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Smelling more or less: Investigating the olfactory experience of the domestic dog

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ABSTRACT

The performance of tracking dogs and drug-, disease-, and explosives-detection dogs is a testament to trained dogs' olfactory acuity. The olfactory experience of an untrained dog, by contrast, has not been well documented. In the current research we begin to remedy that by testing untrained pet dogs' olfactory perception of quantity. While previous research found that dogs could discriminate visible quantities of more or less food (Prato-Previde, Marshall-Pescini, & Valsecchi, 2008), our results find that, by contrast, companion dogs do not reliably discriminate quantities when the food can be smelled but not seen. Sixty-one percent of dogs (39 of 64), given a choice between closed plates with one and five morsels of food, approached plates with the larger quantity: not significantly more than approached plates with the lesser quantity (binomial, $p = .169$). We did find that during dogs' initial investigation of both food amounts, subjects gave more attention to the plate containing the larger quantity (binomial, $p < 0.001$). In a second condition, we replicated, with closed plates, Prato-Previde et al.'s (2008) finding that owner interest in a plate holding a lesser quantity of food reliably leads dogs to approach that plate (binomial, $p < 0.001$). Though research has demonstrated dogs' preference for a larger amount of food (Ward & Smuts, 2007), in a third condition testing the effect of adding a strong odor to a visibly larger food quantity, we found that the addition of odor often *reversed* that preference (44/69 dogs; $p < .03$). Finally, we consider the methodological implications of this work on future dog cognition studies.

As humans see the world, dogs smell it. That is the impression left by an appreciation of the biological differences between humans and domestic dogs. Useful for their forebears (the ancestors of present-day wolves), a heightened sense of smell would have led to the detection of proximate prey and would also have been used for social communication. The anatomy of the domestic dog reflects this olfactory acuity: the dog nose has hundreds of millions more olfactory cells lining the epithelium than the human nose (Lindsay, 2000). The canid olfactory bulb and olfactory cortex are highly developed compared to these regions in the human brain. These features lead to a sense of smell that is some orders of magnitude more sensitive than humans'; able, in theory, to detect one milligram of butyric acid in a space the size of the city of Philadelphia (Lindsay, 2000). Moreover, the inhalation of odors in *Canis familiaris* is managed by an adaptive sniffing process. Respiratory and olfactory streams of inhaled air are separated into different flow paths within the nose (Craven, Paterson, & Settles, 2010), and odor habituation is prevented through side-nostril exhalation (Settles, Kester, & Dodson-Dreibelbis, 2003).

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That dogs have an excellent sense of smell is well known, and dogs are widely used as workers in roles that require they use their noses: in drug- and explosives-detection and in disease-detection, particularly cancers (e.g. McCulloch et al., 2006; Willis et al., 2004), for instance. Trained trackers can reliably determine an absent person's direction of departure in five footsteps, using the differential odor concentration from the first to fifth step (Hepper & Wells, 2005). Explosives-detection dogs use olfactory more than visual cues, allowing search in low- and no-light conditions (Gazit & Terkel, 2003). Dogs can distinguish identical twins by smell alone (Hepper, 1988), and trained dogs are skilled at matching a human odor sample to a cloth from the same individual (Settle, Sommerville, McCormick, & Broom, 1994). But exactly how acute the average dog's sense of smell is – and, especially, how much dogs use or rely on their noses in the anthropogenic environment which is now their natural environment (Miklósi, 2007) – is less well understood. The olfactory experience of an untrained dog, whose nose may be as keen as trained dogs but who has not been trained on smell tasks, has not been explicitly researched.

By contrast, the *cognition* of companion dogs has recently received much attention, mostly through studies of the physical cognition and (especially) the social cognitive abilities of the dog (Cooper et al., 2003), such as their use of human gaze for information (Agnetta, Hare, & Tomasello, 2000), their attention to others' attention (Call, Brauer, Kaminski, & Tomasello, 2003; Horowitz, 2009; Schwab & Huber, 2006), and their following of communicative pointing (Pettersson, Kaminski, Herrmann, & Tomasello, 2011; Soproni, Miklósi, Topál, & Csányi, 2002). It is surprising, on reflection, that nearly all recent studies of dogs have been of their ability to navigate a *seen* scenario, or communicate or interpret communication *visually*, given that dogs are primarily olfactory. Dogs are quite skilled at what could be called visual social problem-solving tasks, but given their ancestry one might expect their *olfactory* problem-solving to be preeminent. Olfaction has been considered in the dog-cognition literature, although largely in its role not as primary motivator of behavior, but as a possible conflicting cue in otherwise visually oriented studies (Szetei, Miklósi, Topál, & Csányi, 2003).

