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Domestic dogs conceal auditory but not visual information from others

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Abstract A number of studies have shown that dogs are sensitive to a human's perspective, but it remains unclear whether they use an egocentric strategy to assess what humans perceive. We investigated whether dogs know what a human can see and hear, even when the dogs themselves are unable to see the human. Dogs faced a task in which forbidden food was placed in a tunnel that they could retrieve by using their paw. Whereas the dogs could not see the experimenter during their food retrieval attempts, the experimenter could potentially see the dog's paw. In the first experiment, dogs could choose between an opaque and a transparent side of the tunnel, and in the second experiment, they could choose between a silent and a noisy approach to the tunnel. The results showed that dogs preferred a silent approach to forbidden food but they did not hide their approach when they could not see a human present. We conclude that dogs probably rely on what they themselves can perceive when they assess what the human can see and hear.

Keywords Social cognition · Domestic dogs · Perspective taking

Introduction

Taking the visual perspective of others is a highly adaptive skill for social living animals (Kummer et al. 1996). To know what others can see is not only helpful when individuals hide from each other (Kummer 1982) while competing over food (Bräuer et al. 2007; Emery and Clayton 2001; Hare et al. 2000; Kaminski et al. 2006) but also in a communicative context, where senders should understand that recipients need to attend to their signal to receive it (Kaminski et al. 2004; Liebal et al. 2004). Numerous species seem to have some understanding about what others are seeing (e.g., chimpanzees: Bräuer et al. 2007; Hare et al. 2000; Melis et al. 2006; rhesus macaques: Flombaum and Santos 2005; Western scrub jays: Dally et al. 2006) or at least are sensitive to the attentional state of others (wolves: Udell et al. 2011, great apes: Kaminski et al. 2004, capuchin monkeys: Hattori et al. 2007, dolphins: Xitco et al. 2004, goats: Kaminski et al. 2005, see also Rosati and Hare 2009 for a review about primates).

Domestic dogs have also been tested in their perspective-taking abilities using three basic experimental approaches. First, dogs have been tested in a situation in which they can beg for food. In the study of Gácsi et al. (2004), dogs could choose between two eating humans based on either the visibility of the human's eyes or direction of the face. Dogs begged more from the attentive than from the inattentive human, indicating that they were sensitive to human attention. In the second experimental approach, dogs were given a command, either to do a certain action (i.e., lie down) or to refrain from doing something (i.e., do not eat the food). The human either looked at the dog or was distracted, having eyes closed or back turned. Dogs obeyed the command better when the human was attentive, and therefore, it was concluded that they are sensitive to human attention (Call et al. 2003; Gácsi et al. 2004; Schwab and Huber 2006; Virányi et al. 2004). Note that in all these situations, dogs could rely on the orientation of the body, the orientation of the head, the visibility of the eyes, and could use them as a cue to obey

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or to beg. Relying on certain stimuli could also be the explanation for the findings of the study of Bräuer et al. (2004). In that study, forbidden food was placed behind different kinds of barriers. The authors found that dogs were sensitive to whether or not the presented barrier was effective or ineffective at obstructing a human's vision. Dogs ate more forbidden food when the barrier was large compared to small or had a window, so that the human could see either the approach to or the taking of the forbidden food. However, it is possible that the dogs' behavior was based on their sensitivity to stimuli, such as seeing certain human body parts instead of their understanding of the human's visual access to the food.

Kaminski et al. (2009) took a different approach that went beyond explanations based on using the presence of certain stimuli to assess whether one is being watched. They tested dogs in a cooperative situation in which the subjects were asked to fetch a toy. Two toys were placed on the dog's side of two small barriers (one opaque and one transparent). In the experimental condition, a human sat on the opposite side of the barriers, such that only the toy behind the transparent barrier was visible to her. She then told the dog to fetch the toy. Dogs preferentially fetched the toy that the experimenter could see, namely from behind the transparent barrier. Dogs did not have this preference in the two control conditions, in which the human could see either both or neither of the toys. The authors concluded that even in the absence of behavioral cues, dogs were sensitive to humans' visual access, even if it differed from their own.

