitate discrimination learning. In the present study, we aimed to extend this research by evaluating the effects of odor preexposure on the acquisition rates of an odor discrimination in dogs in two experiments. In Experiment 1, we assessed whether Pavlovian conditioning (Pavlovian-relevant group) or mere exposure (exposure group) to an odor facilitates the acquisition of an AX-versus-X odor discrimination (where A is the preexposed odorant) relative to two control groups. Experiment 2 extended and replicated the effects of Pavlovian conditioning found in Experiment 1 to an AX-versus-BX discrimination using a within-subjects design.

Experiment 1

In this experiment, we assessed the acquisition performance of dogs that received prior Pavlovian conditioning (Pavlovian-relevant group) or mere exposure (exposure group) to an odor (odor A) on an AX-versus-X discrimination in which dogs were trained to dig in a container of pine shavings containing the target odor A. Dogs were given five days of mere exposure to the odor (odor A; exposure condition), five days of Pavlovian conditioning trials to the odor (odor A; Pavlovian-relevant condition), five days of exposure to no odor (control condition), or five days of Pavlovian conditioning to an irrelevant odor (odor B; Pavlovian-irrelevant condition). All of the dogs were then trained across three sessions to dig in a container of pine shavings holding a scented cotton round rather than a similar container of pine shavings holding an unscented cotton round.

Method

Subjects

A total of 32 healthy dogs between the ages of 6 months and 10 years were recruited for this study. Seven dogs were tested at a rescue organization: The remaining dogs were household pets. The subjects were of varying and mixed breeds, but similar breeds were recruited in approximate multiples of four so that breeds were approximately balanced across groups (see Table 1). All testing occurred at least 4 h after the last feeding.

Materials

We used two odorants that were readily available but likely only slightly familiar to dogs: McCormick anise extract (S+) and almond extract (S′). For food reinforcers, we used commercial dog treats that dogs would readily consume, such as Pupperoni, cut into 1 cm × 1 cm size pieces. For the preexposure phase of the experiment, a tall cylinder was modified to hold all of the experimental materials. The top of the cylinder held a plastic container that served as a food hopper (see Fig. 1a). A funnel and tube were placed below the food hopper to deliver the food to the dog. The inside of the

Table 1 Numbers of dogs of each breed in each experimental group in Experiment 1

Breed	Pavlovian-Relevant	Exposure	Control	Pavlovian-Irrelevant
Pitbull or Cattle dog mix	1	1	1	3
Terrier mix	2	2	3	2
German Shepherd mix	1	2	1	1
Lab mix	2	2	2	1
Toy breed	2	1	1	1
Total	8	8	8	8

cylinder held a 16-oz glass jar that could hold 10 ml of the target odorant, an aquarium air pump, polyethylene air-line tubing, and an air-line valve calibrated to control air flow to 500 ml/min (see Fig. 1b). The air line was fed from the pump to the outside of the cylinder, through the back, to allow the experimenter to control airflow with a main clamp. The air line was then fed into the jar to sparge the odorant, and subsequently fed near the food tubing to allow for odor delivery to the dog, which was either inside a crate appropriate for the dog's size or restricted to a similarly sized space with a baby gate. This design allowed the experimenter to operate the airflow and food delivery from behind the equipment and out of direct sight of the dog.

