

Domestic dogs are sensitive to a human's perspective

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Summary

We investigated dogs' ability to take the visual perspective of humans. In the main study, each of two toys was placed on the dog's side of two small barriers (one opaque, one transparent). In experimental conditions, a human sat on the opposite side of the barriers, such that she could see only the toy behind the transparent barrier. The experimenter then told the dog to 'Bring it here!' (without designating either toy in any way). In the Back Turned control *E* also sat on the opposite side but with her back turned so that she could see neither toy, and in the Same Side control she sat on the same side as the dog such that she could see both toys. When toys were differentiable dogs approached the toy behind the transparent barrier in experimental as compared to back turned and same side condition. Dogs did not differentiate between the two control conditions. In a second study dogs were not sensitive to what a human had or had not seen in the immediate past. These results suggest that, even in the absence of overt behavioural cues, dogs are sensitive to others visual access, even if that differs from their own.

Keywords: dogs, perspective taking, social cognition.

Introduction

Recent studies have shown that dogs, most likely as a result of domestication, possess special abilities to read human given communicative signals (Hare et al., 1998; Miklosi et al., 1998; Agnetta et al., 2000). Each study

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set up situations in which a human hid food in one of several distinct locations and then gave a communicative cue to the dog to indicate where the food was hidden. In this setting dogs display great skills in reading human social-communicative signals such as pointing and eye gaze direction etc. Evidence that these skills are indeed special and probably restricted to the social domain comes from four additional facts. First, even humans' closest primate relatives have severe difficulties in most versions of this so-called object choice task. In about a dozen different studies, from several different laboratories, chimpanzees and other ape individuals without training are very seldom above chance in using any of these social cues to find hidden food (Call & Tomasello, 2005). Indeed, in direct comparisons in the object choice paradigm, dogs outperform apes in reading human social cues (Bräuer et al., 2006; Hare et al., 2002). Second, Miklosi et al. (2003) and Hare et al. (2002) both found that dogs are much more skilful at reading human social cues than are wolves. Miklosi et al. (2003) hand raised dogs and wolf puppies under identical conditions and still, if tested at four month of age, dogs readily followed the communicative cues, while wolves did not (but see Frank & Frank, 1985 for evidence that wolves are more successful in problem solving tasks). Third, dog puppies, with hardly any human contact and from a very early age on readily used human communicative cues (Hare et al., 2002), even if these are directed to a location behind them (Riedel et al., 2008). Fourth and finally, when dogs are compared with chimpanzees in various non-social cognitive tasks (e.g., understanding causal relations), they show no special skills (Osthaus et al., 2005; Bräuer et al., 2006). This suggests that dogs' ability to read human social cues is a relatively focused adaptive specialization that comes not from their evolutionary history as canids, or from their individual experiences with humans, but rather it is a recent evolutionary response to selection pressures during the domestication process within human cultures.

Previous studies have also shown that, besides reading certain communicative signals, dogs are also sensitive to humans' attention. Call et al. (2003) showed that dogs who were forbidden by a human to take a piece of food refrained from taking it when the human was watching, but took it when the adult turned her back, closed her eyes, or was distracted with other activities. The same sensitivity to a human's attention is also expressed in a more cooperative situation in which a dog had to decide who to beg from. Dogs in this study differentiated a person whose eyes were covered with a blindfold

from a person whose eyes were not covered but who wore a blindfold over her forehead (Gacsi et al., 2004). However, dogs' sensitivity in all these situations could be due to the presence of certain stimuli (e.g., the eyes) rather than dogs' sensitivity to humans' perspective (Call et al., 2003). Bräuer et al. (2004), therefore, conducted a study in which dogs' decision would not be based on the sheer presence of certain stimuli but rather on dogs' sensitivity to a human's visual access to a forbidden piece of food. In this study dogs distinguished when a barrier was effective or ineffective in obstructing a human's vision. However, another alternative is possible. Dogs' behaviour may have been based on sensitivity to other stimuli (e.g., seeing body parts of the human) instead of dogs' understanding of the human's visual access to the food. In the current study we investigated whether dogs could take the visual perspective of a human when that differed from their own perspective and that could not be explained as simply reading communicative signals or knowing when the self is being watched by other eyes. More specifically, a human asked the dog, ambiguously, to 'Bring it here!' in the presence of two toys on the dog's side of two barriers, giving no overt behavioural or communicative cues toward either toy. The trick was that the human could see only one of the toys from her perspective, since one barrier was opaque and the other barrier was transparent. If dogs develop a preference for one toy over the other based on the human's visual access to the toy, it would demonstrate more than an ability to read and respond to social cues; it may be evidence that dogs are sensitive to a human's visual perspective.

