一、　通常在一個介紹科學的文章除了主要的標題外，會有幾個重點的"highlights"，請閱讀以下文字片段，給這段文章下個標題並將其整理出三個重點"highlights" (請以英文撰寫)（50 分）

*"If you are currently suffering from an unending state of sickness that seems to have engulfed almost everyone, you are certainly not alone. Whether it be COVID-19, the flu, or any of the other cold-like viruses that are currently surging in the winter, it seems that the feeling of bunged-up noses and scratchy throats may not be going anywhere for now.*
*You may have noticed, however, that your cold seems to get better and worse depending on the time of day, and others are reporting the same thing. Most commonly, you wake up with worse symptoms, which then partially clear up throughout the day, only to get worse once more as you get to bed.*
*But why does this happen? Let's find out.*
*Currently, the leading idea is that symptom severity is linked to our circadian rhythm, which is the innate ability of our cells to essentially tell the time. The circadian rhythm is incredibly important for daily cellular processes and can be affected by the amount of sleep and light we get each day. It also plays a critical role in the regulation of the heart and immune system.*
*While resting, the body uses the downtime to do a huge number of reparations, which is why sleep is so important after you've been to the gym. This also applies when you are ill – the body floods the blood with white blood cells called leukocytes, which result in a coordinated immune response against a disease. This can typically be seen in chronic diseases in which symptoms can get worse at night and better during the day, likely due to the immune system fighting infection (or being overactive, in the case of autoimmune disorders).*
*This, therefore, explains why our cold symptoms get worse as we settle down for a night's sleep or wake up from rest – those symptoms are a result of an active immune system trying to stem the infection. Immune cells recruit other immune cells to the local area (for example, the throat), causing a wave of inflammation and cell death. Cells that are infected by viruses are killed, causing soreness in the affected tissues, and mucus floods the nose to join the fight. It's a good thing, but it really doesn't feel like it, and you wake up feeling like death because of the battle that is happening within.*
*There are other reasons you might feel worse at night. The first is simply gravity – when laying down, mucus builds up in the sinuses, causing pressure and headaches. As you stand up and clear your nose, you start to feel better and gravity helps out a lot more when you are upright. Alongside this, hormonal imbalances can be caused by lack of sleep at night and could also link to immune function, which can lead to a vicious cycle of sleepless nights and then feeling worse as a result.*
*So, be sure to get as much sleep as possible when ill, and when you next wake up feeling like your body hates you, try to remember it's actually a good thing."*

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二、　請閱讀（附件一）文章，並撰寫一篇約 500 字的中文新聞稿介紹此研究成果（50 分）

見背面

附件一

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# A Ball Is Not a Kong: Odor Representation and Search Behavior in Domestic Dogs (*Canis familiaris*) of Different Education

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There has been a growing interest in the cognitive skills of domestic dogs, but most current knowledge about dogs' understanding of their environment is limited to the visual or auditory modality. Although it is well known that dogs have an excellent olfactory sense and that they rely on olfaction heavily when exploring the environment or recognizing individuals, it remains unclear whether dogs perceive odors as representing specific objects. In the current study, we examined this aspect of dogs' perception of the world. Dogs were presented with a violation-of-expectation paradigm in which they could track the odor trail of one target (Target A), but at the end of the trail, they found another target (Target B). We explored (a) what dogs expect when they smell the trail of an object, (b) how they search for an object, and (c) how their educational background influences their ability to find a hidden object, by comparing family dogs and working dogs that had passed exams for police or rescue dogs. We found that all subjects showed a flexible searching behavior, with the working dogs being more effective but the family dogs learning to be effective over trials. In the first trial, dogs showed measurable signs of "surprise" (i.e., further searching for Target A) when they found Target B, which did not correspond to the odor of Target A from the trail. We conclude that dogs represent what they smell and search flexibly, which is independent from their educational background.

*Keywords:* olfaction, representation, search behavior, domestic dog, working dog

*Supplemental materials:* http://dx.doi.org/10.1037/com0000115.supp



In recent years, there has been a growing interest in how animals perceive their environment and what they understand about it. Domestic dogs, *Canis familiaris*, are especially interesting, as they have evolved various skills for functioning effectively in human societies. Indeed, dogs show outstanding skills in the social-cognitive domain (for reviews, see Huber, 2016; Kaminski & Marshall-Pescini, 2014; Miklosi, 2007). Besides their communicative skills, dogs might also have evolved their motivation to cooperate and their perspective-taking abilities during domestication (Bräuer, 2014, 2015; Marshall-Pescini, Dale, Quervel-Chaumette, & Range, 2016). In contrast, regarding their physical cognitive skills (i.e., what dogs understand about their physical environment), dogs seem to perform similarly to other nonprimate mammals and birds (Bräuer, Kaminski, Riedel, Call, & Tomasello, 2006; Erdõhegyi, Topál, Virányi, & Miklósi, 2007; Osthaus, Lea, & Slater, 2005; Miletto Petrazzini, & Wynne, 2016; Rooijakkers, Kaminski, & Call, 2009).

However, until now, studies of dogs mostly took an anthropocentric view, mainly looking for skills and modalities that are important for humans. Thus, most current knowledge about dogs' understanding of their social and physical environment is limited to the visual or auditory modality (Bräuer et al., 2013; Kaminski, Call, & Fischer, 2004; Kundey et al., 2010), even though olfaction is an important sense that dogs use to explore their environment (Gazit & Terkel, 2003; but see also Horowitz, Hecht, & Dedrick, 2013; Szetei, Miklósi, Topál, & Csányi, 2003).