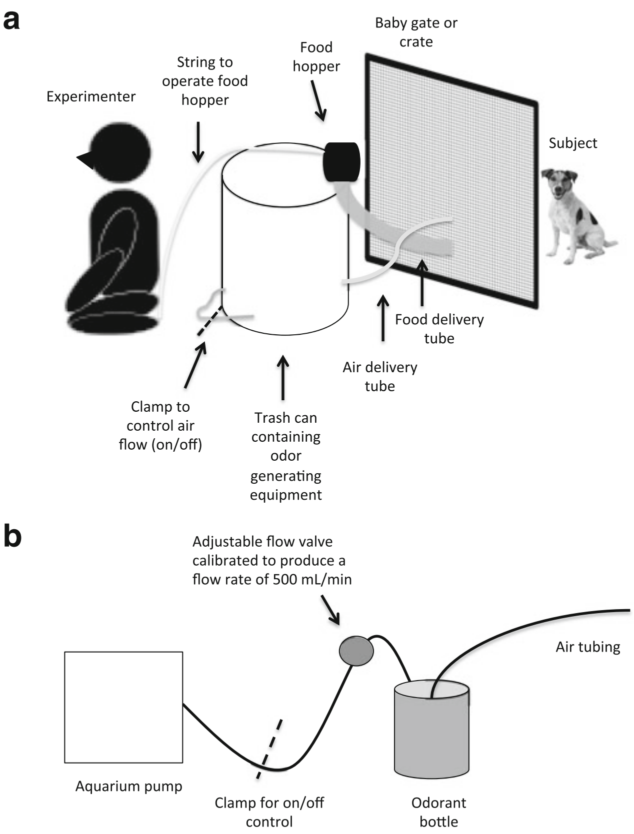

Fig. 1 Odor exposure equipment. (**a**) Layout for exposure sessions. The experimenter was able to control the odor delivery and food delivery from behind the trashcan. (**b**) Schematic of the odor-generating equipment

Exposure conditions

The dogs were randomly assigned to one of four conditions. Each condition ran 30 min a day for five days. At the start of each condition, dogs were restricted to a crate or a similarly sized space behind a baby gate and remained there for the duration of the 30-min preexposure condition. In the *Pavlovian-relevant* condition, dogs were given six delay-conditioning trials per day. For each trial, an anise extract odor stimulus (odor A) was presented for 10 s immediately prior to the delivery of food (a commercial dog treat) from the food hopper and remained on until the dog had consumed the food. All dogs readily consumed the food. The intertrial interval was 5 min. For the *exposure* condition, anise extract was presented for an entire 30-min session. Food was not delivered. This odor presentation method was designed to be similar to the odor enrichment procedures that have previously been shown to facilitate spontaneous odor discrimination (Escanilla et al., 2008; Mandairon et al., 2006a, b). For the *control* group, no odorant was in the glass jar, and air was delivered to the dog for 30 min. For the *Pavlovian-irrelevant* group, dogs were given six delay-conditioning trials identical to those in the Pavlovian-relevant group, except that the odor stimulus was almond extract (odor B) instead of anise extract. Following the exposure phase, all dogs underwent standardized odor-detection training to detect anise extract. See Table 2 for an outline of the experimental design.

Detection training

In the odor-detection training, dogs were presented with two bins of pine shavings and were trained to "alert" to a target odor by digging in the bin containing it using the procedure described in Hall, Smith, and Wynne (2013). In this procedure, one bin contains pine and a 100%-cotton pad with 1 ml of anise extract buried 2.5 cm deep, whereas the other bin contains pine and an unscented cotton pad buried 2.5 cm deep. Therefore, dogs were trained to detect the target odor from a background pine odor, creating an AX-versus-X discrimination, where A represents the anise odor and X represents the background pine-shavings odor.

Alert training At the beginning of each session, dogs were given eight alert-training trials in which they were shaped to dig in a bucket of pine shavings. For the first two trials, dogs were trained to approach and put their heads in the buckets. This was done by visibly placing a piece of food in the target-scented bucket on top of the pine shavings. The dog was

Table 2 Experimental design of Experiment 1

	Pavlovian-Relevant Group	Exposure Group	Control Group	Pavlovian-Irrelevant Group
Type of conditioning	Delay conditioning for anise extract (odor A)	30-min exposure to anise extract (odor A)	No exposure	Delay conditioning to almond extract (odor B)
Odor detection (AX vs. X)	Anise detection (3 days)	Anise detection (3 days)	Anise detection (3 days)	Anise detection (3 days)

The table shows each component of the experiment for all groups

shown the treat in the bin and was allowed to take the food. After consuming the food, the experimenter said “good dog” and delivered an additional treat by hand. For the next three trials, the dogs were taught to dig in the bucket, by burying the food 2.5 cm deep in the pine. Once the dog began to dig in the bucket, the experimenter said “good dog” and gave the dog an additional treat by hand. For the last three trials of alert training, no food was placed in the bin. The scented bin was simply presented. Contingent on digging in the bucket, the experimenter delivered a treat by hand. The bin used for alert training was never used for discrimination training, to prevent potential food-odor contamination.