Pretest

Whereas many dogs fetch moving objects, it turns out that fetching a stationary object is relatively rare, especially when the human does not designate it explicitly in any way. We, therefore, conducted a pretest to identify dogs that would reliably fetch a toy without *E* looking or pointing at it. This pretest also served to determine whether dogs were equally interested in all toys provided during the experiment. Dogs that did not reliably fetch every type of toy were excluded from the study.

Testing took place in a quiet room (8.5 m × 4 m). During the pretest all toys which were later used in the study were presented. Toys were two identical balls as well as one ring-like toy and one egg-like toy. During the pretest each type of toy was tested twice. To avoid establishing a preference for any one

of the different toys we presented only one toy per trial during this pretest. At the beginning of each trial E_2 led the dog to a predetermined spot and E_1 sat on a chair opposite to the dog and called it to attention. Then while looking at the dog but without looking or pointing to the toy in any way, she gave the command to fetch the toy (in German: 'Bring's her!'). After the dog successfully retrieved the toy to E_1 , she rewarded the dog with play. The pretest was deemed successful for an individual dog if it retrieved the toy reliably in all 6 trials (2 trials per toy), in which case it became a subject in the study. Fifty three out of 106 dogs tested in the pretest were accepted into the study. Out of these 53 dogs six had to be later excluded because they refused to participate after the actual experiment had started.

Experiment 1

Methods

Subjects

Forty seven dogs of various breeds and ages (see Table 1) participated in this study. All subjects had been living as pets with their owner, and so they had received the normal obedience training typical for domestic dogs. The dog owners were not present during the test except for one and were not informed about the design and the purpose of the study before it started. Subjects were tested individually.

Materials and design

Testing took place in the same room as the pretest. Two small barriers (65×40 cm) were placed on specified locations in the middle of the room at a distance of 1.20 m between them. One of the barriers was opaque, the other transparent (placement left and right was pseudo-randomized and counter-balanced, but with no more than two trials in a row of the same type). The toys were the same toys that had been used during the pretest.

The design was between subjects, with 16 dogs in the Experimental and the Back Turned Conditions, and 15 dogs in the Control Condition (see below). For each trial in each condition, each of two toys was placed on the dog's side of each barrier. In half the trials the two toys were identical (two balls), and in the other half the two toys were similar but different (the

Table 1. Name, breed, gender and age of the participating dog subjects as well as condition in which each dog participated.

Subject	Breed	Gender	Age (years)	Condition
Freddy	Mongrel (Pinscher and Jack Russell Terrier)	Male*	3	Experimental
Lowis	German Shepherd	Female	1.5	Experimental
Pauline	Portuguese Water Dog	Female	3	Experimental
Mora	Mongrel (German Shepherd and Mongrel Mix)	Female	6	Experimental
Bora	Labrador Retriever	Female	2	Experimental
Falco	Mongrel (Afghan Hound and Mongrel Mix)	Male	10	Experimental
Lea	Mongrel (German Shepherd and Rottweiler)	Female	4.5	Experimental
Fanny	Mongrel (Rottweiler and Mongrel Mix)	Female	7	Experimental
Sydney	Border Collie	Female	3.5	Experimental
Asta	Fox Terrier	Female	4	Experimental
Biene	Labrador Retriever	Female	1	Experimental
Skotty	Mongrel	Male*	9	Experimental
Emma	Labrador Retriever	Female*	5	Experimental
Alexa	Mongrel (German Shepherd and Belgian Shepherd)	Female*	7	Experimental
Fara	Mongrel (German Shepherd and Border Collie)	Female*	5	Experimental
Balou	Mongrel (Labrador and Border Collie)			Experimental
Apollo	Border Collie	Male	5	Back Turned
Marco	Mongrel (German Shepherd and unknown)	Male*	Unknown	Back Turned
Tony	Mongrel (Labrador Retriever and Mongrel)	Male	4	Back Turned
Cocco	Labrador Retriever	Female	4	Back Turned
Cora	Mongrel (Doberman and unknown)	Female	6	Back Turned
Caspar	Mongrel (German Shepherd and Doberman)	Male*	3	Back Turned
Yara	Airedale Terrier	Female*	2	Back Turned
Emily	Labrador Retriever	Female	1.5	Back Turned
Karah	Labrador Retriever	Female	1.5	Back Turned
Hugo	Mongrel (Rottweiler and Schnauzer)	Male*	7.5	Back Turned
Draxi	Hovavart	Female	1.5	Back Turned
Wilma	Mongrel (German Shepherd and unknown)	Female	1	Back Turned
Benny	Golden Retriever	Male	2.5	Back Turned

Table 1. (Continued.)