Olfactory cues play an important role in individual recognition and communication and also for the detection and selection of food (Brown & Johnston, 1983; Cafazzo, Natoli, & Valsecchi, 2012; Köhler, 2004; Lisberg & Snowdon, 2009; Wells & Hepper, 2006). Similar to wolves, dogs possess a large olfactory epithelium, expanded respiratory turbinates, and a huge number of olfactory neurons and receptors (Green et al., 2012; Köhler, 2004; Zhang, Wei, Zhang, & Chen, 2011). Dogs' olfactory acuity, that is, their ability to sense chemicals by smell at low concentrations, is excellent (Köhler, 2004; Miklosi, 2007; Vonk & Leete, 2017; Walker et al., 2006 but see also Horowitz et al., 2013), and they

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can learn to recognize various odors (Hall, Glenn, Smith, & Wynne, 2015; Williams & Johnston, 2002). In detection tasks, they indicate the presence of specific trained odors. Dogs can be trained to discriminate and indicate the presence of odors of narcotics, explosives, plants, parasites, and various diseases, such as cancer and diabetes (Alasaad et al., 2012; Browne, Stafford, & Fordham, 2006; Dalziel, Uthman, McGorray, & Reep, 2003; Furton & Myers, 2001; Gazit, Goldblatt, & Terkel, 2005; Lim, Fisher, & Burns-Cox, 1992; Lippi & Cervellin, 2012). In addition, dogs are also able to match odors (Marchal, Bregeras, Puaux, Gervais, & Ferry, 2016), that is, they can confirm or deny that two odors come from the same source (Brisbin & Austad, 1991; Schoon, 1996).

Interestingly, there are some contradictory findings about breed differences in odor detection. Polgár, Kinnunen, Újváry, Miklósi, and Gácsi (2016) used a natural detection task and compared dog breeds selected for their scenting ability, dog breeds bred for other purposes, dog breeds with exaggerated short-nosed features, and hand-reared gray wolves. As one would expect, it was found that wolves and scent breeds outperformed the other two groups. In contrast, in a study by Hall et al. (2015), pugs outperformed German shepherds in acquiring odor discrimination and maintaining performance when the odor concentration was decreased. Moreover, Jezierski et al. (2014) tested the efficacy of drug detection by police dogs of various breeds and found that German shepherds outperformed the other breeds, whereas terriers showed relatively poorest detection performance. This suggests that performance in an odor task not only depends on olfactory abilities but also on trainability, education, motivation, and the type of test (Polgár et al., 2016).

One further question is how dogs use their olfactory sense to find a target. A study by Hepper and Wells (2005) investigated how dogs determine the direction of an odor trail left by a human. The authors found that dogs trained in tracking humans are able to determine the direction of an odor trail after 1 hr by using only five footsteps (see also Wells & Hepper, 2003). In contrast, Polgár, Miklósi, and Gácsi (2015) used untrained dogs and investigated their strategies to find either their owner or food in one of three locations. Surprisingly, dogs did not perform above chance when the target was more than 1 m away, indicating that dogs could not gather olfactory cues at this distance. Subjects often used a win–stay strategy in that task, that is, they went to the place where the target was located in the trial before. Interestingly, dogs often first attempted to solve the problems based on the little visual information they had, rather than on the available olfactory cues. The authors concluded that despite their ability to successfully collect information through olfaction, family dogs often prioritize other strategies, such as a win–stay strategy, to solve such tasks (Polgár et al., 2015).

However, it remains completely unclear whether and how dogs *represent* objects via odors, that is, whether they have an expectation of something specific when smelling an odor trail. Bräuer and Call (2011) investigated how dogs represent objects. They used a classical violation-of-expectation paradigm with a container with a double bottom ("magic cup") that allowed them to change the type of food that subjects had seen being placed in the container. Whether subjects received a generally preferred or less preferred food and whether the food was substituted varied. It was found that when dogs were introduced to the so-called "surprise condition"—when food was substituted—their search behavior increased and they stayed in proximity to the experimenter. Thus, subjects did not search for just any reward but for exactly that reward that was placed in the container. Bräuer and Call (2011) concluded that dogs were indeed able to individuate objects according to their properties or type, in the same way as apes (and humans) do, and that this ability is, contrary to previous claims, neither uniquely human nor essentially language dependent (Xu, 2002). Although dogs used their sense of smell in the study, the relevant information (i.e., what food was placed) was also given in the visual modality.

Thus, although we know much about cognitive skills and olfaction in dogs, there is a lack of knowledge of how the two are linked together or how olfaction influences cognitive processes in dogs. Hence, the aim of the current study was to investigate whether dogs represent what they smell. We explored (a) what dogs expect when they smell the trail of an object, (b) how they search for an object, and (c) how their educational background influences their ability to find a hidden object. Overall, we expected dogs to not only have excellent olfaction but also represent specific objects from their odors and be able to search flexibly, that is, to use reasonable strategies to adapt to the challenges of the novel search task.

To test this, we adopted the classical violation-of-expectation paradigm of Bräuer and Call (2011). In the critical condition, subjects could track the odor trail of one object (Target A), but at the end of the trail, they found another object (Target B). If subjects represented what they smelled, we predicted that they would show measurable signs of "surprise" by searching (for Target A) when they find Target B, which does not correspond to the odor of Target A from the trail. In contrast, if subjects showed no change in behavior in the critical "surprise" condition compared with a baseline condition in which odor trail and target corresponded, it is likely that they perceive odors as positive (or aversive or neutral) stimuli without the expectation of the object/individual that they smell. In other words, this pattern of response would show that dogs do not associate the smell of an object with the object itself. Because dogs individuate objects according to their kind (Bräuer & Call, 2011), and because dogs have an excellent olfactory sense, our hypothesis was that they indeed have a representation of someone or something when they sense a smell.

In addition, we investigated dogs' search strategies, which was measured by how often they use sniffing to find the object, how long it takes them to find the object, and how they potentially improve over trials. Finally, we compared the performance of the two groups of dogs with or without special training in odor tracking, hypothesizing that dogs with special training would outperform family dogs.