Our question is: Given the olfactory acuity of dogs, to what extent do they use this ability in daily life? In the current research we aimed to begin to unpack the untrained pet dog's olfactory experience by determining empirically if untrained pet dogs discriminate quantities by smell. Previous research has found that dogs could discriminate visible quantities of more or less food (Prato-Previde, Marshall-Pescini, & Valsecchi, 2008). In that study, subjects chose to approach a plate which held eight pieces of food instead of one. In a further trial, when the dogs' owners made enthusiastic noises about the plate with the smaller quantity, though, dogs more often chose the small plate. These results were taken as demonstration of the dog's ability to (a) discriminate quantity, and (b) follow human guidance instead of their own sensory abilities.

In the current study, subjects were also presented with quantity-discrimination tasks; however, in the first condition, the quantities to be compared were covered, instead of being visible. The question explored was whether subjects could distinguish quantity when smelled but not seen. Because dogs show a robust interest in more food (Araujo & Milgram, 2004; Prato-Previde et al., 2008; Ward & Smuts, 2007), the experiment was designed to provide subjects with an opportunity to select a larger quantity of food over a smaller quantity, should they discern the difference.

In the first condition, dogs were presented with two plates, one of which held a single piece of food (hot dog wedge); the other held five pieces of food. The plates were then placed equidistant from the dog, the experimenter moved away, and the dog could, after being released by the owner, make a choice between the plates. If dogs discriminate quantity by smell, they should, given their choice in Prato-Previde et al. (2008), approach the plate with the larger amount. If dogs are not discriminating quantity by smell, they should choose at random.

In a second condition, the further (above-described) trial of Prato-Previde et al. (2008) was replicated with a variant: presenting the subjects with covered instead of open plates, holding differing quantities of food. Here, the owner was asked to make enthusiastic noises about the plate with the smaller quantity. Again, the dog's subsequent behavior in selecting between the plates is the dependent variable.

A further dimension of the domestic dog's olfactory experience is the effect on dogs of odors that human owners add to their environments as fragrance or for cleaning, medicinal, or other purpose. Anecdotally, owners sometimes report dogs' apparent disgust or distaste for specific odors applied to the dog or home (McConnell, 2006). Some scents have been studied in the context of a shelter environment and shown to effect a change in rate of vocalizations or movement (Graham, Wells, & Hepper, 2005). Thus, in a third condition, we explored whether three familiar odors were sufficiently noxious to dogs that they would prompt the dogs to reverse their preference for *more food* and avoid a visible, larger quantity of the same foodstuff in favor of a small quantity with no added scent. The odors we tested were vinegar, a common household cleaner; and two scents not considered to be repellent to dogs (Graham et al., 2005) – lavender, the fragrance in a dog shampoo, and mint, the flavor in a spray billed as a dog breath freshener. Should dogs have an aversion to these odors, they may select the non-odorous, smaller-quantity plate.

Finally, in this study we were also interested in exploring some of the effects of chosen methodology on the dogs' plate selection. Our interest in the dog's experience of the world extends to an interest in the dog's experience of an experimental setting. The effects not just of the independent quantity but also of the experimental design, experimental measure, and human participants are discussed.

Methods

Our protocol was designed to investigate dogs' choice behavior between two differing food amounts. The experimental design involved presenting the dog with two plates and asking the dog to "select" one by approaching it. The specific design is as follows.

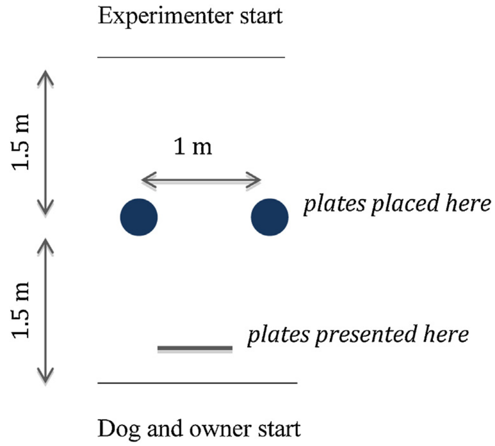

Fig. 1. Experimental testing layout: dog and owner are positioned across from the experimenter at the start of each trial. Plate placement and plate presentation locations noted.

Subjects

Dog owners – and, by proxy, their dogs – were recruited through an extant Horowitz Dog Cognition Lab database, publicly displayed flyers, and online postings.

Sixty-nine companion dogs, 38 male and 31 female, participated in the experiment. The mean age was 4 years, 4 months (range: 7 months to 12 years). Thirty-four dogs were mixed breed dogs, and 35 were purebred dogs (Table 1). Five had scent-work training. Trials were run between April and September 2012.

Procedure

Dog owners signed a consent form and completed a questionnaire providing biographical, behavioral, and any olfactory-experience details of their dog.