Subject	Breed	Gender	Age (years)	Condition
Cherry	Mongrel	Female	4	Back Turned
Bessie	Mongrel (German Shepherd and unknown)	Female	7	Back Turned
Trulla	Border Collie	Female	1	Back Turned
Henry	Jack Russell Terrier	Male	3	Same Side
Emma	Mongrel (German Shepherd and Golden Retriever)	Female	2	Same Side
Bessy	Doberman	Female*	3	Same Side
Wilma	Labrador Retriever	Female	5	Same Side
Pine	Deutsch Kurzhaar	Female*	4	Same Side
Rocky	Mongrel (American Staffordshire Terrier and Boxer)	Male*	6	Same Side
Vincent	Labrador Retriever	Male	3	Same Side
Auguste	Mongrel (German Shepherd and Border Collie)	Female	3	Same Side
Ronja	Golden Retriever	Female*	7	Study 2 Same Side
Aron	Mongrel (Labrador Retriever and unknown)	Male	4.5	Study 2 Same Side
Artos	Labrador Retriever	Male	2	Study 2 Same Side
Rick	German Shepherd	Male	7	Study 2 Same Side
Bones	German Shepherd	Male*	4	Study 2 Same Side
Cara	Labrador Retriever	Female	2	Study 2 Same Side
Gargamel	Mongrel (German Shepherd and unknown)	Male	8	Study 2 Same Side
Paul	Mongrel (Harzer Fuchs and Collie)	Male	4	Study 2
Timo	Mongrel (German Shepherd and Rotweiler)	Male	7	Study 2

* Castrated.

ring-like toy and the egg-like toy; order of trial types random, but with no more than two trials in a row of the same type). We followed this procedure because we hypothesized that dogs' performance with two different toys might be influenced by pre-existing preferences, whereas their performance with two identical toys might be non-differential due to a supposition that it did not matter which one was retrieved.

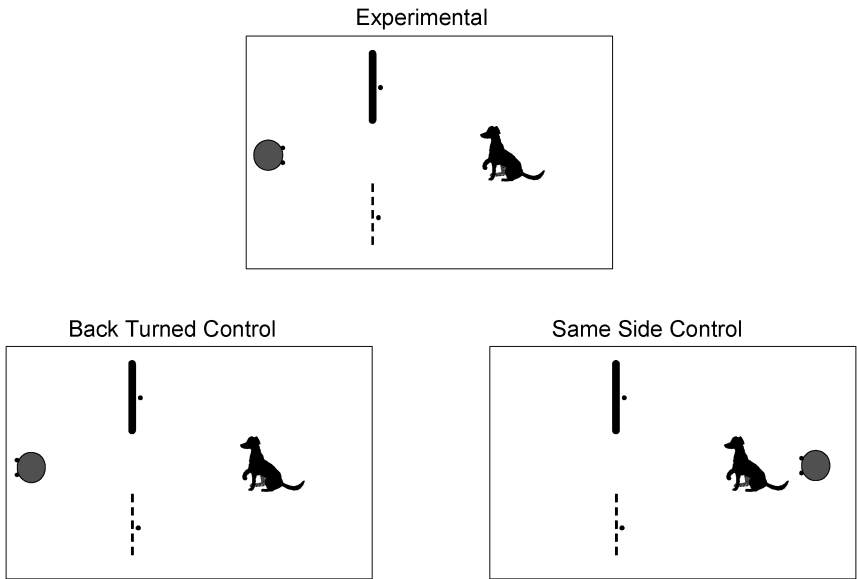


Figure 1. General setting of the three conditions: Experimental, Back Turned Control and Same Side Control.

Procedure

Each dog received a single session with 8 trials. For each trial, the dog was led by E_2 to a predetermined point from which it could see both toys and was equidistant to them (3.10 m). E_1 sat on a chair, also equidistant to both toys. The dogs could always see both toys whereas E_1 's visual access to the toys depended on condition (see Figure 1). In the experimental condition E_1 's visual access was restricted to one toy whereas in the control conditions E_1 could see either both toys or neither toy.