## Method

### Subjects

In total, 48 dogs (21 male and 27 female) of various breeds and ages (ranging from 1 to 12 years) participated successfully in this study (Table 1). The dogs were divided into two groups. The first group consisted of 25 specially trained working dogs (11 male and 14 female, ranging in age from 1 to 12 years, with an average age of 5.3 years) that had passed the exams for either rescue dogs or police dogs and were part of the K9 unit of the Thuringia state

Table 1
*Subjects Participating Successfully in the Experiment (i.e., Met the Two Preconditions for Participating)*

| Subject | Breed | Gender | Age (years) | Educational background |
|---|---|---|---|---|
| Aaron | Belgian shepherd | Male | 3 | Working |
| Agent | Belgian shepherd | Male | 3 | Working |
| Akela | Belgian shepherd | Female | 6 | Working |
| Alice | Belgian shepherd | Female | 4 | Working |
| Angel | German shepherd | Female | 1 | Family |
| Angus | Labrador retriever | Male | 2 | Family |
| Azana | Golden retriever | Female | 1 | Family |
| Bella | Mongrel (Belgian shepherd and unknown) | Female | 8 | Working |
| Bill | Golden retriever | Male | 6 | Family |
| Bruno | Belgian shepherd | Male | 1 | Working |
| Cero | German shepherd | Male | 7 | Working |
| Cora | Golden retriever | Female | 1 | Family |
| Darwin | Labrador retriever | Male | 5 | Family |
| Dina | Lagotto Romagnolo | Female | 5 | Family |
| Duke | German shepherd | Male | 6 | Working |
| Ella | Nova Scotia duck tolling retriever | Female | 3 | Working |
| Fero | Mongrel (Belgian shepherd and unknown) | Male | 8 | Working |
| Finja | Tervueren | Female | 4 | Working |
| Frau Buber | Briard | Female | 7 | Family |
| Godin | Belgian shepherd | Male | 9 | Working |
| Isie | Belgian shepherd | Female | 4 | Working |
| Jack | Mongrel (German shepherd and schnauzer) | Male | 2 | Family |
| Joran | Collie | Male | 3 | Family |
| Kiba | Border collie | Female | 1 | Working |
| Kilo | German shepherd | Male | 4 | Family |
| Lina | Labrador retriever | Female | 4 | Family |
| Lotte | Mongrel (poodle and schnauzer) | Female | 8 | Working |
| Luna | Old German shepherd | Female | 4 | Working |
| Maja | Mongrel (border collie and Labrador retriever) | Female | 6 | Family |
| Mephisto | Standard poodle | Male | 10 | Family |
| Michel | German shepherd | Male | 4 | Working |
| Mira | Mongrel (Labrador and unknown) | Female | 5 | Working |
| Mira | Mongrel (Podenco and unknown) | Female | 9 | Family |
| Pearl | Australian shepherd | Female | 12 | Working |
| Pepsi | Belgian shepherd | Female | 3 | Working |
| Polly | Golden retriever | Female | 4 | Family |
| Prinz | German shepherd | Male | 4 | Working |
| Quino | Groenendael | Male | 5 | Working |
| Reni | Belgian shepherd | Female | 6 | Working |
| Rudy | Mongrel (Belgian shepherd and unknown) | Male | 6 | Working |
| Shari | Mongrel (Berger Blanc Suisse and golden retriever) | Female | 6 | Family |
| Tiffany | Mongrel (border collie and fox terrier) | Female | 7 | Family |
| Toni | Muensterlaender | Female | 1 | Family |
| Unique | German shepherd | Female | 1 | Family |
| Uschi | Mongrel (German shepherd and unknown) | Female | 9 | Working |
| Victor | Mongrel (Great Dane and Labrador) | Male | 4 | Family |
| Willy | Golden retriever | Male | 4 | Family |
| Yoshi | Mongrel | Male | 8 | Family |

police at that time. The second group (referred to as family dogs) included 23 family dogs (13 male and 10 female, ranging in age from 1 to 12 years, with an average age of 4.6 years) that had received no special training. For both groups, the owners were only informed about the research question, and the specifics of their dogs' tasks in the study, after the test was completed to avoid potential training or influence by the owners.

All subjects lived with their owners and were registered in our database. The dogs' owners decided voluntarily to take part in this study. Dogs were tested individually and were motivated to participate with toys. The dogs were encouraged to explore all testing rooms before the test. The study adhered to the *Guidelines for the Use of Animals in Research* of Germany.

## Preconditions

There were two preconditions for participating in this study. The first precondition was that every participating dog would be generally interested in playing with two different toys, which was ensured by the pretest. Subsequently, two toys of similar size were chosen that had to be equally interesting to the dog. To make sure that both toys were equally interesting, each dog was individually tested in a small test room. The dog was held by the collar by the first experimenter E1, who was seated about 1.5 m away from the second experimenter E2. Two toys were placed on the floor 1 m apart by E2, who sat on a small stool. Then, E2 pointed at one object and said, "Fetch this!" (in German: *Hol's dir!*) to the dog.

who was released in that moment to fetch the toy. E2 and the dog then played with the toy for a short period. In total, there were 10 trials presented according to a predetermined counterbalanced order, five for each object, including a short break after five trials. The decisive criterion was that the dog should bring each object at least four times. If the objects, however, were not equally interesting or were completely ignored, another toy combination was chosen and the pretest was repeated. If subjects could not be motivated to play with any toy (i.e., ignoring the toy when the experimenter was throwing it), they were listed as dropouts and could not take part in the experiment. Eight dogs did not meet this precondition, either because they did not fetch any toy or because they always had a stronger preference for one of two objects.

The second precondition to participate successfully in the test was that dogs entered the target room (with E1 and E2, but also alone) in a short familiarization phase before the experiment without showing fearful behavior and fetched the toy at least once in the test (see procedure). Two dogs did not meet this precondition.

## Materials

All tests were performed in the testing facilities of the dog lab at the Max Planck Institute for the Science of Human History in Jena. The pretest took place in the small test room (4.0 × 4.0 m), whereas the main test took place in Compartments 1 and 2 that were interconnected as depicted in Figure 1a. Compartment 1 consisted of two large rooms (13.0 × 5.0 m and 7.0 × 5.0 m) with a connecting double door. Compartment 2 was the target room where the target was hidden (3.5 × 3.5 m; this room was a former kitchen that had not been used for 1.5 years before the experiment started). The shortest distance between the starting point in Compartment 1 and the target in Compartment 2 was about 18 m.