However, one alternative interpretation is that dogs preferred the transparent barrier simply because they wanted to sustain visual contact with the human while fetching the toy (Kaminski et al. 2009). Also, in the other two experimental approaches, dogs could have relied on whether the human or his eyes were visible. In most cases, the egocentric strategy of assuming that "When I see you (and your eyes) then you see me" is very successful (Kummer 1982). However, if animals are really able to take the visual perspective of others, then they should be able to understand the perspective of the other *independent* of their own perspective.

Melis et al. (2006) investigated this question with chimpanzees. They used a competitive situation in which chimpanzees competed with a human for food. The human sat inside a booth, with one piece of food to her left and one to her right. She could retract either piece of food from her chimpanzee competitor's reach as needed. The chimpanzees could approach either side of the booth unseen and then could reach for the food through one of two tunnels. One tunnel was opaque and one was transparent. The chimpanzees preferred to reach through the opaque tunnel, indicating that they could take the visual perspective of the competing human, and that they actively concealed information from her. The important point here is that the chimpanzees could *not* solve the problem on the basis of what they themselves saw—because they could not see the human while they reached for the food. In other words, they could not rely on the egocentric strategy "When I see you, then you see me." In the current study, we wanted to investigate whether dogs are also able to judge what a human can see when they are not able to see the human.

Melis et al. (2006) suggested that if subjects are also able to conceal information in a modality other than the visual, this would show a deeper understanding of the other's perceptual states. Indeed, they found evidence that chimpanzees knew what humans can hear by using the same basic procedure described above but with auditory information (but see Bräuer et al. 2008). Again, chimpanzees competed for food with a human who sat inside the booth. But now, both tunnels were clear and the human was looking away, but one of the tunnels made a loud noise when it was opened. Chimpanzees preferentially reached through the silent tunnel, successfully concealing their taking of the food from the human competitor. The authors concluded that chimpanzees can actively manipulate the auditory perception of others by concealing information from them. Santos et al. (2006) found similar results with rhesus macaques using silent and noisy containers with food inside them. Monkeys selectively choose the silent container over the noisy container, suggesting that they knew that the noisy container might alert the human competitor.

There is also evidence that dogs are sensitive to what humans can hear. Kundey et al. (2010) also tested dogs using containers rather than tunnels. Dogs could choose to eat food from a silent or a noisy container. Subjects preferred to eat from the silent container when the human was *not* looking at them. In contrast, they had no preference when the human was looking at them. The authors concluded that the dogs tried to retrieve food silently only if silence was relevant to obtaining food unobserved by a human gatekeeper. In contrast to other studies, the food during the test was not forbidden but the experimenter had forbidden the dogs to take food prior to the test. More importantly, dogs could see the human while taking the forbidden food. Thus, the use of an egocentric strategy, such as trying to be silent when the human's eyes are not directed at them, is still viable.

In sum, a number of studies have shown that dogs are sensitive to human perspective but it remains unclear whether they use an egocentric strategy to assess what humans can hear and/or see. In the current study, we investigated whether dogs' perspective taking goes beyond this egocentric strategy. We used the basic setup as Melis et al. (2006), except that the dogs did not compete with the human, but food was forbidden by the human. In the first study, we investigated whether dogs know what a human can see even when they are unable to see the human. While the dog is retrieving forbidden food with her paw, she *cannot* see the experimenter but the experimenter can potentially see the dog's paw. Would the dogs conceal their approach to the forbidden food by retrieving the food from an opaque as opposed to a transparent tunnel? In the second study, we investigated whether dogs would conceal their approach by avoiding the production of auditory cues. Would they prefer a silent as opposed to a noisy approach to the forbidden food?

Experiment 1: Concealing visual information

Methods

Subjects

Seventy-eight dogs (41 females and 37 males) of various breeds and ages (see Table 1) participated in this study. Additionally, 42 dogs had to be excluded because they showed signs of discomfort without the owner or did not pass the pretest. All subjects had been living as pets with their owner and had therefore received the normal obedience training typical of domestic dogs. The dog owners were not present during the test and were not informed about the design and the purpose of the study before it started. Subjects were tested individually with only the experimenter present in the room.

Materials

Testing took place in the "dog-bungalow" of the MPI EVA in Leipzig in a quiet room (8.70 m × 4.00 m × 2.85 m) with two doors. Figure 1 shows the experimental setup. The room was separated into two parts by 1.80-m-high movable walls with the test apparatus in the middle. During training, the outer parts of these walls were removed so that the dog could walk around and get familiar with the apparatus. During test trials, the dog was always in part A and the experimenter in part B (or outside) of the room (see Fig. 1).