The trial started when both E_1 and the dog were on their predetermined positions. E_1 then called the dog's attention by calling its name and told the dog to fetch (in German 'Brings her') without looking or pointing at either of the two toys. To avoid gazing at one of the toys, E_1 looked at predetermined spot at the opposite wall behind the dog. If the dog did not fetch immediately, E_1 repeated the command and called the dog again. After the dog successfully retrieved a toy she/he was rewarded with play. She/he was praised independently of which toy was fetched. The dogs were randomly assigned to one of the three conditions:

'Experimental': E_2 waited with the dog outside the testing room while E_1 arranged the setup of the barriers and the two toys. E_1 then sat on the opposite side of the barriers, such that she could see only the toy behind the transparent barrier — and looked at the predetermined spot on the opposite wall. E_2 then entered the room with the dog and led him/her to the starting position. E_1 then gave the command to fetch the toy. E_2 stood still until the dog had made its choice. If the dogs were sensitive to E_1 's visual access, dogs should preferably fetch the toy that the human could see, i.e., the toy behind the transparent barrier.

'Same Side': E_1 waited with the dog outside the testing room while E_2 arranged the setup of the barriers and the two toys. E_1 then entered the room with the dog and sat on a chair right behind the dog's predetermined location. Therefore, E_1 , like the dog could see both of the toys, just as the dog. E_1 then gave the command to fetch the toy. This condition assessed whether subjects preferred the toy next to the transparent barrier independently of E_1 's visual access.

'Back Turned': The procedure of this condition was identical to the Experimental condition, except that E_1 sat on the chair with her back turned to the dog and the toys, and so could not see either of them. E_1 then gave the command to fetch the toy. Dogs, just like in the same side condition, should not necessarily bring one toy over the other as E_1 had visual access to none. However, this control condition was perhaps somewhat ambiguous as it required the dog (i) to understand that E_1 could not see either toy from the corner of her eye, and further (ii) to be confident that E_1 had not previously been facing the toys from her current position (and so had seen them a moment before).

Scoring

All trials were videotaped and analyzed subsequently by the first author. We scored the first toy approached up to approx. 10 cm without touching it (Approach). A second coder, unaware of the purpose of the study, coded 20% of the material for reliability. Reliability was scored excellent (Cohen's Kappa = 0.97, $N = 76$). In addition to the approach measure we also initially scored the first toy taken in mouth (Take) and the first toy the dog brought back to E_1 such that E_1 could get hold of it (Bring) which were often the same toy but not always. However, in trials in which both toys

were identical, some of the dogs in some trials repeatedly reconsidered their choices such that it was either impossible to code which toy the dog finally brought or the final choice could not be considered deliberate. In trials in which toys were different, dogs developed a strong preference to fetch the egg-shaped over the ring-shaped toy. We, therefore, focused on the approach measure as it was very little affected by these difficulties.

One dog received one more trial in the different than in the same condition, and so we calculated percentages. To make sure that the human gave no inadvertent cues, a coder naive to purpose of the study and blind to the position of the barriers watched the videotape of the experimenter's behaviour 20% of the trials and attempted to guess the direction of the transparent barrier in the Experimental condition, and the opaque barrier in the Same Side and the Back Turned Condition. She was not able to do this at above chance levels ($N = 76$, Cohens's Kappa = 0.003, NS).

We also took a closer look at the experimenter's behaviour throughout trials ($N = 232$) from a subset of dog subjects to see whether she would for instance praise the dog or call the dogs' attention more or less depending on the dogs' behaviour. We scored two different utterances from the human (i) number of times the human told the dog to fetch ('bring's') and (ii) number of times the human praised the dog (e.g., 'fein gemacht'). We analyzed the mean number of utterances depending on whether the dog approached the toy next to the transparent or opaque barrier and conducted several ANOVAs comparing the three groups of dogs and looking at the number of utterances of the experimenter in the trials in which the dog went for one toy or the other. None of the ANOVAs conducted produced any significant effect.