Dogs were tested by two experimenters, E1 and E2. E1 was a member of the dog lab and was unfamiliar to the dog. For practical

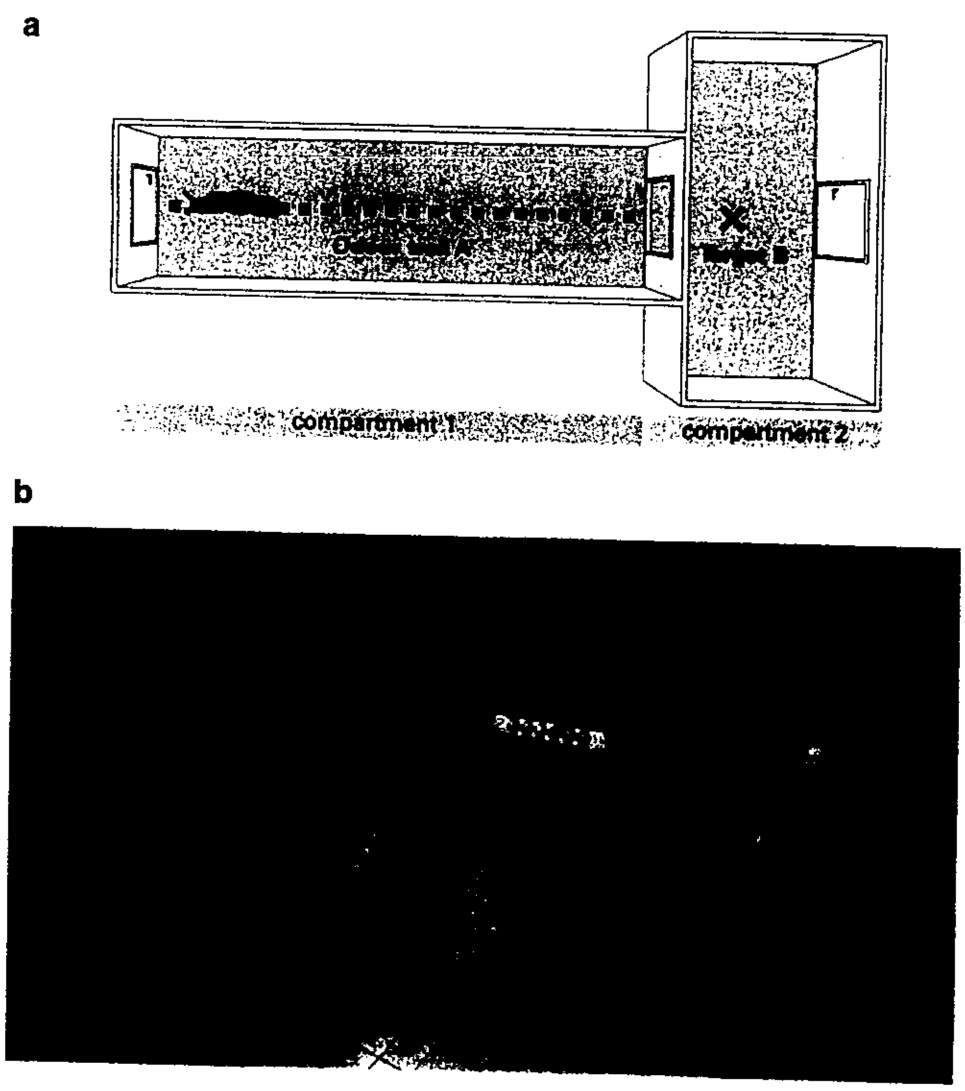


*Figure 1.* (a) Schematic setup of the experiment. (b) Target room with barriers. See the online article for the color version of this figure.

reasons, E2 could be either the dog's owner/handler (for 20 working and 14 family dogs) or a member of the dog lab (for five working and nine family dogs). The material for this experiment included toys such as balls, kongs, and ropes made out of rubber, leather, or cloth. Depending on her/his preferences, each dog was tested with a particular combination of two toys (usually consisting of similar materials, e.g., ball and kong), which had the same value for the tested dog. These toys were not new, dogs had played with them before, either in the dog lab or in their homes. Moreover, both toys were handled by E1 and E2 before and during the test; thus, the toys contained odors of E1, E2, and the subject dog and were not cleaned between trials. E1 regularly walked through both compartments, and E2 did so at least once during the familiarization phase. Care was taken that the toys were only carried through the compartments in plastic bags, except when they were slid on the floor and when the dog fetched one of them to E2. If the toys were not needed in the test, they were placed separately into plastic ziplock bags, then into a plastic box, and finally in the storage room located close to Compartment 2.

Before the experiment started in Compartment 1, little color markers (1 × 4 cm) were taped to the floor at a distance of about 2 m. These markers indicated four different routes in red, yellow, blue, and green that did not cross each other, so that the toy was not always slid on the same route (see below) and E1 could clean the predetermined route after each trial. In the target room (Compartment 2), two t-shaped barriers made of plastic were located 55 cm apart and about 2 m away from the entrance of the target room. Each barrier had a size of 60 × 50 cm with a dividing barrier of 60 × 50 cm in the perpendicular direction, so that two hiding places were formed. These four spots behind the two barriers, which were labeled with numbers from 1 to 4, served as hiding places for the toy and, thus, blocked visual access when the dogs entered the room (Figure 1b). All trials, including the pretest, were video-recorded. There were two cameras installed in the target room, Camera 1 that filmed the whole Compartment 2 and Camera 2 that filmed in the direction of Compartment 1.



## Procedure

After a short familiarization phase in the compartments and after passing the pretest, the subject waited in the small test room. Both objects, which were successfully evaluated as equally interesting in the pretest, were put separately into ziplock plastic bags, which were then closed. Depending on the condition, E1 took one of the toys out of the plastic bag and slid it with pressure on the starting point in Compartment 1. Then, E1 continued sliding the object on the floor through Compartment 1 following one of the four routes indicated by the color markers. When she entered Compartment 2, she slid the object on a direct path that ended at one of the four hiding places. Both the color of the route and the hiding place were predetermined. Then, the toy was put back into the plastic bag and taken out of the test rooms into the box in the storage room. Immediately after that, E1 either carried the same toy back, took it out of the plastic bag, and placed it in the hiding place (baseline condition) or carried another toy back, took it out of the plastic bag, and placed it in the hiding place (surprise condition).