Discrimination training For each trial, the experimenter placed a scented bin and a nonscented bin 0.25 m apart and equidistant from the dog, which was held by an assistant 2 m back. After placing both bins down, the experimenter stepped at least 1 m back, placed his arms behind his back, and looked straight down at the ground. An observer, naïve to which bucket contained the target odor, watched the dog and called out “choice” when the dog began to dig in one of the buckets. This informed the experimenter of a response. He then looked up to see which bucket the dog was responding to, and delivered the appropriate consequence (a “good dog” and food for digging in the target bin, or removing the bins without spoken comment or food for an incorrect response). If a dog failed to respond in 30 s, the bins were picked up and re-presented. If the dog again failed to respond in the subsequent 30 s, “no choice” was recorded. The intertrial interval was approximately 20 s and corresponded to the time required for the experimenter to prepare for the next trial.

Each session consisted of the initial eight alert-training trials, 30 odor-detection training trials, and six control trials per day for three days. Alert training was run at the beginning of the first session to train the dogs to dig, but was continued for each session thereafter as “warm-up” trials. Throughout training, the location of the target bin was determined pseudorandomly, with the stipulation that the same location was not correct more than twice in a row. If the dog responded to the same location on four consecutive trials, a correction trial was conducted. For a correction trial, the experimenter put down both discrimination bins, but prior to the dog approaching either, the experimenter picked up the incorrect bin, forcing the dog to walk to the other location to respond. If dogs failed to respond (i.e., made “no choices”) for two consecutive trials, or responded incorrectly for three trials in a row, two alert-training trials in which the food was placed on top of the pine were conducted. The purpose of these trials was to ensure that the dog was motivated to participate. If a dog failed to take food while it was freely available on top of the pine, trials were suspended for that day. If this occurred, the next session started the following day. If the dog failed to take food when it was freely available in pretraining trials on two consecutive days, testing for that dog was terminated. No dogs met this exclusion criterion during the experiment.

Control testing Due to each group of dogs having a unique preexposure procedure, the experimenters were unable to be kept blinded to group assignments. However, multiple measures were taken to limit observer and experimenter bias, and these potential sources of biases were directly assessed throughout the study. First, all experimenters were informed that it was uncertain whether any group would perform differently, and that it was important to train every dog in the same way. The potential for experimenter influence was limited by having all experimenters stand at least 1–2 m away from the bins, keep their arms behind their backs, and look down at the ground with their eyes closed during each trial. In addition, experimenter influence was directly assessed by the use of control trials in which neither bin held the target odorant, but one container was designated prior to the experiment to be the “correct” container. Control trials were run every six trials throughout the experiment. The consequences for responding were identical in control trials and experimental trials. The purpose of these trials was to assess whether dogs could identify the target container in the absence of the target odorant, using any other cue than the target odor. To control for observer bias, the observer was blind to the location of the target bin. In addition, a subset of sessions (ten sessions) was scored from video by a second, naïve observer to calculate agreement. The second observer agreed with the first observer on 95.6% of the trials.

Statistical analyses

The data were analyzed in Microsoft Excel, SPSS, and R. Before conducting analyses, the dependent variable (percentages correct) was assessed for departures from normality using visual inspection of the residual plots and histograms. The data appeared to deviate from normality, since some dogs performed at chance, whereas others performed above chance. We therefore transformed all percent accuracy data using a rank transform, allowing us to use a traditional analysis of variance (ANOVA) procedure that was both powerful and robust for our repeated measures design (Iman, Hora, and Conover 1984). Graphs are presented of the untransformed percent-correct data for ease of interpretation, although statistical tests were conducted using ranks. To test for differences between groups, a repeated measures ANOVA of the ranks was conducted, followed by pairwise comparisons of the ranks with the Newman–Keuls post hoc test.