Results

For analyses we focused on the mean percent of trials in which dogs approached the visible toy. An ANOVA with the within-factor type of toy used (identical vs. different) and the between-factor condition revealed that type of toy had no effect on the behaviour of the dogs ($F_{1,44} = 0.024$, $p = 0.88$) irrespective of condition ($F_{2,44} = 0.348$, $p = 0.71$). However, condition had an effect on the behaviour of the dogs ($F_{2,44} = 5.908$, $p = 0.005$). Post-hoc pairwise comparisons showed that dogs preferred approaching the toy next to the transparent barrier more in the Experimental than in the

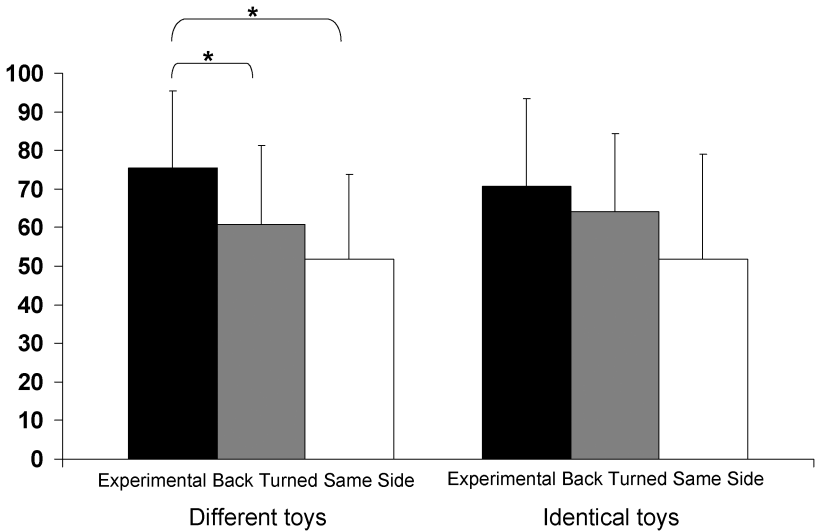


Figure 2. Mean percentage of trials the dogs approached the toy next to the transparent barrier as a function of type of toy in Experimental, Back Turned Control and Same Side Control trials.

Same Side Control condition ($p = 0.001$). However, dogs showed a marked preference for the egg-shaped toy in trials with two different toys (one-sample $t_{46} = 4.37$, $p < 0.0001$, mean = 68%) irrespective of condition ($F_{2,46} = 0.09$, $p = 0.914$). Since this intrinsic preference for one of the toys may have biased the results, we analyzed both types of trials separately (see Figure 2).

Figure 2 presents the mean percent of trials in which dogs approached the visible toy as a function of the type of toy. A one-way ANOVA on the different toy condition showed that experimental condition had an effect on dogs' choice ($F_{2,46} = 5.294$, $p = 0.009$). Post-hoc comparisons between the conditions showed that dogs approached the toy next to the transparent barrier more often in the Experimental condition than in the Same Side Control condition ($p = 0.002$). Also dogs tended to approach the toy next to the transparent barrier more often in the Experimental condition than in the Back Turned Control condition ($p = 0.051$). One-sample t -tests against chance (50%) revealed that dogs approached the toy next to the transparent barrier in the Experimental ($t_{15} = 5.19$, $p < 0.001$) and the Back Turned Control condition ($t_{15} = 2.15$, $p = 0.048$) but not in the Same Side Control condition ($t_{14} = 0.29$, $p = 0.77$).

A one-way ANOVA on the identical toy condition showed that dogs did not differentiate between conditions in their approach towards the toy ($F_{2,46} = 2.55, p = 0.09$). One-sample t -tests against chance (50%) revealed that dogs approached the toy next to the transparent barrier in the Experimental ($t_{15} = 3.61, p = 0.003$) and the Back Turned Control condition ($t_{15} = 2.76, p = 0.014$) but not in the Same Side Control condition ($t_{14} = 0.235, p = 0.82$).

Discussion

Dogs showed behavioural strategies which are best explained with an existent sensitivity to the humans' visual access to the toys. Overall, the dogs seem to have a strong tendency to approach the toy next to the transparent barrier. However, they approached that toy more in the condition in which the human had exclusive visual access to it than when the human could not see either of the toys (back turned condition) or both toys equally well (same side control). These results together with findings from other studies support the idea that dogs are sensitive to a human's visual perspective. Dogs showed this strategy more clearly when toys were different than when they were identical. This may be because in trials in which the toys were identical the human's command to 'fetch' may be more ambiguous, because dogs may not have understood the experimenter watched one toy specifically. In this respect it is also interesting that in the condition in which both toys were identical dogs had a strong tendency to fetch both toys simultaneously.