Then, E1 left Compartments 1 and 2 and the subject was brought to Compartment 1 by E2. Once they had entered, E2 drew the dog's attention to the starting point of the odor trail by pointing at it, released the dog from the leash, and gave the command "Search for it! Fetch it!" (in German: "Such's! Bring's her!"). E2 did not know which toy was hidden and whether it had been replaced.

While the dog explored the room, E2 motivated him/her by talking to him/her and repeating the command. E2 usually stayed close to the starting point, but in cases where the dog had problems finding the toy, she was allowed to follow the dog halfway into Compartment 1, but not so far that she was able to see the toy in the hiding places. After fetching the toy, the dog was praised and allowed to play with the toy for a while in an additional room before the next trial started. If the dog, however, did not fetch the toy within 120 s, the trial was over. E1 entered through Compartment 2 and showed the toy to the dog, but the dog was not allowed to play with it. Between each trial, there was a break of at least 10 min. During that time, the dogs stayed in the small test room and the floors of the two compartments were cleaned with a mild detergent (Frosch® Neutral Reiniger: Erdal Rex, 55120 Mainz, Germany), in particular at the color marks of the previous trial.

## Design

We used a within-subjects design, and dogs were presented with four conditions. We manipulated the colored routes where the toys were slid on the ground, the hiding places in Compartment 2, and whether there was an agreement between Toy A (toy slid on the ground) and Toy B (toy found behind the cupboard), resulting in two baseline and two surprise conditions. Every dog was confronted with each of the following four conditions (counterbalanced):

(1) *Baseline AA*: Toy A was slid on the floor to produce an Odor Trail A. Toy A was also present/hidden behind one of the hiding places in Compartment 2.

(2) *Baseline BB:* Same as Baseline AA with the alternative in the toy being used. In this condition, Toy B was slid on the floor and also found behind one of the hiding places in Compartment 2.

(3) *Surprise AB*: Contrary to the baseline conditions, the surprise condition varied in the toy slid on the floor and the toy found in Compartment 2. In this condition, Toy A was slid on the floor and Toy B was found behind one of the hiding places.

(4) *Surprise BA*: Likewise, as in Surprise AB, there is a difference in the odor trail that is produced by a toy and the toy found. More precisely, Toy B was slid on the floor and Toy A was found behind one of the hiding places.

The hiding places, which were labeled with numbers from 1 to 4, were also assigned in randomized order. Each dog was tested once in each of the conditions, resulting in a total of four trials. Half of the dogs started with the baseline condition and half of the dogs started with the surprise condition (i.e., 12 dogs started with one of the four conditions, so the order of each condition was *Baseline AA, Baseline BB, Surprise AB, Surprise BA*). The subsequent three trials were counterbalanced in the 24 possible orders, so that each

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order of conditions was experienced by two dogs. The total duration of the experiment was about 60 to 90 min.

### Data Scoring and Analysis

The behavior of the subjects was coded from the videos of Camera 1 in the target room (as the angle of Camera 2 was too narrow for useful coding of the behavior in Compartment 1). We coded the latency until subjects fetched the toy, the occurrence and the kind of sniffing behavior, hesitation before fetching the toy, whether dogs approached the toy directly, and what hiding places the dogs visited before finding the toy.

(1) For latency, the time was measured from the closing of the door of Compartment 1 until the dog took the toy into his or her mouth before immediately carrying it back through the door of the target room to bring it to E2.

(2) The occurrence of sniffing was defined as (a) dog performed an audible sniffing noise, (b) dog moved his or her nose to within 3 cm of the floor or toward an object (such as barrier) while mouth was closed, or (c) dog held closed mouth in the air. When sniffing occurred, we distinguished between two kinds of sniffing: ground-scenting (all sniffing occurred within 3 cm of the floor/an object) and air-scenting (all sniffing occurred with head in the air), so that in a given trial, dogs could either show air-scenting only, ground-scenting only, or air- and ground-scenting.

(3) Hesitation was defined as either not immediately approaching and fetching the toy, even though the dog obviously detected it (as her/his muzzle was directed at it within a distance of less than a meter), or approaching and grabbing it but dropping it again (see online supplemental materials for an example video clip). This was easy to distinguish from trials with no hesitation, as dogs usually approached and fetched the toy immediately using the shortest approach after detecting it.

(4) Direct approach was coded when dogs directly went to the object after entering the target room using the same route as the object when it was slid on the floor.

(5) Visiting a hiding place was coded when subjects approached an empty hiding place and sniffed there with their nose on the floor.

A coder who was unaware of the goal of the study scored 20% of the trials to assess interobserver reliability. Interobserver agreement was above 0.9 for all measures (Spearman $r = .97$, $N = 38$ for latency; Cohen's $\kappa = 1.00$, $N = 40$ for sniffing; Cohen's $\kappa = 0.91$, $N = 39$ for hesitation; Cohen's $\kappa = 0.93$, $N = 37$ for direct approach; Cohen's $\kappa = 0.95$, $N = 40$ for visiting an empty hiding place).

All statistical tests were nonparametric two-tailed and the alpha level was set to 0.05: We used Friedman's test, Cochran's Q test, Wilcoxon's signed-rank test, and McNemar's test for comparisons between conditions; Mann–Whitney U test and Fisher's exact test for comparisons between groups and trials; and binominal test to test whether a hiding place was revisited. We analyzed the differences between the conditions, evaluated search strategies, and compared the performance of two groups of dogs with or without special training in odor tracking. The color of the routes did not influence the performance of the subjects (latency: Friedman = 2.68, $N = 37$, $df = 3$, $p = .344$; sniffing: Cochran's Q test = 2.47, $df = 3$, $N = 48$, $p = .515$; hesitation to fetch the toy: Cochran's Q test = 2.79, $df = 3$, $N = 39$, $p = .452$; direct approach: Cochran's Q test = 0.379, $df = 3$, $N = 37$, $p = .976$).