Testing took place in two relatively bare rooms in New York City: an all-purpose training room at an animal shelter and a partitioned area in a dog daycare facility. The testing area used in both rooms measured 2.75 by 7.5 m. The experimental stage included a start position for dog and owner, at which the owner sat, 1.5 m in front of a center point. The experimenter presenting the plates began by standing 1.5 m on the other side of that same point. After presenting the plates to the subject, the experimenter placed the plates approximately 1 m from one another, 0.5 m to either side of the center point (Fig. 1). Dog in-test behavior was video-recorded using a hand-held Flip Video camera positioned in one corner of the testing area.

Owners were asked not to feed their dogs for 3 hr prior to testing to promote in-test motivation. Upon arrival but prior to testing, owners and dogs entered the testing room, and the dog was let off leash to explore freely. All owners consented to their dogs eating small pieces of hot dog during the study (one dog lacked interest in hot dog and freeze-dried liver treats were used instead). Hot dogs were cut into 1.25-cm sections, quartered into wedges, and placed on small paper plates.

Dogs were tested under two presentation methods: a closed-plate presentation and an open-plate presentation. For the closed-plate presentation, two food quantities were used: *small*, consisting of a single piece of hot dog, and *large*, consisting of five pieces of hot dog. Those quantities were selected on the strength of evidence that dogs can discriminate two quantities visually given a large numerical difference – at least two; more reliably, four – between them (Ward & Smuts, 2007). Plates were sealed shut with two pieces of tape. In the open-plate presentation, dogs were exposed to three trials pairing a plate with a single piece of hot dog and another plate with three pieces of hot dog and a novel scent. The novel scent was always applied to the plate with more food. The novel scents were lavender (Earthbath Lavender Deodorizing Spritz), mint (Petco Fresh Breath Dog Spray) and vinegar (Supreme Star White Distilled Vinegar, 5% acidity).

All dogs experienced two pre-training trials wherein they were allowed to approach and eat a visible piece of hot dog on a plate placed on either side of the center point by the experimenter.

Each subject participated in three different conditions: Condition 1: Quantity comparison – present subject with two closed plates; Condition 2: Owner enthusiasm – present subject with two closed plates followed by a display of owner preference for the smaller-quantity plate; Condition 3: Addition of fragrance – present subject with two open plates with a novel, possibly noxious scent applied to the larger quantity. All dogs except three experienced the experiment in the order described above: these three experienced the open-plate presentation first to help them engage in the paradigm. In every condition, the test trial was the subject's choice between – approach to – the plate with either the larger or smaller quantity, when the owner released the subject.

Below is a detailed description of the three conditions.

Table 1
Age range: 7 months to 13 years. Sex: 31 females, 38 males.

Subject	Age	Breed	Sex
A.J.	2.8	Mixed	F
Allie	7.5	Mixed	F
Amber	12.0	Mixed	F
Anouk	6.0	Mixed	F
Asia	2.0	German Shepherd	F
Bailey	4.0	Mixed	M
Batman	8.5	Mixed	M
Biffy	6.0	Mixed	M
Charlie	7.0	Mixed	F
Clyde	1.0	French Bulldog	M
Daisy	5.5	Dogue De Bordeaux	F
Dakota	12.0	Labrador	M
Dipper	8.0	Portuguese Water Dog	F
Duffy	1.5	Shetland Sheepdog (Sheltie)	M
Ella	2.5	Mixed	F
Ellis	1.6	Chihuahua	M
Fern	7.0	Mixed	F
Fina	3.0	Mixed	F
Frankie	4.5	Cairn Terrier	M
Grayson	0.6	Mixed	M
Gus	3.0	Petit Basset Griffon Vendéen	M
Harris	4.0	English Shepherd	M
Hennrey	6.0	Clumber Spaniel	M
Henry	0.9	Mixed	M
Horatio	3.0	Cavalier King Charles Spaniel	M
Hudson	4.0	Labrador	M
Jack	11.0	Mixed	M
Jackson	3.0	Mixed	M
Jake	4.0	Mixed	M
Jake	6.5	German Shepherd	M
Joey	2.0	Mixed	M
Leila	7.0	Maltese	F
Lucy	1.2	Mixed	F
Lucy	1.7	Toy Poodle	F
Lucy	3.5	Dachshund	F
Madison	5.5	Toy Poodle	F
Maebe	3.5	Labrador	F
Maggie	2.3	Border Collie	F
Marlow	1.5	Mixed	F
Merlot	3.0	Shetland	M
Mia	2.0	Mixed	F
Mia	7.5	Tibetan Terrier	F
Mojo	2.3	Mixed	M
Monty	5.5	Cocker Spaniel	M
Mugsy	13.0	Mixed	F
Olive	5.0	Mixed	F
Oliver	0.8	Mixed	M
Oliver	1.8	Mixed	M
Olivia	1.6	Mixed	F
Pebbles	3.5	Mixed	F
Porter	1.0	Mixed	M
Rex	3.3	Maltese	M
River	1.4	German Shepard	F
Sadie Alexandra	3.5	Cavalier King Charles Spaniel	F
Scooter	5.0	Jack Russell Terrier	M
Shakey	2.0	Havanese	F
Shane	1.8	Boxer	M
Shelby	5.0	Corgi	F
Stitch Casbar	5.0	Labrador	F
Teddy	5.0	Mixed	M
Theo	12.0	Mixed	M
Theodore	8.0	Mixed	M
Walter	4.0	Mixed	M
Webster	6.0	Mixed	M
Wilbur	5.0	Pug	M
Wilson	4.0	Mixed	M
Wyatt	1.2	Mixed	M
Xero	6.0	Chihuahua	M
Zoey	3.5	Chihuahua	F