The apparatus had an hour glass shape and was 1.66 m long. Its width was 0.48 m in the middle and 0.83 m at the ends. The apparatus was constructed from wood and open on the experimenter's side so she could get inside to place the food in the middle of the tunnel. The tunnel was made of Plexiglas and was located in the middle of the apparatus. The opening of the tunnel in the middle of each side of the apparatus was 0.06 m wide and 0.27 m high. The dog could reach into the tunnel from the right or left side. A black cover was put on one side of the tunnel making it opaque—so that when a dog reached through, the experimenter could not see the dog's paw. The other side remained transparent. From the dog's side, there was a 0.10-m wide Plexiglass gap in the apparatus. Through this gap, the dog could see the tunnel and the experimenter. In that gap, there was one hole (diameter 0.04 m) 0.56 m above the ground, which was used to show the food to the dog at the beginning of each trial.

There was a separate training tunnel with the same size, but half as long as the tunnel used in the test. It was placed beside a wall in part B of the room and was only used for training.

Procedure

Training and pretest The dogs had to learn to get the food from the tunnel using their paws. They were therefore trained to get food from a tunnel outside the apparatus. This training tunnel, half as long as the one used in the test, was attached to the wall in part B of the testing room. The experimenter put the food in the training tunnel and encouraged the dog to get it out with its paw (in the test

Table 1 Breed, gender, and age of the participating dog subjects

Experiment	Breeds	Gender	Age (years)
Experiment 1: Concealing visual information	2 Airedale Terrier, 4 American Staffordshire Terrier, 3 Border Collies, 1 Cocker Spaniel, 1 Great Dane, 6 German Shepherds, 1 English Bulldog, 1 Flat Coated Retriever, 10 Golden Retriever, 1 Husky, 15 Labradors, 1 Magyar Vizsla, 1 Malinois, 16 Mixed breeds, 1 Portuguese Water Dog, 1 Rhodesian Ridgeback, 1 Schapendoes, 1 ShibaInu, 2 Tibet Terrier, 2 Weimaraner, 1 Welsh Terrier	33 Males (16 neutered) 39 Females (26 neutered)	Range: 1–10 Mean: 4.47
Experiment 2: Concealing auditory information	1 Airedale Terrier, 1 American Staffordshire Terrier, 1 Australian Cattle dog, 2 Australian Shepherds, 1 Beagle, 1 Berger des Pyrenees, 3 Border Collies, 1 Cocker Spaniel, 1 DogoCanario, 2 German Pinscher, 4 German Shepherds, 5 Golden Retriever, 1 Husky, 5 Labradors, 3 Magyar Vizsla, 5 Malinois, 20 Mixed breeds, 1 Parson Jack Russel Terrier, 1 Rottweiler, 1 Weimaraner	30 Males (10 neutered) 30 Females (18 neutered)	Range: 1–11 Mean: 4.05