Results and discussion

Five of the eight dogs in the Pavlovian-relevant group alerted to the target odorant correctly on more trials across the three days of training than did *any* of the 24 dogs in the remaining three groups. The Pavlovian-relevant group had a median of 70% correct on the first training session, whereas no other group exceeded 52%. By the end of three training sessions, the Pavlovian-relevant group's median was 93% correct, whereas the remaining groups' medians ranged from 53% to 68% correct (see Fig. 2). No other group showed systematic differences from the control group.

A repeated measures ANOVA on the rank-transformed data indicated significant effects of group [$F(3, 22) = 3.40$ $p < .03$] and session [$F(2, 56) = 39.4$, $p < .001$], but no interaction [$F(6, 56) = 1.5$, $p > .05$]. Newman–Keuls post hoc tests indicated that the mean rank of percent accuracy was higher for the Pavlovian-relevant group than for the Pavlovian-irrelevant group (mean rank difference of 28), the control group (mean rank difference of 26), and the exposure group (mean rank difference of 23). These results confirm the visual inspection of the percent accuracy data in Fig. 2.

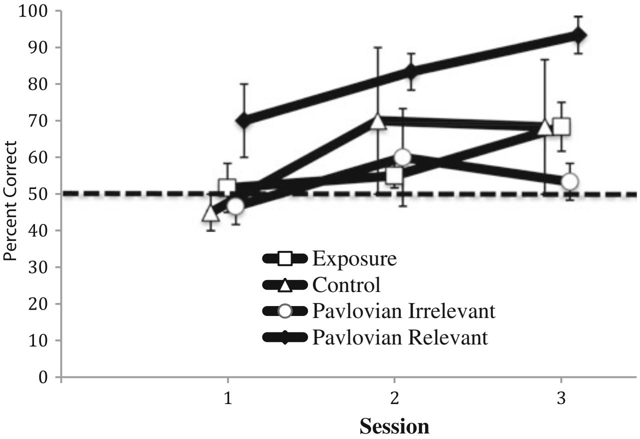

Fig. 2 Percentages correct in Experiment 1. The median percentages correct for each group in Experiment 1 are shown. Error bars indicate the median absolute deviations, and the dashed line indicates chance performance

Median performance across all groups on the control trials did not indicate that the dogs were following any other cues (median performance across groups: 50% correct). To further confirm that control trials were at chance, we removed trials in which a response was not made (e.g., a "no choice") and only scored trials in which a choice was made during control trials. The percent accuracy still did not differ from chance on a Wilcoxon one-sample signed rank test (median percentages correct: Pavlovian-relevant, 50%, $p > .9$; exposure, 60%, $p > .9$; control, 50%, $p > .33$; Pavlovian-irrelevant, 50%, $p > .58$).

These results indicate that prior odor exposure does have a significant effect on discrimination training performance; however, the type of exposure is important. Exposure alone resulted in no change in performance over the control group. Pavlovian conditioning, in contrast, resulted in a significant increase in performance over the no-exposure control group and the Pavlovian-irrelevant control group, indicating that paired exposure to the relevant odor significantly increased discrimination training accuracy. We therefore found no evidence that massed exposure alone (30 min a day for five days) had an impact on discrimination performance; it neither facilitated nor retarded discrimination performance.

Our exposure group was an adaptation for dogs of the enrichment procedures that have been effective for enhancing discrimination in rodents. One factor that may have contributed to our failure to replicate in dogs the effect of exposure alone found by others in rodents is that our parameters were too short to be effective. Our exposure phase was shortened relative to the rodent studies, for the convenience of the dogs' owners. Prior research with rodents has used 1- to 2-h blocked exposures for 10 or 20 days (Escanilla et al., 2008; Mandairon et al. 2006a, b), as compared to our 30 min for five days. It is also theoretically possible that shorter, distributed exposure trials similar to the Pavlovian conditioning trials, rather than longer, massed exposure parameters, might have been more effective in sensitizing the subjects to the target odor.