Fig. 2. Examples of simultaneous (left) and one half of sequential (right) plate presentation.

Condition 1. Quantity comparison (closed-plate).

Each owner sat in a chair with his or her hand on her dog or dog's collar, facing the experimental stage. Owners closed their eyes and each was instructed not to engage socially with her dog during the trials but to allow her dog to investigate (with mouth or nose) the two plates presented. An experimenter stood directly across from the dog/owner dyad, holding two plates, one in each hand, and began each trial by saying *Hi, puppy!* in a high-pitched voice to get the dog's attention. After gaining the dog's attention, the experimenter approached the dog and presented the covered plates to the dog, saying *What's this?*. To test whether presentation order had any effect on subsequent choice, for 32 subjects, the two plates were presented sequentially, and for 37 subjects, the plates were presented simultaneously. In sequential presentations, the experimenter placed the plates on their designated spots on the floor visible to the dog/owner dyad. The experimenter then held out one plate for the dog to investigate for approximately 3 s, and placed the plate back on the floor before presenting the next plate in the same manner. In the simultaneous presentations, the experimenter approached the dog holding both plates shoulder-distance apart and by slightly moving the plates forward and back, allowed the dog to investigate both plates for approximately 3 s each (Fig. 2).

After presentation of the plates to the subject, the experimenter placed both plates on their designated spots on the floor, taking care not to look at either plate, and turned to face away from the dyad. The owner was then instructed to release her dog, saying *Okay!* if necessary, and when the dog approached a plate, the experimenter turned and tossed one piece of hot dog to the dog. During Condition 1, dogs were rewarded for whichever plate they approached to maintain their engagement in the paradigm. Condition 1 was run up to six times, although not all dogs continued to make choices on every trial.

Condition 2. Owner enthusiasm (closed-plate).

In this single-trial condition, a second experimenter (the second author) took the place of the owner holding her dog, and the owner stood beside them. After the first experimenter presented the plates as described in Condition 1, the owner approached the plate with the smaller quantity, and showed preferential behavior toward the plate, as described by Prato-Previde et al. (2008): holding the plate, the owner spoke to her dog, saying (some version of) *Oh boy, this is good food, yummy*. The owner then placed the plate back on the floor and returned to stand beside her dog. The dog was then released to approach either plate; as before, subjects received one piece of hot dog for approaching either plate.

Condition 3. Addition of fragrance (open-plate).

Each owner sat in a chair holding her dog before the experimental stage. The experimenter presented the plates as described in Condition 1, but this time, the plates were not covered. As previously, the dogs attended to each plate for approximately 3 s, the plates were placed on the floor, and the dog was released to approach one of the two plates. Subjects were permitted to eat from the selected plate, and the non-chosen plate was removed. Dogs experienced one presentation of each novel scent.

In every condition, the position of larger and smaller quantities was counterbalanced on each dog's left and right side across trials, and the same quantity was not placed on the same side more than twice in a row. When the plates were covered, the experimenter presenting the plates was ignorant of the plate contents.

Person cues

Hauser, Comins, Pytka, Cahill, and Velez-Calderon (2011) cautioned that handler and owner behavior are potential sources of informative cuing to the subjects, as well as likely sources of experimenter error. The dependent relationship between dog and owner may reduce dogs' problem-solving capacity on a particular task when the owner is present (Topál, Miklósi, & Csányi, 1997); indeed, in experimental settings, dogs show differential attention to owner and experimenter, gazing at the former and only glancing at the latter (Mongillo, Bono, Regolin, & Marinelli, 2010). Any protocol testing dogs thus requires careful control of both experimenter and owner behavior. For these reasons, we limited both experimenters' and owners' knowledge, and the owners' behavior was restricted to holding their dogs during plate presentation, which we allowed for the dogs' comfort. Any trial in which the owner had further communication with the dog was aborted and re-done. In our covered-plates conditions, to avoid inadvertent cuing toward one of the plates, the experimenter was blind to which plate held more food: she received plates already baited with food and covered. Additionally, she turned her back to the dogs before they were released to make a choice. Owners were also blinded to the covered-plates' contents, and in the first condition their actions were restricted to releasing their dogs when instructed to by the experimenter.