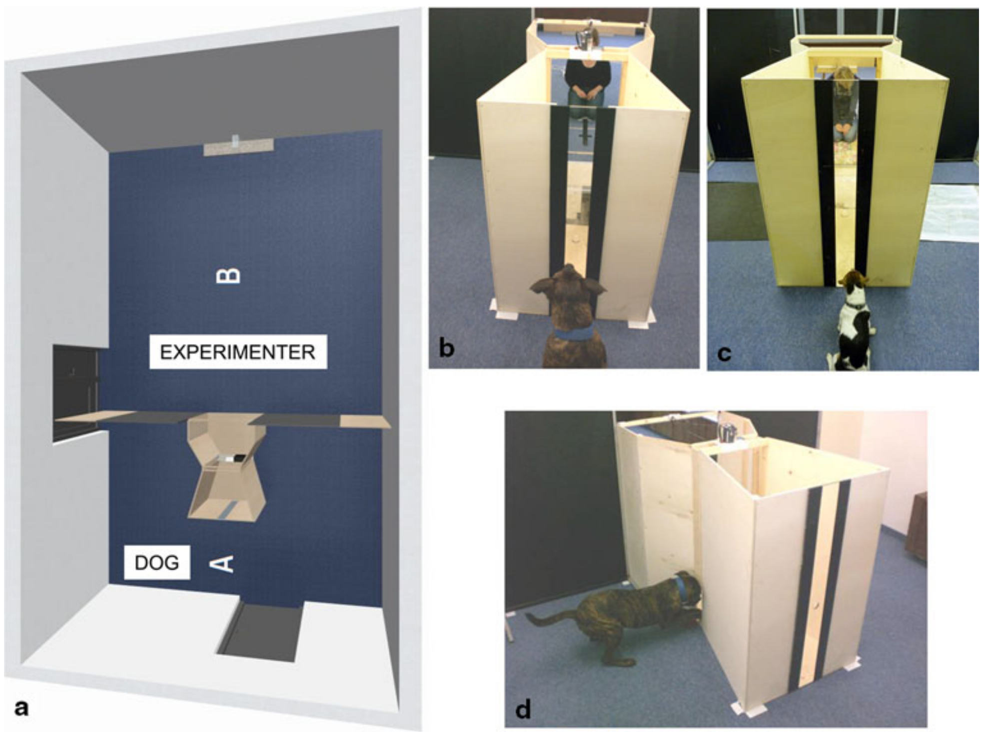

Fig. 1 Experimental setup: **a** plan view of the room and the apparatus, **b** apparatus from the view of the dog in Experiment 1, **c** apparatus from the view of the dog in Experiment 2, **d** approach to the tunnel

tunnel attached to the apparatus, the food was located in the middle and dogs could reach for it from both sides). Every trial the experimenter placed the food deeper in the tunnel so that the dog had to insert her paw further in order to get the food. This procedure was repeated until the experimenter could put the food at the very end of the tunnel close to the wall and the dog was able to get it. In every second training trial, the experimenter put the black cover on the tunnel so that the dog got used to it and did not develop a preference for the opaque or the transparent tunnel. Before the test trials began, each dog had to pass a pretest consisting of getting the food out of the training tunnel within 1 min, four times in a row. In addition to the training, dogs were allowed to explore the test apparatus, so that they could see it from every side. But prior to the test, they never had to retrieve food from the tunnel of the apparatus.

Test The experimenter entered the apparatus in part B of the testing room (see Fig. 1). Then, the dog was sent into part A of the room by a second person who then left the room and closed the door. At the beginning of each trial, the dog was called to the Plexiglas gap where the experimenter showed her/him a piece of food. The experimenter put the food into the tunnel while talking to the dog according to the condition (see below). Then, the experimenter sat on the predetermined place opposite the dog or left the room (Non-social Control). The dog now had the chance to get the food from the tunnel, either from the opaque or from the transparent side. The experimenter always looked straight ahead through the Plexiglas gap and did not react to the dog's behavior. After 1 min, the trial was over. The experimenter took the food from the tunnel if it was still there, and the dog was called out of the room by the second experimenter. The dogs were randomly assigned to one of the three conditions. Each dog was given one trial only.

Experimental condition (visual): While putting the food into the tunnel, the experimenter forbade the dog from taking the food ("Nein" or "Aus") and moved one meter backwards to the predetermined position.

Non-social control (visual): While putting the food into the tunnel, the experimenter forbade the dog from taking the food ("Nein" or "Aus") and then immediately left the room.

Motivation control (visual): While putting the food into the tunnel, the experimenter motivated the dog to take the food ("Hol Dir das Leckerli!") and moved one meter backwards to the predetermined position.

One side of the tunnel was always opaque (blocked by the black cover) and the other side transparent. The sides were alternated between dogs, so that in each condition for half of the dogs, the left side was opaque, and for the other half, the right side was opaque.

Scoring

All trials were scored from the videotapes. We coded two dependent measures: where and when the tunnel was approached. An approach was defined as the dog putting one part of the body (paw or nose, usually both) into the tunnel so that it was potentially visible to the experimenter. We coded:

(a) side of the first approach—whether the visible or the opaque side was approached (This also included a few unsuccessful reaches for the food.)
(b) latency to approach: latency from the moment the food was placed inside the tunnel until the dog first approached one side of it.

A second coder, blind to the experimental hypothesis, coded 20 % of the videotapes. All behaviors were scored perfectly reliably (side of the first approach: Cohen's Kappa = 1.0, $N = 20$, latency to approach: Spearman = 0.999, $N = 16$).