Overall, these results extend the research of Bower and Grusec (1964) and Mellgren and Ost (1969), who showed that Pavlovian conditioning can facilitate subsequent acquisition of discrimination training, to the use of Pavlovian conditioning to a single odor stimulus to facilitate acquisition of an odor discrimination in dogs. To further confirm that Pavlovian conditioning may be a simple way to facilitate subsequent acquisition of an odor discrimination, we extended the finding of Experiment 1 to an AX-versus-BX discrimination using a within-subjects design.

Experiment 2

In Experiment 2, we utilized a more powerful within-subjects design to replicate the effect of Pavlovian conditioning on subsequent discrimination training, as identified in Experiment 1. In this experiment, six dogs were given five Pavlovian conditioning sessions to odor A (anise extract or almond extract). All of the dogs were then trained in six discrimination sessions on both an AX-versus-BX discrimination and a CX-versus-DX discrimination in alternating blocks of trials, in which the dogs were required to dig in a container of pine shavings scented with the target odor. We hypothesized that Pavlovian conditioning would facilitate acquisition of the discrimination in which dogs had prior Pavlovian conditioning to the target odorant. In addition, although we took several measures to control for possible experimenter cuing in Experiment 1, in Experiment 2 we instituted an additional blinding step for all experimenters and conducted a set of additional double-blinded control trials.

Subjects

Seven pet dogs of varying breeds were recruited for the experiment, but one dog failed to take food when it was freely available during initial training and was subsequently dropped from the study (more information is provided below). All of the dogs were tested in the owners' homes at times convenient for the owners. All of the dogs had not eaten within 4 h of all testing sessions, to maintain motivation.

Exposure conditions

The same equipment and the same procedure for conducting the Pavlovian conditioning was used for Experiment 2 as in Experiment 1. Three dogs were randomly assigned to receive six conditioning trials a day for five days to anise extract (paired-AN), and three dogs received six conditioning trials a day for five days to almond extract (paired-AL). The odorants were prepared identically to Experiment 1.

Discrimination training

Odors All dogs were trained on two odor discriminations: anise extract from cinnamon extract, and almond extract from coconut extract. All of the odorants were prepared by placing 1 ml of the extract on a cotton round and burying the cotton round in the pine shavings.

Procedure Dogs were trained on both discriminations in rapid alternation. Each session comprised six blocks of six trials each. Each block of trials contained five discrimination trials for one of the odor discriminations and one control trial. The two odor discriminations were alternated across blocks throughout the session. The odor discrimination that was trained first was counterbalanced across sessions within and across dogs. To reduce the possibility of experimenter error in presenting the correct bins, the colors of the bins for the two discriminations were different (the anise-vs.-cinnamon discrimination used tan bins, whereas the almond-vs.-coconut discrimination used white bins). All dogs were trained for six sessions.

Dogs received eight alert-training trials for both discriminations immediately prior to the first block of trials for each respective discrimination in a session. The procedures for alert training and correction trials, and the criteria according to which subjects would be dropped from the study, were identical to those in Experiment 1. One dog completed four discrimination trials of the first discrimination but failed to respond thereafter, even when food was free available on the top of the pine shavings (i.e., alert training) for two consecutive days, and was therefore not included in the present analysis. One dog failed to take free food after 18 trials in Session 3, although it responded readily during Session 4. The data from Session 3 are reported for this dog only for the completed trials (see "Mavi" in Fig. 3 in the Results).

Control testing As in Experiment 1, every sixth trial was a control trial. Unlike in Experiment 1, all experimenters were blind to the odor to which the dog had been preexposed (anise or almond). In addition to control trials, for each dog, 12 of the scheduled regular trials were double-blind trials (six trials per session for two randomly selected sessions), in which the observer and the experimenter did not know which bin contained the target odor. A third person organized the bins for the experimenter to put on the ground; however, the experimenter did not know which bin was correct. The third person then walked away from the testing area. When the dog made a choice, the observer informed the third person of the choice, who in turn told the experimenter and observer whether the choice was correct. The appropriate consequence was then delivered to the dog. We compared the accuracy on the trial immediately preceding the double-blind control to the accuracy during the double-blind control trial. Thus, if the experimenter was not unintentionally cuing the dog, we would expect performance on the double-blind control trials to be no different from that on regular trials, and for the other control trials to remain at chance. In addition, a naïve second observer scored a subset of the trials (315 trials) from video to calculate agreement for rooting. The second observer agreed with the first observer on 95.8% of the trials.