Data analysis

The dog's approach behavior was scored in real time and then scored again from the video recordings made of the trials. An "approach" was identified when the subject made physical contact with or came within 30 cm of one of the plates. Dogs who did not unambiguously approach one plate were scored as making no choice. There were no discrepancies in scoring. Each dog's approach behavior was averaged across trials in each condition, and the performance of all dogs within each condition was evaluated using one-sample binomial probability tests. Following Prato-Previde et al. (2008), we considered the dog's average performance (i.e., performance over all trials), where random choice would give a score of 0.5 (on a scale from 0 to 1). We used the Mann–Whitney *U* test for determining a difference in choice between groups. Additionally, we used Cohen's Kappa statistic for inter-observer reliability. Statistical tests were all two-tailed and the alpha value was set at 0.05.

We also coded the degree of each dog's attention to the plates in the closed-plate presentation (Conditions 1 and 2). Previous research has looked at *time* spent sniffing to determine attention (Salvin, McGrath, McGreevy, & Valenzuela, 2012); to this criterion, we added a component of the intensity of that investigation. "Stimulus attention" was gauged by time spent directed toward – with head toward and near – a plate when it was presented by the experimenter, as well as any visible sniffing of or biting the plate. Each trial was scored as having equivalent, left-plate-biased, or right-plate-biased stimulus attention; coding was performed blind to plate content.

Sixty-nine dogs participated in this experiment. The data from four dogs were eliminated from analysis in the first and second conditions because they chose the plate on a single side (right side bias: $n = 2$; left side bias: $n = 2$) on every trial across conditions, and the chances of same-side selection occurring randomly across six trials is 0.0156. One dog did not make a choice in Condition 1; thus, data were analyzed for $n = 64$ dogs. Condition 2 was run and completed on $n = 53$ dogs; Condition 3 was run and completed for all $n = 69$ dogs. For the stimulus-attention score, videos for two dogs were unavailable, so behavior of $n = 62$ dogs was reviewed on videotape.

Results

Dogs did not reliably discriminate quantities when the food could be smelled but not seen. In Condition 1, 61% of dogs ($n = 39$ of 64), given a choice between closed plates with one and five morsels of food, approached plates with the larger quantity: more but not significantly more than the number approaching plates with the lesser quantity of food (binomial, $n = 64$, $p = .169$). There was no effect of age (below or above 5 years old: $p = .381$), sex ($p = .811$), or scent-work training ($p = .74$) on the subjects' performance – although for the latter, the small number of subjects (5) is surely relevant.

In Condition 2, we found that owner enthusiasm about a (covered) plate holding a lesser quantity of food reliably led dogs to approach that plate (binomial, $n = 53$, $p < 0.001$), a significant change from Condition 1 (Mann–Whitney, $n = 113$ trials, $p < 0.001$). The result is the same if one considers only the dogs who chose the bigger plates in Condition 1 (binomial, $n = 36$, $p < .01$) (Fig. 3).

Stimulus-attention scores indicate that 44 dogs paid more attention to one plate, on presentation, than the other plate, in one or more trials. For this group, they attended significantly more often to the plate which held the larger quantity (77%; $n = 113$ trials) than the smaller-quantity plate (23%; $n = 34$) (binomial, $n = 147$, $p < 0.001$) (Fig. 4). Inter-observer coding of a randomly selected 20% of these trials found agreement in 28/29 cases (Cohen's kappa = 0.931). Though these subjects showed more attention to the larger plate during the plate presentation, their choice behavior follows the trend of the larger group: they selected the larger-quantity and smaller-quantity plate equally often (binomial, $n = 138$, $p = 1$).

In Condition 3, when the food quantities were visible and a scent was added to the larger-quantity plate, 44 of 69 (64%) dogs changed their preference to the smaller plate in at least one sub-condition (scents of vinegar, mint, or lavender) (binomial, $n = 69$, $p < .03$) (Fig. 5). When considering the individual scents, though, no scent in particular guided their choice: dogs more often chose the larger plate with lavender (binomial, $p < 0.001$), mint (binomial, $p = .009$), and vinegar (binomial, $p = .003$).