## Results

All dogs solved the problem and fetched the toy within 120 s in nearly all trials. Only 11 out of 48 dogs did not fetch the toy in all trials (nine of these dogs failed in the first trial). This was independent from condition (dogs failed to fetch the toy in nine trials in the baseline and five trials in the surprise condition, Wilcoxon's test: $t = 27.00$, $N = 8$, $p = .289$), but working dogs tended to perform better than family dogs (eight family and three working dogs failed once or twice; Mann–Whitney U = 217.50; n1 = 23; n2 = 25; $r = .30$; $p = .056$). See Table 2 for the mean values of the coded behavior and online supplemental materials for a detailed data file of all behaviors.

### Surprise Versus Baseline

Overall, dogs did not hesitate more in the surprise compared with the baseline condition (Wilcoxon's test: $t = 44.00$, $N = 12$, $p = .724$), and they did not fetch the toy faster in the baseline condition compared with the surprise condition (Wilcoxon's test: $t = 606.00$, $N = 47$, $p = .639$).

However, when only considering the first trial, significantly more dogs hesitated to fetch the toy when it was replaced (surprise condition) compared with the baseline condition (Fisher's exact test: $p = .026$, $N = 41$; Figure 2). Regarding the latency to fetch the toy, there was no significant difference between conditions in the first trial (Mann–Whitney U = 172.50; n1 = 21; n2 = 18; $r = .064$; $p = .651$).

Table 2
*Mean Values for the Coded Behaviors of the Working Dogs and Family Dogs (Values for the First Trials in Brackets)*

| Educational background | *M* % of trials fetching the toy within trial | *M* latency until fetching the toy in seconds | *M* % of trials sniffing behaviour | *M* % of trials hesitation | *M* % of trials direct approach |
|---|---|---|---|---|---|
| Family | 88 (69) | 35 (60) | 72 (85) | 20 (41) | 21 (19) |
| Working | 97 (92) | 38 (43) | 78 (79) | 12 (13) | 28 (22) |



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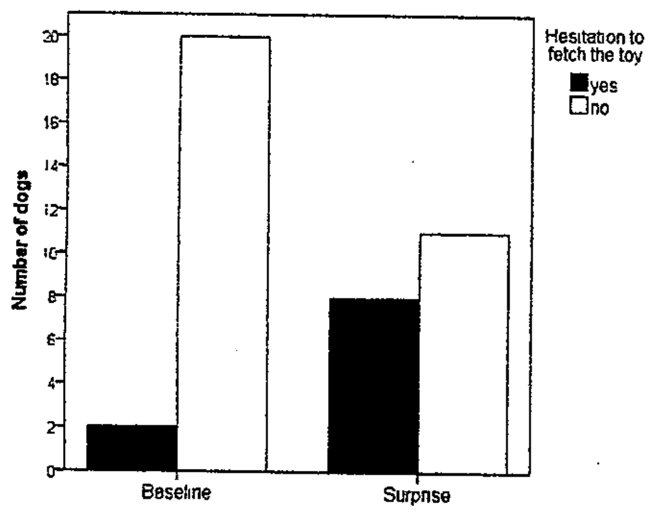


*Figure 2.* The numbers of dogs that did and did not hesitate in the baseline and the surprise condition in the first trial.

## Search Strategies

Dogs showed sniffing behavior in 75% of the trials, indicating that they often used their sense of smell to find the object in the target room. In some of these trials, dogs showed air-scenting only (21% of all trials) or ground-scenting only (15% of all trials) but usually both (38% of all trials). It is not surprising that it took dogs longer to fetch the toy in trials when they sniffed compared with when they did not sniff (Wilcoxon's test: $t = 355.50$, $N = 29$, $p = .002$). Similarly, they took more indirect approaches when they sniffed than when they did not sniff (Wilcoxon's test: $t = 276.00$, $N = 23$, $p < .001$).

Interestingly, dogs showed a different search behavior depending on the place where the toy was hidden, although all four hiding places were easily approachable and did not differ much in their distance from the door of Compartment 2 (see also Dumas & Dorais Pagé, 2006). There was a significant difference in sniffing behavior depending on hiding place (Cochran's $Q = 28.06$, $N = 43$, $df = 3$, $p < .001$). In particular, dogs sniffed in more trials when the toy was hidden in Hiding Place 1 or 4 compared with Hiding Place 2 or 3 (McNemar's test: 1 vs. 2, $N = 45$, $p < .001$; 1 vs. 3, $N = 47$, $p < .001$; 1 vs. 4, $N = 45$, $p = .625$; 2 vs. 3, $N = 46$, $p = 1.000$; 3 vs. 4, $N = 46$, $p = .002$). Similarly, there was a difference in the kind of approach (Cochran's $Q = 29.62$, $N = 37$, $df = 3$, $p < .001$). Dogs never or rarely approached Hiding Places 1 and 4 directly but approached Hiding Places 2 and 3 significantly more often directly (McNemar's test: 1 vs. 2, $N = 42$, $p < .001$; 1 vs. 3, $N = 43$, $p < .001$; 1 vs. 4, $N = 38$, $p = .125$; 2 vs. 3, $N = 45$, $p = 1.000$; 2 vs. 4, $N = 40$, $p = .003$; 3 vs. 4, $N = 41$, $p = .003$). However, there was no difference between hiding places in the latency to fetch the toy (Friedman = 3.36, $N = 35$, $df = 3$, $p = .366$) and in hesitation to fetch the toy (Cochran's Q test = 2.36, $df = 3$, $N = 37$, $p = .547$).

During their search, 39 out of 48 dogs went in some trials to a hiding place in which the toy was not hidden. It turned out that in 36 out of 61 cases (62%), dogs revisited the hiding place in which the toy was hidden in the trial before (note that for this analysis, the first trial was excluded). Assuming that the probability that dogs visit one of the four hiding places is 25%, there was a significant effect for dogs revisiting the correct place of the previous trial (binominal test: $N = 61$, $p < .001$). This suggests that dogs used a win–stay strategy. Dogs also became much faster at fetching the toy between the first trial and the fourth trial (Wilcoxon's test: $t = 614.00$, $N = 38$, $p < .001$), but they did not change their behavior over time in the other measures (McNemar's test: sniffing: $N = 44$, $p = .727$; hesitating to fetch the toy: $N = 41$, $p = .146$; direct approach: $N = 38$, $p = 1.000$).