Statistical analyses

The data were rank transformed as in Experiment 1. A repeated measures ANOVA was calculated to test for differences in performance between the odor discrimination in which the target odor was Pavlovian conditioned, as compared to the discrimination in which the target odor was novel.

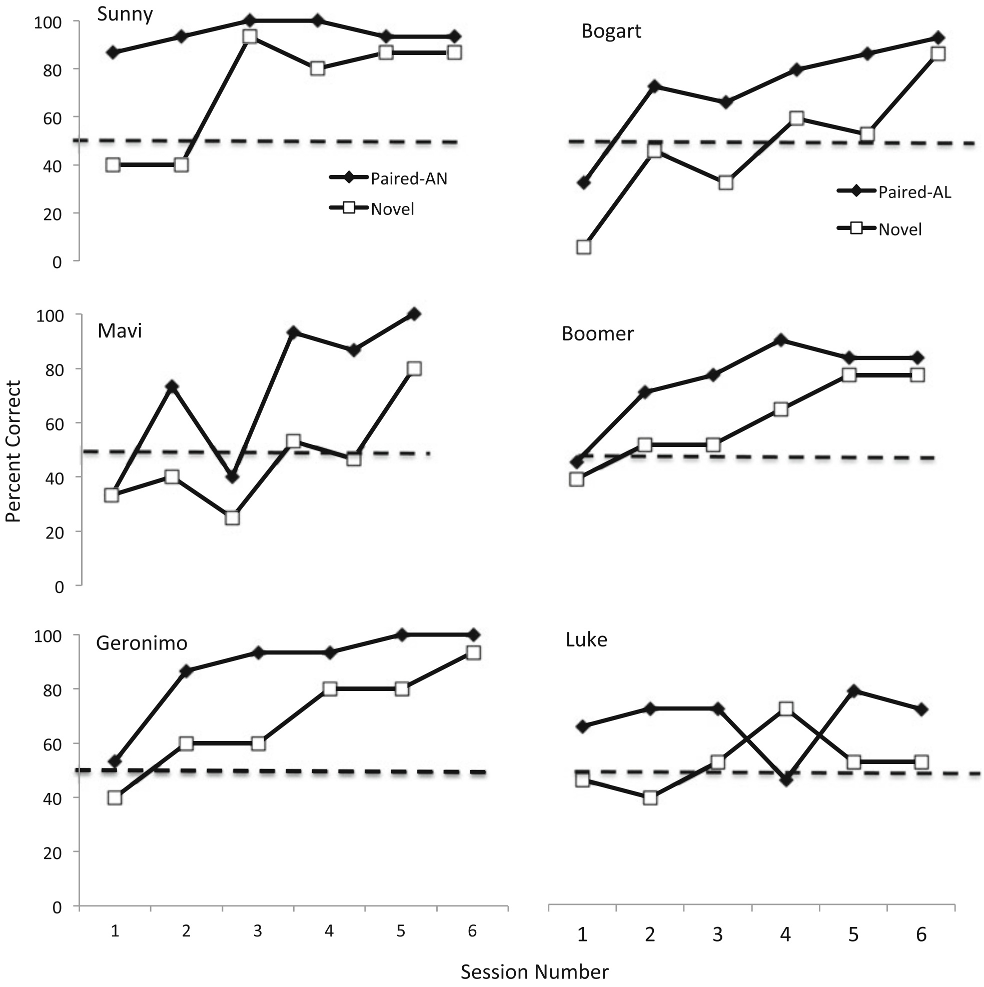

Fig. 3 Percentages correct for each dog in each session in Experiment 2, shown for the paired discrimination (filled diamonds) and the novel discrimination (open squares). The first column shows the dogs that received Pavlovian conditioning to anise (paired-AN), and the second column shows dogs that received conditioning to almond (paired-AL). The dashed lines indicate chance performance

Results and discussion

Figure 3 shows the performance of each dog on the odor discrimination in which it received Pavlovian conditioning to the target odor and the discrimination in which both odorants were likely novel. The first column shows dogs that received pairing to anise, and the second column shows dogs that received pairing to almond. Figure 3 indicates that, out of the 36 sessions recorded, the dogs did *not* perform better on the paired discrimination in only two sessions.