We concentrated in our analysis on the subjects that tried to take food from the apparatus during the trial. Note that from the dog's perspective, it is not "wrong" not to approach since the food is forbidden. 11 dogs were excluded from the analysis because they did not approach the tunnel at all: 4 in the Experimental Condition, 5 in the Non-social Control, 2 in the Motivation Control. We used Fisher's exact and Binominal test to compare between conditions and against chance, respectively. We used the Kruskal–Wallis and Mann–Whitney U tests to compare the latencies across conditions.

Results

Figure 2 presents the number of dogs who first approached the hidden or the visible side of the tunnel in the three conditions. There were no significant differences between conditions in the side approached (Fisher's exact test $P = 0.747$). Moreover, dogs showed no preference for the hidden tunnel in any of the conditions (Binominal test, $P > 0.424$ for all three conditions).

Overall, there were no significant differences between conditions in the latency to approach the tunnel (Kruskal–Wallis $\chi^2(2) = 4.63$; $P = 0.099$). Nonetheless, we compared the conditions and found that subjects approached the food faster when they were encouraged to take it than when the food was forbidden and the human stayed in the room (Mann–Whitney $U = 168.0$, $n1 = 21$, $n2 = 25$, $P = 0.037$).

Discussion

The dogs showed no preference for approaching the tunnel from the hidden side when the food was forbidden.

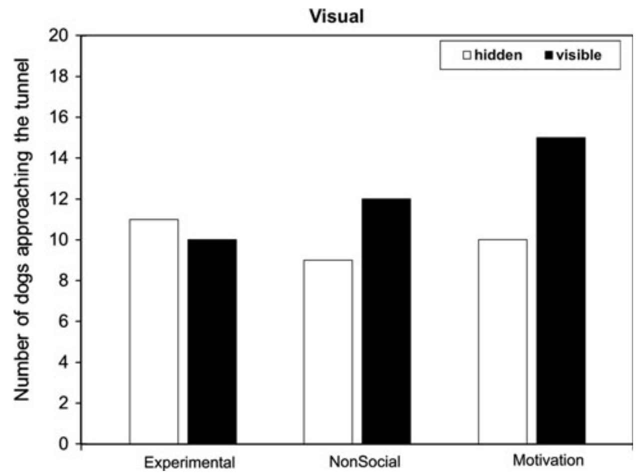

Fig. 2 The number of dogs approaching the hidden and the visible side of the tunnel in the three conditions of Experiment 1

This means that, unlike the chimpanzees tested by Melis et al. (2006), dogs did not conceal their approach to the forbidden food. These results provide no evidence that dogs can assess what humans can see independent of their own perspective, a result that is apparently at odds with some of the data reported in previous studies (e.g., Kaminski et al. 2009). In the following, we therefore analyze the various aspects of the current task in more detail. At the beginning of the trial, dogs have to *assess* what the human can and cannot see—in particular that the human cannot see into the opaque part of the tunnel. They also have to *understand* that this is the tunnel they are going to put their paw inside, although from the side of the apparatus, they can only see the entrance hole of the tunnel. Finally, they have to *remember* not only that the food is forbidden but also that the human is still there (in the experimental condition).

Kaminski et al. (2009) found that dogs were sensitive to human perspective even when it differed from their own. In that study, the dogs distinguished the toy the human could see from the one the human could not see, although the dogs themselves could see both toys. Thus, dogs might be able to assess from their starting point what the human can see. A number of studies have also shown that dogs are able to remember and obey a command that was given one minute ago (Call et al. 2003; Gácsi et al. 2004; Schwab and Huber 2006; Virányi et al. 2004). However, the crucial point in our study might be that the dogs could not see the human while they put their paws inside the tunnel. Dogs not only had to remember that the human was still there, but also to keep in memory that the experimenter was still looking at them and potentially seeing the paw in the transparent tunnel. It might be too challenging for a dog to remember what view the human had when the dog was at the starting point and to keep that in mind while they are taking the food. In fact, Kaminski et al. (2009) found no evidence that dogs knew what others have seen in the recent past. More specifically, dogs failed to differentiate between the two toys on the basis of whether or not the human had seen them. Kaminski et al. (2009) concluded that dogs may be unable to engage in perspective taking based on the memory of past events. It is possible that in the current study, dogs could not take into account what the human could see because there was a delay between visual cues at the starting point (where they could see the human and the tunnel) and the moment in which they put their paw into the tunnel.

