Title
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Journal
International Journal of Comparative Psychology, 33(0)

ISSN
0889-3675

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Publication Date
2020

DOI
10.46867/ijcp.2020.33.01.02

INTERNATIONAL JOURNAL OF COMPARATIVE PSYCHOLOGY

2020, 33
Heather M. Hill
Editor
Peer-reviewed

Discrimination of Person Odor by Owned Domestic Dogs

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In the field of dog cognition research, many studies assume that their subjects have multimodal recognition of their owner: Experiments using the face or voice of the person have proliferated. An outstanding question is whether owned domestic dogs represent the people with whom they live via smell. Olfaction is a principal sensory modality for dogs, and there is evidence that it is integral to recognition of conspecifics. In the current study, we investigated whether owned dogs spontaneously (without training) distinguished their owner's odor from a stranger's odor. Using natural body odor captured on a t-shirt, we found that dogs habituated to a familiar odor and dishabituated to an unfamiliar odor. This finding begins to answer the question of how dogs recognize and represent humans, including their owners.

Keywords: domestic dog, olfaction, discrimination, odor

Domestic dogs are skilled social actors interspecifically with humans. They are able to interpret gestural, visual, and auditory information from humans (Hecht & Horowitz, 2015; Miklósi et al., 1998) and have been demonstrated to interpret visual and auditory emotional information, such as facial expressions and crying or laughing, appropriately (e.g., Müller et al., 2015; Yong & Ruffman, 2014).

In the current study we begin to ask how dogs recognize and represent the humans with whom they live. Previous research has examined whether dogs recognize their owners' voices (Coutellier, 2006) or match their owner's face with their owners's voice (Adachi et al., 2007). Other studies have looked at whether the presence or behavior of their owners, versus a stranger, has a differential effect on a dog, as by changing responsiveness to informative gestures (Elgier et al., 2009). Many other studies take advantage of the implied recognition of the owner by using owners within the experiment, such as to gauge the subjects' ability to distinguish facial expressions of different emotional valence (Merola et al., 2012) or owners' influence on dog's behavior in a food-choice task (Prato-Previde et al., 2008).

Although the majority of studies have used visual or auditory modalities for stimuli, olfaction is also a fundamental sensory modality for dogs (Berns et al., 2015). Natural social behavior of dogs, including anogenital sniffing and marking behavior, suggests that dogs send and receive identity information of conspecifics via smell. Given the role of olfaction in dogs' social lives, olfactory stimuli are more ecologically relevant to the species than visual stimuli (Nielsen et al., 2015).

In prior research, we demonstrated that dogs can distinguish both between their own (urinary) odor and others dogs' urinary odors and between their normal odor and a modified version of it (Horowitz, 2017). Bräuer and Belger (2018) demonstrated that dogs represent objects, in particular, dog toys, through smell. Behavior of working dogs indicates that they may recognize other species by odor as well. The ability of search-and-rescue dogs to track humans by odor left in footsteps and sloughed from skin is well known; Hepper and Wells (2005) found that dogs could determine the direction in which a person had traveled from five footsteps left behind. Although there are certainly other sensory cues that could corroborate dogs' identification of where a human was or is, odor is recognized to be their primary source of information.

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Very few studies have examined trained dogs' recognition of humans by smell, absent the physical presence of the person. Hepper (1988) found that four dogs could distinguish dizygotic twins, or monozygotic twins whose environment differed, when their t-shirts were presented to the dogs (see also Kalmus, 1955). Trained dogs have been found to be highly reliable in match-to-sample tasks in scent lineups (Marchal et al., 2016). Using similar methods, Von Dürckheim et al. (2018) found that African elephants, too, could match to human odor samples. Indeed, trained canines are sufficiently reliable in identification of human odor that they have been used as the measurement device in analyzing the endurance of human odor on materials (Curran et al., 2005).