Figure 4 shows the median percent accuracy for the conditioned odor and the novel odor discriminations. Across all six sessions, performance was higher for the conditioned odor than for the novel odor. Overall, dogs' median percent accuracy was 32 points higher for the discrimination in which the target odor was conditioned than for the novel-odor discrimination.

A repeated measures ANOVA confirmed the results from visual inspection of Figs. 3 and 4. We observed a significant effect of pairing procedure [$F(1, 58) = 9.40$, $p < .003$], showing that dogs learned the odor discrimination in which the conditioned stimulus was the target odor faster than the novel-odor discrimination. Dogs also showed significant improvement across sessions [$F(5, 58) = 10.40$, $p < .001$], with no evidence of an interaction [$F(5, 58) = 0.50$, $p < .79$].

Performance on control trials remained at chance, as expected. Across all dogs and sessions, the median percent correct on control trials was 50%, and was still at chance when "no choice" trials were removed (median: 50%; one-sample Wilcoxon signed rank test, $p < .09$). The median performance on double-blind trials was very similar to performance on the regular trials immediately preceding the double-blind trials, with no indication of any performance decrement on double-blind trials (double-blind trials, 67% correct; immediately preceding trials, 50% correct). A paired Wilcoxon signed-rank test indicated no difference between double-blind trials and the immediately preceding trials across the 12 sessions in which they were conducted ($p > .36$). Thus, it is unlikely that experimenters were cuing the dogs unintentionally, given that

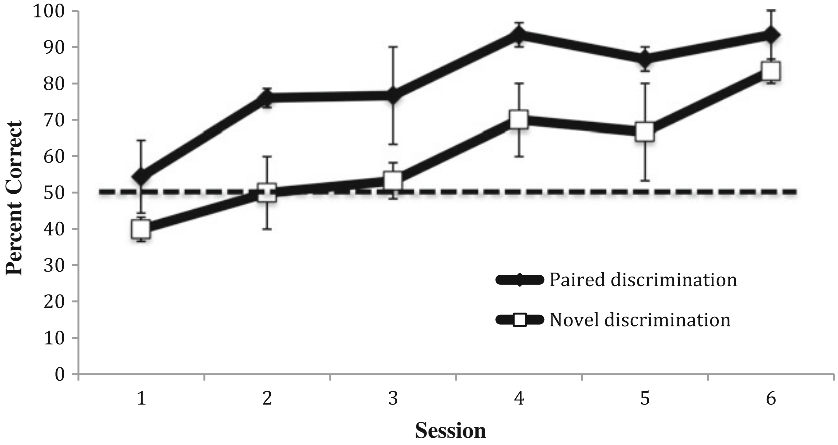

Fig 4 Median percentages correct in Experiment 2. The lines indicate median performance, and error bars show the median absolute deviations for the paired discrimination and novel discrimination in Experiment 2. The dashed line indicates chance performance

when the experimenters were unaware of which bin was correct, performance remained unchanged.

General discussion

The effects of repeated exposure to an odor have been proposed as a possible means of enhancing canine odor detection (Goldblatt et al. 2009). Basic research on this topic, however, has provided conflicting reports on the effects of odor exposure on the acquisition of an odor discrimination. In Experiment 1, we separated exposure into two categories, mere exposure and Pavlovian conditioning. We found that mere exposure had no effect on the acquisition of an odor discrimination in dogs; however, Pavlovian conditioning significantly improved acquisition. Experiment 2 was designed with additional controls to replicate and confirm the finding in Experiment 1, and we found similar results across experiments, confirming that exposure to an odor in the form of Pavlovian conditioning has a significant impact on the acquisition of an odor discrimination.