Methodological effects

We examined the difference between two plate-presentation styles, sequential and simultaneous, on dogs' preferences. There was no difference, over all conditions, on the dogs' choice of quantities (Mann–Whitney *U*, $n = 557$ trials, $p = .174$) (Fig. 6). When just considering Condition 3, there was a trend toward presentation style changing the dogs' choice behavior: subjects

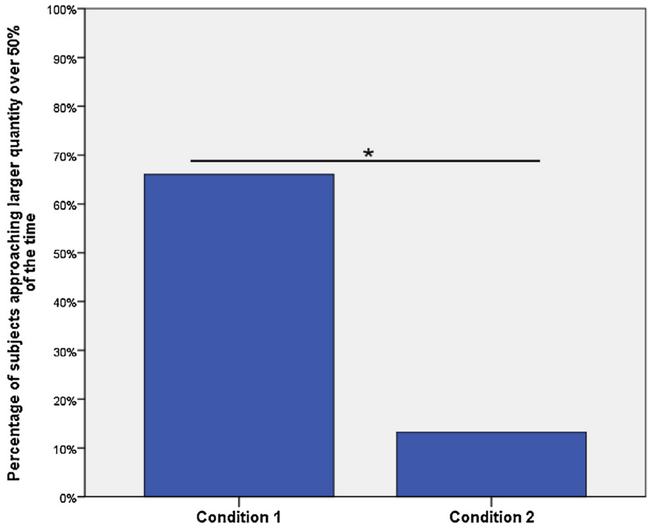

Fig. 3. Percentage of subjects approaching larger quantity over 50% of the time in the two closed-plate conditions, one with no information from the owner (Condition 1), the other with owner-displayed enthusiasm for the smaller quantity plate (Condition 2). Approaches to the plates were significantly different between conditions ($p < 0.001$).

in the simultaneous-presentation group chose bigger more often than those in the sequentially-presentation condition, although not significantly (Mann–Whitney *U*, $n = 65$ trials, $p = .092$).

Despite the non-significant result above, when considering each method in turn, our data show that the dogs' behavior was changed by the stimulus presentation method. Dogs in sequential-presentation trials were more likely to subsequently choose the plate presented second (binomial, $n = 105$, $p < 0.001$): a demonstration of a kind of "recency effect" (Deese & Kaufman, 1957). Excluding these data, and considering dogs in simultaneous-presentation trials, subjects did not differ from the main trend of the data: dogs chose the larger plates more often (60% of the time), but not significantly more often (binomial, $n = 34$, $p = .123$).

Having excluded the four dogs with a side bias, the remaining 65 subjects did not show a side preference overall: the plates on the right were not chosen more than the plates on the left, or vice versa (binomial, $n = 623$ trials, $p = .414$).

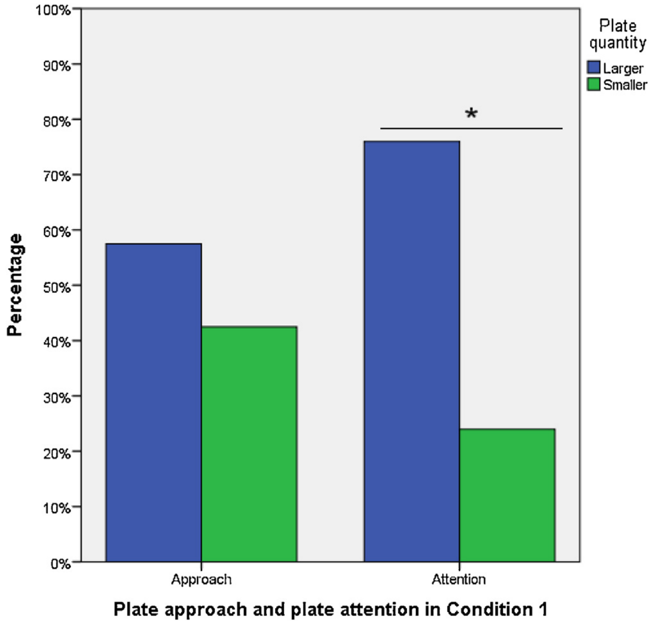

Fig. 4. Percentage of subjects in Condition 1 either approaching or showing more attention to the plates with larger- and smaller-quantity foodstuffs (approach: $p = .169$; attention: $p < 0.001$).

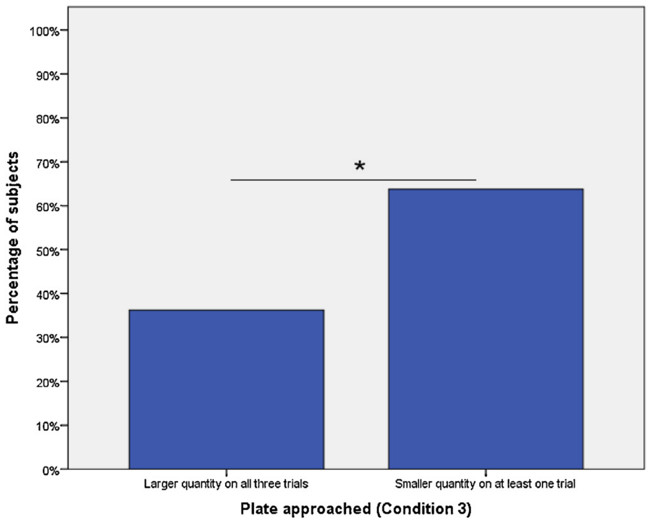

Fig. 5. Percentage of subjects approaching the plate with a smaller quantity on at least one trial in Condition 3 (open-plate presentations with additional scent on larger-quantity plate) ($p < .03$).