Whether naive, untrained dogs also identify or recognize persons by their odor is less well studied. Salvin et al. (2012) demonstrated the use of an odor habituation paradigm using dog urine to show age-related decline in olfaction in untrained dogs. In this research, we aimed to extend the body of knowledge about dog recognition of humans by odor. We presented owned, untrained dogs with stimuli representing the smell of their owners – natural body odor left on a shirt – and asked if dogs spontaneously distinguished their owner's odor from a stranger's odor. We hypothesized that even dogs untrained in a smelling task will distinguish a familiar from unfamiliar person odor, absent the presence of the persons.

Method

Subjects

Dogs and owners were recruited through the Barnard Dog Cognition Lab database, to which interested parties have submitted their contact information, and social media websites. Subjects were required to have lived in their current home for at least six months, to have evidence of up-to-date vaccinations, and to be comfortable in new situations and with new people. With an interest in determining if subjects were actively discouraged from sniffing by their owners (Salvin et al., 2012), owners were asked "Do you let your dog sniff (lampposts, sidewalk smells, tree trunks, etc) on walks?" Each subject's owner assented to this statement.

Thirty-eight domestic dogs (17 F, 21 M) began the study. Mean subject age was 6.8 years old (range: 11 mo to 16 yr 6 mo). All but two were spayed or neutered. Fifteen dogs were identified by their owners as purebred; 23 were mixed-breeds.

Owners brought their dogs to the Dog Cognition Lab on Barnard College's campus in New York City, completed a consent form, and were instructed as to their role in the trials, as outlined below. We scheduled participants to arrive in sequence, so no dogs nor owners were present at or witness to trials prior or subsequent to their own. No other dogs were present in the room while the trials were run. Testing took place from January 2019 to March 2019.

Testing Room and Stimuli

Testing Room

A research assistant met owners and dogs at street level and then walked them upstairs to the Dog Cognition Lab site on the second floor. The Lab is a room of size 3.53 × 3.35 m, with a single door and no windows. With an interest in identifying sources of possible unintended odors in the room (Horowitz & Franks, 2019), we noted the following: One vent in the ceiling provided heat in the winter; there were no other sources of airflow. The center two thirds of the floor were covered with interlocking Eco-Soft Foam Tiles, which were cleaned with a solution of 70% isopropyl alcohol between subjects. In cases where a subject left visible hair or moisture, the floor was cleaned between trials. The temperature of the room, recorded at the beginning of the trials, varied from 68.5-79°F (mean 72.9).

In one corner of the room, a chair was provided for the owner; cattycorner to that chair was a short table with a computer and backup video recorder. The room was otherwise without furniture. The room was ringed by a shelf 4’5” above the ground; an iPad secured on these shelves, to the right of the box from the subject's perspective, recorded each trial. Stimuli, forms, cleaning materials, and other equipment were also on shelves behind a flexible curtain, which was pulled closed. Dog treats used for the study and toys provided at the study's completion were kept in sealed containers on a high shelf.

Odor Source

Previous studies successfully used cotton t-shirts to capture odor sources: in particular, t-shirts worn by persons for a specified period of time (Hepper, 1988; Polla et al., 2018). In this study, we provided dog owners with identical, new, white t-shirts, and gave them instructions about how and when to wear it. Owners wore the shirts on the two nights preceding their dog's scheduled visit to the Dog Cognition Lab. We asked owners to refrain from bathing right before putting on the shirt, and not to use soap, cleanser, or fragrance of any kind while wearing the shirt. Between wearings, owners secured the shirt in a Ziploc bag; after the second night, it was also placed in the bag, which was sealed. A second member of the household then brought the secured bag to the lab with the subject on the scheduled visit date and hour. Experimenters did not handle the shirt before its presentation to the subject (as described below). The secured bags were placed in dedicated lidded, shallow (25 × 20 × 7.6 cm) boxes; owner t-shirts were put in dedicated boxes, separate from stranger t-shirts. A second t-shirt, worn under identical conditions by a stranger to the dog (Stranger Odor) and delivered separately, was placed in a second box. Both "male" and "female" stranger t-shirts were available.