However, it is also possible that dogs know what humans can see independently of their own egocentric view, but the setup of the experiment was too complicated for them. Dogs had to learn to use their paws to retrieve the food. From their starting point, they had to approach the food on the side of the apparatus. They had to understand that the holes on the sides of the apparatus lead into the tunnel, and they had to make a choice between the two parts of the tunnel. Thus, it is possible that dogs did not understand how the apparatus worked and therefore showed no preference for the opaque side of the tunnel.

In Experiment 2, we wanted to investigate whether dogs would conceal their approach to hidden food in the auditory modality. We used exactly the same method as in Experiment 1. Thus, we could also investigate whether dogs did not prefer the hidden tunnel in Experiment 1 because they were simply unable to cope with the setup. If dogs were sensitive to what humans can hear in the same setup, this would suggest that dogs' performance in the current experiment is not due to the challenging setup but to the fact that they do not understand what humans can see independent of their own egocentric view.

Experiment 2: Concealing auditory information

In Experiment 2, we investigated auditory perspective taking. Kundey et al. (2010) found that dogs prefer to eat food from a silent container when a human is not looking at them. Here, we used the setup of Experiment 1 so that dogs could not see the human while they reached for the food but added an auditory cue to one side of the tunnel. If dogs can take humans' auditory perspective, they should approach the forbidden food from the silent side of the tunnel. Moreover, if dogs show such a preference for the silent side, this would also indicate that dogs can cope with the complexities of the apparatus.

Methods

Subjects

Sixty-three dogs (32 females and 31 males) of various breeds and ages, who had not taken part in Experiment 1, participated in this experiment (see Table 1). A further 7 dogs had to be excluded because they showed signs of discomfort without the owner or did not pass the pretest. As in Experiment 1, the dogs were family dogs and were tested individually by one experimenter who was not the owner. Most of the dogs were familiar with the testing facilities as they had participated in other experiments about social cognition.

Materials

Materials were similar to the first experiment with two exceptions, see Fig. 1c: First, both sides of the tunnel in the apparatus were transparent. Second, two distinct mats (135 cm long $\times$ 81 cm wide) were used. They were placed in front of each side of the apparatus and extended into the tunnel (see shape of the mats in Fig. 1c). The dogs were able to see the mats from their starting position and had to walk over one to approach the food. One mat was white and produced a noise when the dogs walked over it because it was made of crinkly plastic foil (=noisy side). The other mat was black, it was a normal mat and produced no noise when the dogs walked over it (=silent side).

Procedure

Training and pretest were similar to Experiment 1 except that the training tunnel was transparent. Instead, the mats were put in front of, and inside, the tunnel (in the same way that they would later be put into the tunnel of the apparatus during the test.) After every training trial, the experimenter changed the mat so that each subject got experience with both mats. Additionally, there was an obedience task before the beginning of the test in which the experimenter made sure that the dog would not take the forbidden food on the floor for 30 s. This was to make sure that the dogs obeyed the command not to take the food.

The test procedure was similar to Experiment 1 except that when the experimenter stayed in the room, instead at looking through the Plexiglas gap she closed her eyes and oriented her face downwards. The dogs were randomly assigned to one of the three conditions and received a single trial.

Experimental condition (auditory): While putting the food into the tunnel, the experimenter forbade the dog to take the food ("Nein" or "Aus") and moved one meter backwards to the predetermined position, closed her eyes, and oriented her face downwards.

Non-social control (auditory): While putting the food into the tunnel, the experimenter forbade the dog to take the food ("Nein" or "Aus") and then immediately left the room.

Motivation control (auditory): While putting the food into the tunnel, the experimenter motivated the dog to take the food ("Hol"s Dir" or "Hier ist das Futter") and moved one meter backwards to the predetermined position, closed her eyes, and oriented her face downwards.

The side of the tunnel where the noisy mat was located was alternated between dogs, so that in each condition for half of the dogs, the left side was noisy and for the other half, the right side was noisy.