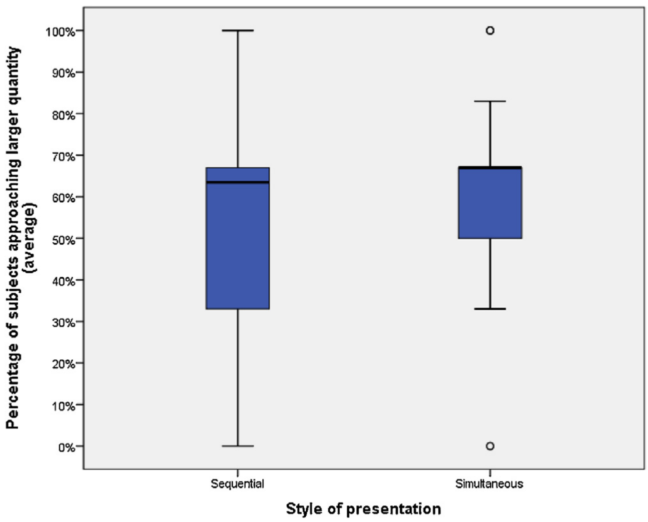

Fig. 6. Subject approach to larger-quantity plate during sequential and simultaneous presentation trials in Condition 1 (closed-plate). Median and 25–75th percentiles represented; outliers noted in simultaneous presentation. There was no difference between the groups ($p = 0.602$).

Discussion

Olfactory discrimination

Our results suggest that dogs are not making relatively subtle discriminations of odor concentration of foodstuffs in their natural environments. While dogs chose the larger-quantity plate more often than the smaller-quantity plate, the difference was not significant. This result contrasts with the findings of Prato-Previde et al. (2008), in which 74% of dogs selected the larger quantity of food, when the food was detectable visually. Our subjects' behavior is surprising, given the olfactory acuity of nearly all dogs. But our results highlight the importance of training to bring dogs' attention to small-grade differences in odors. Especially for an owned domestic dog, provisioned with food regularly throughout the day (owners of 68/69 of our subjects reported giving their dogs food treats at home in addition to one or more meals), it may not be necessary to notice small differences in food quantities. This result is consistent with Szetei et al. (2003), who found dogs less than perfect (median: 75% reliability) at detecting even the presence or absence of food in a bucket two meters from the subject. When an experimenter stood next to the bucket, but did not gesture informatively, subjects' choice of which bucket to approach was random. Interestingly, a few reports from scent-detection training programs indicate that fewer than 50% of dogs selected for the programs successfully complete the programs (Hall, Smith, & Wynne, 2013), so the olfactory skills of trained dogs may

Fig. 7. Subject approach of smaller-quantity plate in Condition 3.

not be representative of the species. Neither might our results represent the species: some dogs may be able to discriminate odors, while others do not.

Two notable conclusions emerge from these studies: one, that companion dogs are not using their noses to their capacity, as compared to scent-trained dogs; two, that presence of a person may inhibit their own information-finding through olfaction or other sensory modality. Indeed, in the second condition, when owners gave enthusiastic reports about the smaller-quantity plate, dogs who had selected the larger-quantity plates in the first condition (and subjects overall) chose the owner-directed plate. These results affirm Prato-Previde et al.'s (2008) finding of owner influence on dog choice. Much research has indicated that dogs will look to humans to solve problems (Miklósi et al., 2003), and, indeed, it appears that the mere presence of humans leads dogs to ignore their own sensory and possibly cognitive capacities. We also observed, informally, that some subjects who did not make a choice on a trial in the first condition instead approached the experimenter, despite the fact that she had her back turned. This accords to the notion that dogs may, situationally, look to a proximate person for information or to solve a problem – even if the person is not the owner (who was unresponsive to the dog during the choice trials).

What are we to make of the inability of these dogs to use their noses? It is possible that the quantity difference between plates was insufficient for the dogs to detect, or, better, to make decisions based thereon. Future work might explore what the olfactory-discrimination threshold is, as has been done with visual quantities (Ward & Smuts, 2007). Similarly, though the evidence that dogs prefer a "larger amount" of food, when given a choice, is robust, we could not be certain that our subjects were intent on finding the larger amount; a preference test between visible plates of differing quantities would have improved our certainty. Further, it would be interesting to note whether companion dogs could be easily trained to attend to and note small distinctions of quantity by smell alone. Still, the present results do have consequences for future studies. Most dog cognition experiments use food as motivator and reward. Food serves both to direct the subjects' attention and to make salient the essential elements of an experimental setting which will be unfamiliar to the dogs. On the one hand, the results of the current study indicate that a protocol involving food may not need to control for olfactory cues, as the subjects may be ignoring said cues. On the other hand, the very fact that dogs are ignoring sensory cues which are, given the biology of the dog nose and brain, preeminent in the dog's experience, should give us pause. Dogs are often not demonstrating their full capacities in experimental settings – or, experiments are not well enough designed to lend naturally to such a demonstration. It is remarkable that even when plates are fully visible, dogs are not choosing the larger plate every time: in Prato-Previde et al. (2008), only three-quarters of the dogs chose the larger quantity over 50% of the time. This result affirms that dogs are not acting at capacity in experimental trials.