Experimental Design

When subjects arrived at the testing room, owners were allowed to remove or drop their dog's leash, and the dog was permitted to investigate the room independently for five minutes or until they had visibly calmed. At that time, the owner was given a leash to put on their dog and was asked to sit in a provided chair in one corner of the room, facing the center of the room (Figure 1). Experimenters were instructed to avoid interacting with subjects before the trials: they did not engage with, touch the dog, or call the dog's name.

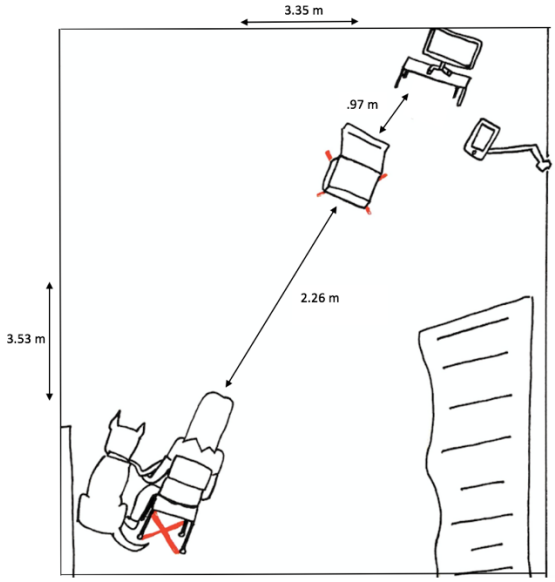

Figure 1. **Experimental room showing dog and owner location at start (red X) and box location during trials (red X).** Location of doorway, curtain concealing supplies, and video recorders noted.

Although owners knew that the worn t-shirts were to be used in this study, they did not know the experimental question. They were only asked to approach the presented stimuli with their dogs in the nature described (below). We further instructed the owners to let their dog act "naturally," emphasizing that there was no "right or wrong" behavior. Experimenters verbally explained to the owner how they should behave in the study. The protocol instructed owners to remain seated with their dog on leash, by their feet or by their side, during stimulus presentation. When the experimenter finished the presentation and stood, turning her back, that was the cue to the owner to stand up and walk to the stimulus. While standing by the box, the owner was instructed to gaze at their hands, not at the dog, and, at all times, to avoid gesturing at, talking to, or touching their dog. For each trial, after 10 s, the experimenter turned around and asked the owner and dog to sit down again. Experimenters could view owner behavior in a mirror, and owners were corrected as needed.

Procedure

The experimenter gathered the t-shirt from the owner (Owner Odor) and, behind the curtain and out of sight of owner and dog, placed it in a box. She also placed a t-shirt worn by a person unfamiliar to the dog in a separate box (Stranger Odor). In order to attempt to control for any sex-specific odor effects, the stranger and owner t-shirts were matched by gender: if the owner who wore the t-shirt was male, the male stranger t-shirt was used; if the owner was female, the female stranger t-shirt was used.

A third box (Orientation) was prepared with a single dog biscuit (chicken-flavored). If the dog owner specified an allergy to chicken, we used a salmon-flavored dog biscuit. It was intended to encourage the subject to approach the presented boxes.

The first box presented was the Orientation box. The experimenter placed the box on a designated spot on the floor, 2.26 m from the owner's chair and kneeled down behind it. She opened the lid, and, alternating glances at the box and at the dog, she repeated the script "Hi puppy, what's this?", repeating "what's this?" two more times, in a high-pitched (natural "dog talk"; Burnham et al., 2002) voice, tapping the sides of box with each "what's this." The experimenter then stood up and moved to the corner behind the computer table, with her back to the owner and dog. Using a mirror, the experimenter determined when the dog ate the treat, and turned and retrieved the box. If the dog did not eat the treat, the trial was repeated with a new treat. If the dog did eat the treat, the stimulus-box presentations began.