Scoring

Scoring was identical to Experiment 1. We coded the side of the first approach and the latency to approach. A second coder, blind to the experimental hypothesis, coded 20 % of the videotape. All behaviors were scored perfectly reliably (side of the first approach Cohen's Kappa = 1.0, $N = 12$, latency to approach: Spearman = 1.0, $N = 11$). Again, we restricted the analysis to the subjects that tried to take food from the apparatus during the trial, and therefore we had to exclude 13 dogs (6 in the Experimental Condition, 3 in the Non-social Control, and 4 in the Motivation Control). We used the same statistical analyses as in Experiment 1.

Results

Figure 3 presents the number of dogs who first approached the silent and the noisy part of the tunnel in the three conditions. There was a significant difference between conditions in approached side (Fisher's exact test $P = 0.033$). Moreover, dogs in the Experimental condition preferentially approached the silent tunnel (Binominal test, $P = 0.007$), whereas they showed no such preference in the other two conditions (Binominal test, Nonsocial Control $P = 1.000$, Motivation Control $P = 0.815$).

There were significant differences between conditions in the latency to approach the tunnel (Kruskal–Wallis $\chi^2_2(2) = 15.72$; $P < 0.001$). Subjects approached the food faster when they were encouraged to take it than when the food was forbidden (Motivation Control vs Experimental Condition, Mann–Whitney $U = 39.5$, $n1 = 15$, $n2 = 18$, $P < 0.001$) and the experimenter left the room (Motivation Control vs Nonsocial Condition, Mann–Whitney $U = 55.0$, $n1 = 17$, $n2 = 18$, $P = 0.001$). There was no difference in the latency to approach between the two conditions in which the food was forbidden (Mann–Whitney $U = 109.0$, $n1 = 15$, $n2 = 17$, $P = 0.484$).

Discussion

The dogs preferred to approach the forbidden food from the silent side of the tunnel. One might argue that the dogs just wanted to avoid walking on the crinkly mat and that is why

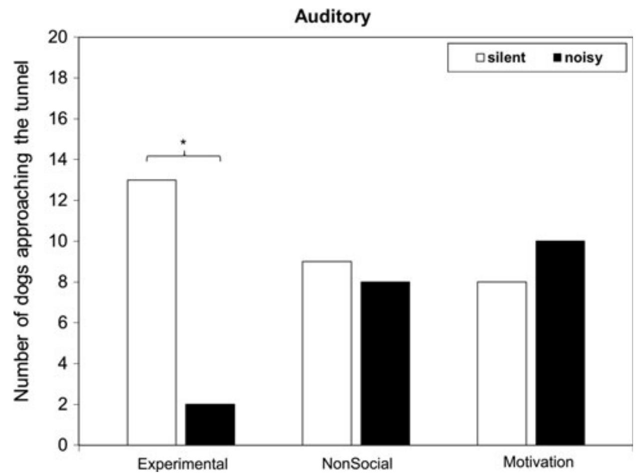

Fig. 3 The number of dogs approaching the silent and the noisy side of the tunnel in the three conditions of Experiment 2

they preferred to approach the side with the silent mat. However, the dogs did not prefer either side in the control conditions in which the food was not forbidden (Motivation Control) or when the human left the room (Non-social Control).

In accordance with the findings of Kundey et al. (2010), our results indicate that dogs can take into account what humans can hear. We showed that even with this challenging apparatus, dogs chose the silent tunnel. There were three main differences between the current study and the study of Kundey et al. (2010). First, in our study, the human forbade the dog to take the food. Second, we used the Motivation Control in which there was objectively no reason to prefer the silent tunnel because the experimenter allowed the dog to take the food; Kundey et al. (2010) used a Looking Condition in which the human saw the dog approaching the containers. And third, and most important, in the current study, dogs could *not* see the human while they took the forbidden food. But it is likely that they remembered that the human was there and behaved appropriately: they approached silently. Thus, we replicated and extended the findings of Kundey et al. (2010).

General discussion

When taking forbidden food from a tunnel, the dogs preferred to be silent, but not to be hidden. Compared to previous studies (Call et al. 2003; Gácsi et al. 2004; aKaminski et al. 2009; Schwab and Huber 2006; Virányi et al. 2004), dogs in the current task could not rely on what they themselves could see when attempting to take the food. To solve the current task, dogs had to infer that the human would see them, although they could not see the human. Unlike chimpanzees tested in this setup, dogs did not conceal their approach. Once the human was out of sight, they failed to take her perspective into account, thus suggesting that in visual perspective-taking tasks, dogs rely on an egocentric strategy "When I see the other, then the other sees me."