Additional fragrances

In our third, entirely novel condition, we explored how the dogs' choice behavior would change when additional scents were added to the larger-quantity – and more desirable – plate. Surprisingly, the scents led to a reversal of the dogs' choice, with more dogs choosing the smaller quantity for one or more scents (Fig. 7). No one scent deterred all dogs: their aversions were spread relatively equally among lavender, mint, and vinegar. These results suggest that dogs' behavior can be dramatically changed by an additional scent in their environments, and that dogs' aversions are not identical species-wide but instead represent individual tastes and perceptions. The additional odors were, of course, new in this context, and one might suggest that dogs simply evinced an aversion to the "new" odor. But provocatively, these scents are all commonly found in companion dogs' natural environments: both the lavender and mint were, indeed, fragrances in products intended for application on dogs; and the vinegar is common to many household cleaners. What owners' use of human-chosen scents around the dogs' environment does to the dogs' behavior at home is an open question, but one that would be useful to explore.

Methodological implications

Experimental design

In this study, we were also interested in the influence of experimental test procedure on the choices made by dogs. Prior studies suggested that dogs may have a side bias (Miklósi, 2007) or are subject to a recency effect (Tapp, Siwak, Estrada, Holowachuk, & Migram, 2003), leading to a preference for the second of two apparatuses presented, for instance. While we did have to eliminate four dogs from the trials for a consistent side bias, even among these four the bias was not unidirectional: two went to their left on every trial, and two went to their right. The other dogs did not show a side bias in these trials. Side bias does not appear to be a major methodological concern for dog-cognition research, in trials with a sufficiently large subject group.

By contrast, there was evidence that dogs were subject to the recency effect, choosing the plate to which they most recently exposed in presentation. This appeared in the sequential-presentation trials and could be a display of the primacy of short-term memory on behavior which serves to eclipse the intended quantity comparison. The recency effect finding argues for simultaneous presentation of stimuli. In our case, however, it did not change the course of the results in either of the closed-plate conditions.

Another consideration in experimental design is stimuli presentation. While there was no difference in the main result between those dogs in the simultaneous- and sequential-presentation groups, there are conditions in which these varying presentation modes may influence subjects' behavior. In the third condition, indeed, the behavior of those in the two groups suggested that simultaneous presentation differed experientially from sequential presentation. Given that dogs more often went for the larger amount in simultaneous presentations, it seems possible that the visual stimulus of *more food* is so powerful as to be determinant of their choice, regardless of other proximate cues. When the plates were presented sequentially, other cues had the opportunity to influence the subject's choice.

Experimental measure

The present results highlight points about subjects' attention and about the selection of an experimental measure. First, most dog-cognition experiments require that their subjects *attend* to a presentation or demonstration before making a choice or attempting to solve a problem. *Attention* is usually determined by simply noting subjects' head-direction (Range, Heucke, Gruber, & Konz, 2009). However, there is good reason to think that a facing dog is not always an attentive dog. Certainly dogs can be *directed* toward a person without *attending* to the person's actions, for instance. More troublesome, for an olfactory animal, visual attention may be secondary to olfactory attention. In this study, we attempted to determine olfactory attention to the presented plates. Data of stimulus attention showed that dogs did "select", through their attention, the larger quantity. However, these dogs did not approach the larger quantity plate, when allowed free choice. This inconsistency demonstrates that our methodology did not capture every dog's perception of the situation. Perhaps the short delay between presentation and choice was too long for the dogs' memory, perhaps vision took over as the dogs proceeded to approach the plates, or perhaps the dogs did not connect the plates placed on the floor with the ones they had just recently smelled. In either event, future research should look at direct, rather than indirect, methods of determining the dogs' attention (as attempted, for instance, in Salvin et al., 2012). In a further olfactory-discrimination design, a direct measure of attention could also serve as the experimental measure of the subjects' perceptual abilities.

Summary

In this study we explored the dog's use of olfactory information in a quantity-discrimination task. Subject performance suggests that dogs are not always attending to olfactory information in their environment. For dogs living among humans, olfactory cues are not primary. Their natural inter-specific environment does not reward smelling, and dogs may have reduced their attention to odors, as a result. On the other hand, strong odors used by humans can lead even these low-smelling dogs to change their behavior. Researchers of dog cognition should continue to explore the olfactory experience of dogs in what is almost certainly the odd-smelling anthropogenic environment.

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