## Difference Between Groups

Surprisingly, in the comparison of all trials, there was no significant difference in all measures between the two dog groups of different educational background. Considering only the first trial, however, the working dogs were significantly faster to fetch the toy than family dogs (Mann–Whitney U = 102.50; $n1 = 16$; $n2 = 23$; $r = .30$; $p = .019$), but this effect was not there in the fourth trial (Mann–Whitney U = 268.50; $n1 = 22$; $n2 = 25$; $r = .08$; $p = .895$). Figure 3 shows that family dogs were slower to fetch the toy in the first trial but improved their searching behavior, so that they became as fast as working dogs. For the direct approach, there was no difference in the behavior of the working and the family dogs in the first trial (Fisher's exact test: $p = 1.000$, $N = 39$) but a significant difference for the fourth trial (Fisher's exact test: $p = .025$, $N = 47$), indicating that working dogs approach the toy more often directly in the last trial than family dogs. For the other measures, there was no difference.

Finally, we tested whether E2's identity, as either the owner of the dog or not, influenced the dog's behavior. Whereas there was no difference in fetching the toy (21% of dogs tested with E2 as owner and 29% of dogs with E2 as stranger did not fetch the toy in all trials), dogs hesitated less often when E2 was the owner (Mann–Whitney U = 134.00; $n1 = 14$; $n2 = 34$; $r = .41$; $p = .006$). Moreover, when E2 was the owner, dogs were significantly faster to fetch the toy in the first trial (Mann–Whitney U = 82.00:

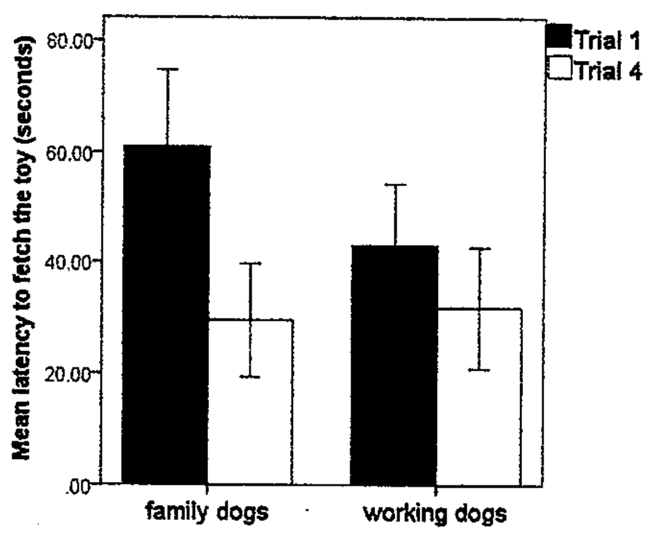


*Figure 3.* The mean latency to fetch the toy in the first and the last trial for the family dogs and the working dogs (error bars represent 95% confidence intervals).

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$n1 = 11$; $n2 = 28$; $r = .41$; $p = .023$) but not in the fourth trial (Mann–Whitney $U = 215.50$; $n1 = 13$; $n2 = 34$; $r = .06$; $p = .883$). For all the other measures, there was no difference. More importantly, the whole analysis with only the dogs tested with E2 as owner ($N = 34$) revealed exactly the same result patterns as for all dogs (see online supplemental material), indicating that—although dogs tested with owners hesitated less and were faster in the first trial—there was no interaction between owner identity and performance in the two conditions or over trials or between the two groups.

## Discussion

Dogs in the current study successfully found and fetched a toy that was hidden in another room. In the first trial, significantly more dogs hesitated to fetch the toy when it was replaced, that is, when the odor trail of the toy was not identical with the hidden toy (surprise condition) than when it was not replaced (baseline condition). Our results suggest that dogs (a) could distinguish between the two toys by odor, (b) tried to localize the identified toy, (c) represented what they smelled—that is, they had an expectation of what they would find at the end of the trail and did not simply perceive the odors of the given toy as positive stimuli, and (d) hesitated less in general when they were tested with their owner.

However, the effect of hesitation was only present in the first trial. In subsequent trials, dogs did not hesitate more often when the object was replaced. It is highly unlikely that dogs no longer had an olfactory expectation in subsequent trials, but there are two possible explanations for that finding that are not mutually exclusive. First, due to their excellent olfactory sense, it is not unlikely that dogs still perceived the smell of previous trials. We tried to avoid this by using different routes (that we marked with color stripes so that the experimenters could find them) for each trial and by cleaning the track after each trial with a mild detergent that does not prevent dogs from using their nose. Moreover, according to dog professionals, even naïve dogs have a tendency to follow the most recent track, which has ecological implications, as in a variable environment, the most recent information should be weighted more because it is more certain (Devenport & Devenport, 1993).

Second, it was also possible that, as dogs were always rewarded with playing as long as they fetched an object, they learned rapidly (a) that it did not matter whether they fetched the toy that corresponded with the odor trail and (b) to search for the toy determinedly in the target room. It is possible that from the second trial on, the dogs relied more on the visual prompts like the barriers than on the olfactory trail, as they now knew the task. However, there was no decrease in sniffing behavior over the trials, indicating that the dogs still used olfaction in Trials 2 through 4.

That leads to the question of how the dogs understood what they were searching for. Gadbois and Reeve (2014) referred to three processes to localize olfactory stimuli: searching, trailing, and tracking. "Searching" requires subjects to have an identified target. The only cue the dogs in the current study received was that E2 pointed at the starting point of the odor trail and said to the dog "Look for it! Bring it!" These cues were obviously sufficient for all dogs to fetch the toy in most trials. The dogs then "trailed," that is, tried to localize the identified target by sniffing. What odors dogs used to trail (i.e., what volatiles of the toy) and how the airflow influenced the scent remain unclear but were not the questions of the current study.