Interestingly, dogs could solve the task when it was presented in the auditory modality, that is, when they had to take into account that the human could hear, rather than see, their approach to the food. In that situation, they walked on the silent mat to get the forbidden food out of the tunnel. The question is why dogs could solve the problem in the auditory but not in the visual modality. One possible explanation for this difference is that the silent/noisy mats were more salient for the dogs than the opaque/transparent tubes. Moreover, hearing might be more important for dogs than vision, and therefore their appreciation of what others can and cannot hear can be deployed more flexibly. However, although dogs are able to hear ultrasound, and can localize sound sources more precisely than humans, they mainly rely on olfaction and not on hearing (Miklósi 2007, Chapter 6).

Another explanation may be based on the intrinsic differences between the way visual and auditory information is propagated. Whereas two subjects can have a completely different view–for example, when they stand opposite each other, both subjects will hear the same sound when they are in one room. The crucial point here is that while the dog is approaching the tunnel on the crinkly mat, s/he can hear it her/himself. Thus, in that moment, she can hear what the human can (and should not!) hear. In other words, she can use the egocentric strategy "When I hear the noise, then the other hears it." By contrast, in Experiment 1 in the moment when she puts her paw into the tunnel, she cannot see what the human can see. In this sense, the problem is easier to solve in the auditory compared to the visual modality.

Note also that the dogs produced and controlled the noise themselves. This was also the case in the studies and reports in which primates showed sensitivity to what others can hear: Chimpanzees and rhesus macaques avoided a noisy tunnel in an experimental competitive setup (Melis et al. 2006; Santos et al. 2006). Subordinate chimpanzees may suppress vocalizations in mating contexts (de Waal 1986) and refrain from producing food calls that might attract dominants when they encounter food resources that can be monopolized (Brosnan and de Waal 2003). Moreover, at the borders of their home ranges, chimpanzees avoid making noises that might alert their neighbors (Watts and Mitani 2001) and often remain silent more than they normally would when hunting for monkeys (Boesch and Boesch-Achermann 2000). Similarly, Western scrub jays (*Aphelocoma californica*) reduced auditory information during caching by avoiding a noisy tray to reduce the chances of cache theft by conspecifics (Stulp et al. 2009). In all these studies, subjects could control whether or not they themselves produced a noise. In contrast, when the noise is produced by someone else even chimpanzees fail to take into account what others can hear. Bräuer et al. (2008) tested pairs of chimpanzees competing over two pieces of food. One piece of food was hidden by the experimenter in a very noisy manner, the other was hidden silently. Previous studies have shown that subordinate chimpanzees avoided the piece of food that the dominant could see (Bräuer et al. 2007; Hare et al. 2000).

In contrast, Bräuer et al. (2008) found that chimpanzees did not avoid the food piece that was placed with a noise, although they were able to locate the hiding place using the noise. The authors suggested that producing the noise, as opposed to hearing the noise, may have substantially simplified the problem. Subjects may have learnt the consequences of making sounds in certain situations, while lacking a full understanding of what others can hear.

This could also be the case for domestic dogs. During their life with humans, dogs have the opportunity to learn to be silent when doing something forbidden. Moreover, there could even be a predisposition to be silent in critical situations for carnivores, but also for prey species. For example, dogs' ancestors, wolves, try not to be detected when stalking prey (Peterson and Ciucci 2003). The interesting finding in our study is that the dogs did not just prefer to be silent when they approached the forbidden food, but that they distinguished between a situation in which the human could hear them and a situation in which the human was absent and therefore could not hear them. This suggests that dogs do not simply use strategies such as approaching forbidden food silently but that their sensitivity to what humans can hear is flexible. However, it is possible that they have learned over the course of their experiences with humans to approach forbidden food silently only in cases when a human is in the room.

In conclusion, dogs prefer a silent approach to forbidden food but they do not hide their approach when they cannot see a human present. It is likely that dogs rely on what they themselves can perceive when they assess what the human can see and hear. Thus, they prefer the silent approach because in that moment, they hear what the human can hear. It is conceivable that this sensitivity to what others can hear is widespread in the animal kingdom. Future studies about perspective taking should also take into account which modality is important in which situation.

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Conflict of interest We declare that the experiments comply with the current laws of Germany. We also declare that we have no conflict of interest.

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