These results indicate that future studies into the effects of "familiarity" or prior exposure to an odor on subsequent discrimination performance should evaluate different types of exposure, instead of just comparing exposure and no exposure. The form and parameters of the exposure may have a major impact on discrimination acquisition. In our case, only Pavlovian conditioning enhanced later discrimination acquisition. Future studies could further manipulate the parameters of exposure alone to explore why some studies have shown enhancement of discriminability (e.g., Mandairon et al. 2006b), whereas others have shown no effect (e.g., Laing and Panhuber 1980).

The mechanism by which Pavlovian conditioning improves discrimination training deserves consideration. The present results suggest that when an odor is conditioned as an appetitive CS, it may more readily become an operant discriminative stimulus. This mechanism is similar to the Pavlovian-to-operant transfer of stimulus control proposed by Bower and Grusec (1964) and Mellgren and Ost (1969). Our discrimination training was an explicit operant contingency in which the reinforcer was delivered contingent on digging in the correct bin. The Pavlovian conditioning could have facilitated the operant training by increasing the likelihood that the subject would approach the target bin (sign-tracking) rather than the nontarget bin, which increased the speed with which the subject would contact the digging contingency. Thus, a Pavlovian approach response could have facilitated correct "choosing" by increasing approach to the correct container, in which subsequent digging under operant control would lead to reinforcement.

Alternatively, the results could be explained by the initial Pavlovian conditioning facilitating a Pavlovian discrimination, in which digging was the conditioned response. Although the experimental contingency during discrimination training was an operant one, the functional contingency may have been Pavlovian, in which an odor (CS) was followed by an experimenter delivering food (US), with digging being the conditioned response.

We suggest that the likely mechanism for our results was transfer from Pavlovian to operant conditioning. The experimental contingency placed on digging was operant: That is, food was only delivered contingent on digging. In addition, we did not observe any digging-like conditioned responses to the odor during the explicit Pavlovian conditioning phase, but observed digging rapidly during discrimination training, when food was presented contingent on digging.

These two different mechanisms could have important consequences. If the present results were the product of creating a Pavlovian digging response to the target odor, this could suggest that the facilitation of discrimination training may be limited to specific behavior topographies (conditioned responses)—in the present case, digging. This interpretation predicts that, had a different arbitrary response been chosen (e.g., sitting), the facilitation would not have been observed, since sitting is an unlikely conditioned response to an odor (CS) or food (US). In addition, it further suggests that if digging were an undesirable topography (as, e.g., in the detection of land mines), then additional Pavlovian training that created a digging conditioned response would be undesirable. In contrast, if the results were the product of Pavlovian to operant transfer, possibly via sign-tracking leading to approach of the correct container, followed by operant digging, this would suggest that the topography of the alert could be changed from digging to a different arbitrary response with minimal effect on the outcome.

Overall, the present research suggests that Pavlovian conditioning to an odor may reduce the training time for an odor discrimination in dogs, though additional parameters need to be evaluated before it could be concluded that Pavlovian conditioning is in general more efficient than operant training alone. For example, we only evaluated the effects of 30 Pavlovian conditioning trials across five days of training. Perhaps fewer conditioning trials would provide a similar impact on discrimination training success. In addition, in an applied context, the financial costs associated with Pavlovian procedures would need to be compared with those of additional days of operant training. Pavlovian procedures may have an advantage, in that they are time-based and do not require the dog to emit a specific response that a trainer needs to observe. Thus, they may well be less expensive to deploy than further operant training, which may require more work from experienced trainers. Although more work must be done before Pavlovian conditioning could be deployed to facilitate operant training of detection dogs, the present results certainly suggest that the technique holds promise.

Author note We thank Marc Branch and Jesse Dallery for numerous discussions on this research topic. We also thank Haile's Angels and the many research assistants who helped on the project: Courtney Huffman, Joey Galluzo, Adriana Collada, Yoko Tanka, and Laura Arango. This project was supported in part by a Masters Research Grant from the Society for the Advancement of Behavior Analysis (SABA) to N.J.H.

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