Interestingly, dogs rarely "tracked" by following the exact path of the target by sniffing only the floor (Gadbois & Reeve, 2014; Miklosi, 2007; Thesen, Steen, & Døving, 1993). This is illustrated by the fact that dogs in the current study hardly ever approached the outer hiding places (1 and 4, respectively) directly. Thus, they did not follow the track exactly in the way that the object was slid to the baited hiding place. Indeed, even police dogs trained for man-trailing do not exactly follow the track of the target person but take shortcuts (personal observation during training sessions of the K9 unit of the Thuringia state police).

Remarkably, dogs in the current study sniffed more often when the object was hidden in the outer hiding places, but they were not slower in fetching the toy in those cases. In accordance with previous studies, in which dogs searched for their owners or food (Polgár et al., 2015), this may suggest that dogs search for the object by vision and learned strategies, using their nose merely in cases when it is necessary (see also below). Indeed Gagnon and Doré (1992) found that dogs sniffed more in difficult than in simple object permanence tasks and concluded that dogs might gather information from other sensory modalities when one was not sufficient. Indeed, in the current study, dogs either found the object on their direct approach or sniffed on the indirect approach, also suggesting that they sniffed in particular when they did not find the toy by vision. Both strategies were obviously effective, as dogs were equally successful (i.e., equally fast) in fetching the toy in all four hiding places, indicating that they either found the toy during their—often direct—approach to the inner hiding places or sniffed and then found the toy in the outer hiding places.

It is not surprising that dogs also improved their searching behavior over time and fetched the toy much faster in the last trial compared with the first trial. Probably their familiarity with the visual setup and task helped them fetch the toy faster, but they still used their nose for sniffing, which did not decrease over the trials.

The dogs also often revisited the hiding place in which the toy was hidden in the previous trial. This win–stay strategy is in line with previous findings (Polgár et al., 2015, see above). In a study by Claude Dumas (1998), dogs had to retrieve a hidden object on the basis of the place (or the feature) of the hiding location. Dogs associated spatial cues (but not feature information) and followed egocentric search criteria (see also Fiset, Gagnon, & Beaulieu, 2000; Fiset, Landry, & Ouellette, 2006). Kaminski, Fischer, and Call (2008) tested two specially trained dogs that had to fetch two sets of objects that were placed in two rooms. Subjects were asked to retrieve the objects that were called by name, one after the other. Both dogs successfully retrieved the correct objects. One dog was even able to integrate information about the object's location, as from the second trial on, he chose the correct location in which the object had been placed. Similar to these findings, dogs in the present study took into account what they had experienced in the trial before.

One further aim of the current study was to compare the two groups of dogs with or without special training in odor tracking. As expected, working dogs were significantly faster to fetch the toy than normal family dogs in the first trial, and they also approached the toy often more directly in the last trial. One also might speculate that the working dogs would not search for the toy but for the targets they were trained for (drugs, explosives, corpses, and living humans). However, that the dog handler pointed to the starting point of the odor trail was obviously sufficient enough for the working dogs to adapt to the new task.

Surprisingly, the working dogs were not faster in the fourth trial, and overall, working dogs did not outperform family dogs. Thus, family dogs learned within four trials to be as effective as working dogs. These results could reflect a ceiling effect, that is, the task was so simple that the working dogs were unable to show further improvement. However, as it still took working dogs about 30 s on average to fetch the toy from a distance of about 18 m (see Figure 3), it is also possible that they always performed the strategic search they were trained for. Other studies that compare the performance of working and nonworking dogs have produced mixed results. Whereas dogs with special training outperformed family dogs in understanding the communicative intent of a human (Kaminski, Tempelmann, Call, & Tomasello, 2009), working dogs were not better than family dogs in using communicative cues to locate hidden food (Gácsi, Kara, Belényi, Topál, & Miklósi, 2009). Furthermore, in a study by Topál, Miklosi, and Csanyi (1997), in which dogs were observed in a simple problem-solving task, working dogs did not outperform nonworking dogs. Instead, dogs' problem-solving abilities depended on their kind of relationship to their owner/handler. Indeed, also in the current study, dogs showed more hesitation to fetch the toy and were slower (in the first trial) when the person asking for the toy was unfamiliar to them, suggesting that it was less obvious to these dogs what to do.[1] Thus, it is likely that education per se—that is, training for a specific duty, including an exam—does not improve the performance of dogs in a given task, but many other factors play a role here, that is, the kind of training, the kind of task, and the relationship to the dog handler (Polgár et al., 2016).

In conclusion, our results confirm that dogs can use olfactory information in an adaptable way: Their hesitation in the first trial indicates that dogs indeed represented what they smelled—that is, had an expectation about which toy they would find in the end of the trail. We also found that family dogs improved their searching behavior quickly and that dogs do not always use their nose but also search for the object using their vision and the win–stay strategy. It is an open question how these issues are linked together, that is, what factors play a role (such as the target, education, previous experience, and relationship to the handler) so that dogs use their nose or other search strategies.

As for dogs, for other macrosmatic animals, we currently lack knowledge about how exactly olfaction and cognition are linked. Plotnik, Shaw, Brubaker, Tiller, and Clayton (2014) found that Asian elephants relied on olfaction to locate food and to exclude nonrewarding food locations but failed to use auditory information. Likewise, in rodents, olfaction seems to be the main sense used to explore the environment (Lavenex & Schenk, 1998; Maruniak, Darney, & Bronson, 1975), and olfactory cues play an important role in kin recognition and individual recognition (Drickamer, 2001; Hurst, 1993; Klemme, Eccard, Gerlach, Horne, & Yloenen, 2006; Solomon & Rumbaugh, 1997). The question is whether other macrosmatic animals besides domestic dogs represent what they smell and, thus, have a clear expectation when they smell something—or whether they perceive the smell as a positive or aversive stimulus. For rodents, the latter could be hypothesized, as captive rodents that have no experience with predators also react to odors of their predators (Ylönen, 2001). It is also possible, however, that olfaction is linked with cognition in a similar way in such distinct macrosmatic animals as carnivores (Green et al., 2012), rodents, and elephants.

[1] Note also that the two dogs that showed hesitation to fetch the toy in the baseline condition in the first trial were tested by an unfamiliar person.



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