Stimulus box presentations followed the same script, though, unlike the Orientation trial, the experimenter unzipped the Ziploc bag to reveal the t-shirt after opening the box lid. Experimenters presented the stimuli boxes to subjects on up to four consecutive trials. The first presentation trials (P1, P2, and PF) were exclusively of the Owner Odor; the last presentation trial box (PN) held the Stranger Odor. Thus, subjects had three presentations in which to habituate to the original odor, after which they were presented with the novel odor. If the subject habituated to the Owner Odor after 2 exposures, the third exposure was skipped and the subject was presented with the Stranger Odor.

Each complete presentation trial lasted approximately 30 s, in which time the box was placed on the ground and the dogs were able to approach the box and investigate it. After 10 s, or when the dog had stopped sniffing, whichever was longer, the box was removed by the experimenter, an intertrial interval of 20 s was observed, and the next box was presented.

Dogs were said to have reached habituation when their investigation time decreased by 50% or more from their initial investigation time (P1) (Cohen, 2004).

Data Analysis

Each subject's session was videotaped for later frame-by-frame playback (30 fps, iPad) to determine investigative olfactory behavior (Horowitz, 2017; Thompson et al., 2016). Investigation was defined as beginning when the dog's nose was 10 cm (4") from the box (Horowitz, 2017; Lisberg & Snowdon, 2009) and directed toward the box. Only the part of the box holding the t-shirt, exclusive of the lid of the box, was considered. Investigation was scored as ending when the dog's nose was moved out of the box at a distance of greater than 10 cm or in a direction away from the box.

Coders were blind to the experimental hypothesis and contents of the boxes. We applied the Wilcoxon signed-rank test to compare investigation duration between the presentation of the Owner Odor at which habituation was achieved (PF) and the presentation of the novel, Stranger Odor (PN). A second individual, blind to the contents of the boxes, independently coded 35% (n = 11) trials. Inter-observer agreement was high for length of investigation in trial PF (Pearson's correlation: $r = 0.997$, $p < 0.01$) and length of investigation in trial PN (Pearson's correlation: $r = 0.995$, $p < 0.01$).

Results

Thirty-eight dogs began the study. Three dogs did not approach any of the boxes or only approached the first box. As they did not habituate, they were not tested for dishabituation. In four cases, due to experimenter error (mistaken adjustment of camera position), subject behavior could not be coded.

Of the remaining 31 subjects, 4 dogs did not habituate after three presentations of the box (10.5% of original group). This percentage is in line with other studies showing a wide range of subjects not habituating over repeated presentations of the same stimulus, from 13% (Salvin et al., 2012) to 31-50% (Pullen et al., 2012). Twenty-seven dogs reached the criterion for habituation and were used for analysis.

Overall, subjects dishabituated to the novel stimulus, the Stranger Odor, at a significant rate (Wilcoxon signed-rank, $z = 4.45$, $p < 0.01$, two-tailed). Twenty-six subjects showed dishabituation, in that they investigated the novel stimulus significantly longer than the final presentation of the initial stimulus; one subject did not dishabituate. Figure 2 shows the distribution of investigation times for the initial presentation (P1), the final presentation when habituated (PF), and the novel presentation (PN).

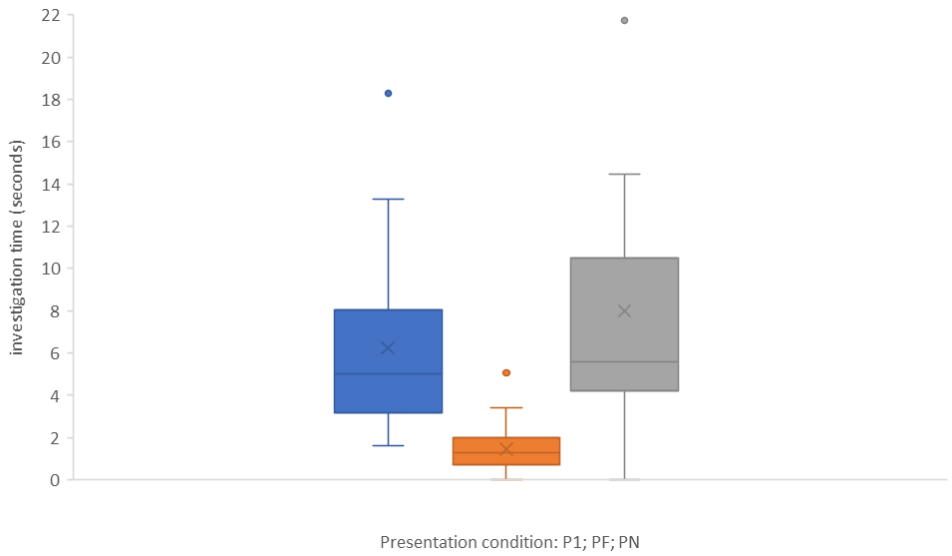

Figure 2. **Tukey box-and-whiskers plot showing the interquartile range and outliers for the investigation time for the first (blue) and habituated (orange) presentation of the Owner Odor, as well as the presentation of the Stranger Odor (gray).** Excluded is one outlier at 35.07 seconds (Stranger Odor).

Discussion

Naive dogs in this study demonstrated an ability to discriminate their owner's and a stranger's odor, as captured on t-shirts, independent of the presence of the individuals or any other signal. After habituating to their owner's scent, nearly all dogs dishabituated to a novel odor. This result was consistent with the hypothesis that dogs would be able to distinguish two persons' odors when one was a familiar person.

With an interest in the perceptual experience of owned pet dogs, we tested untrained dogs in this experiment. We would expect that dogs who had been trained on the task, or dogs trained to detect specific odorants, might perform similarly. Although dogs discriminated their owner's scent from another person's scent, this is not evidence that they associated that scent with their owner. To determine whether dogs have this ability, one would need to see if dogs can match a scent to a person or identify audio or visual representation of a person with that scent. One study found that dogs could match an owner's voice to a photograph of her face (Adachi et al., 2007); the current study demonstrates that a similar test could be done with an owner's odor.

In this study, we were agnostic about the constituents of the owner's odor and stranger's odor. The protocol of collecting human odor by asking individuals to wear a clean t-shirt overnight and avoiding fragrances is widely used to capture of the odor of a person with characteristics of experimental interest, such as being either male or female (Sorge et al., 2014; Thornhill et al., 2003), a woman during ovulation (Miller & Maner, 2010), familial relatedness (Ferdenzi et al., 2010), or simply to capture human body odor (Cecchetto et al., 2019). There remains a possibility that odors of the t-shirt-wearer's house, including other occupants, are also captured on the t-shirts to some degree, in addition to the human odor.

The habituation protocol, previously found to be useful in testing for age-related changes in olfaction in dogs (Salvin et al., 2012), is a straightforward and accessible way to test discrimination of odorants. Previous work has similarly demonstrated its usefulness in studies with mice (Wesson et al., 2010). Despite the primacy of olfaction for dogs, there is still a dearth of research investigating domestic dogs' experience of odors in the

anthropogenic environment (Horowitz & Franks, 2019). More attention to olfaction may improve dogs' welfare (Duranton & Horowitz, 2019); understanding the role of olfaction in dogs' experience may, too, improve the relationship between people and their dogs.

Acknowledgments

Thank you to all the dog and owner participants. Thanks to all lab members, integral to smooth running of the experiments and video coding, especially Blakeley Bagwell, Madelyn Baker, Sophie Baum, Kazandra Estorque, Melissa Flores, Courtney Garrity, and Leah Kim. Special thanks to Leah Kim for providing the drawing of the lab layout. This research was approved by the Institutional Animal Care and Use Committee (IACUC) at Columbia University and the Institutional Review Board (IRB) at Barnard College. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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Financial conflict of interest: No stated conflicts.
Conflict of interest: No stated conflicts.

Submitted: *November 21st, 2019*
Resubmitted: *January 29th, 2020*

Accepted: *February 2nd, 2020*