Previous studies have shown that dogs can determine when a human is or is not attentive (Call et al., 2003; Viranyi et al., 2004) or does and does not have visual access to food (Bräuer et al., 2004). Dogs are also sensitive to gaze direction in a variety of communicative situations (Hare et al., 1998; Miklosi et al., 1998; Hare & Tomasello, 1999). However, in all of these studies it is not clear whether the dogs' behaviour was based on an appreciating of the human's visual access or mainly on dogs' sensitivity to certain stimuli (e.g., eyes) or behavioural cues (but see Bräuer et al., 2004). In contrast, in the current study dogs were given no overt cues whatsoever indicating the human's line of sight (and the absence of cues was confirmed by coding of E_1 's behaviour), but rather to make their choice between both toys they had to determine which toys the human had or had no visual access to — when that differed from what they had visual access to.

One alternative interpretation is that dogs preferred the transparent barrier simply because they wanted to sustain visual contact with the human and, in particular, with the human's eyes while fetching the toy (even though they were not directed at them). However, there are certain factors which make this explanation of the dogs' behaviour unsatisfactory. Dogs made their choice mainly after first hearing the command to fetch. As the barriers were relatively small and fairly distant from the dogs, they could see the human (and her eyes) equally well, regardless of the barrier they approached. The only moment when dogs may have potentially lost visual contact with the human was while bending down to take the toy behind the opaque barrier. Thus, if sustaining visual contact to the human was the dogs' only motivation, this would mean that they planned their route ahead accordingly, which would be a cognitively quite demanding task. Moreover, if tracking the position of the human was the critical feature, it is unclear why there was no difference between the back turned control condition and the same side control condition. However, future research is needed to further address questions regarding the underlying mechanisms.

Dogs' sensitivity to a human's perspective even when that differs from their own compares favorably with similar abilities displayed by chimpanzees in a different, competitive experimental paradigm (Hare et al., 2000, 2001; Bräuer et al., 2007). In those studies chimpanzee subordinates selectively pursued pieces of food that a dominant competitor could not see, sometimes in situations in which they could not see the competitor's line of sight specifically. However, in a competitive situation, chimpanzees are able to determine not only what a competitor does and does not see, but also what he has and has not seen in the immediate past. Specifically, Hare et al. (2001) found that subordinate chimpanzees avoided food a dominant chimpanzee could not see (which they normally would pursue), if the dominant had witnessed the hiding process a few moments before (and so 'knew' it was there). In the next study we investigated this to see if dogs understand what a human experimenter has seen in the past when it is assessed in this more cooperative/communicative setting.

Experiment 2

In this study we used the basic paradigm of study 1 except that there were two opaque barriers. The dog watched while the experimenter witnessed one toy

being placed behind its barrier, but the experimenter was out of the room for the placing of the second toy (order and side counterbalanced). Thus, from her side of the barriers the human could see neither toy — but she knew of one's (and only one's) existence from her previous observations. *E* then told the dog to 'Bring it here!'.

Methods

Subjects

Eight dogs of various breeds and ages, some of whom participated in Study 1 (see Table 1), participated in this study. All subjects had been living as pets with their owners and had received the normal obedience training typical for domestic dogs. Dog owners were not present during testing and were not informed about the design and the purpose of the study beforehand. Subjects were tested individually with one or two experimenters present depending on experimental condition.

Procedure

Materials and procedure were similar as in Study 1, with the exception that both barriers used were opaque. E_1 sat opposite to the dog in each trial like in the Experimental condition of Experiment 1 (see Figure 1). She could not see any of the toys but had witnessed the placement of one of the two toys.

When the trial started, E_1 sat on the chair whereas E_2 stood close to the dog that was fixed by a leash at his predetermined position on the opposite side of the barrier. Depending on whether E_1 witnessed the first or the second toy being placed, the course of event was slightly different.

'Witness First': E_1 remained seated witnessing E_2 placing the first toy behind one of the two barriers in full view of the dog and E_1 . After that E_1 left the room while E_2 placed the second toy behind the other barrier again in full view of the dog. After that E_1 entered the room again, without being able to see any of the toys behind the barriers. E_1 sat down on the chair and looked at a predetermined spot on the opposite wall. She then gave the command to fetch the toy. Thus, if the dogs were sensitive to what E_1 had seen, upon hearing the command to fetch they should preferably fetch the toy that E_1 had witnessed being placed, i.e., the toy that had been placed first.

'Witness Second': E_1 left the room while E_2 in full view of the dog placed the first toy behind the barrier. Then E_2 went back to the dog while E_1 entered the room, without being able to see the toy behind the barrier. E_1 remained seated while now E_2 placed the second toy behind the other barrier in full view of the dog and E_1 . Then E_2 went back to the dog while E_1 looked at a predetermined spot on the opposite wall and gave the dog the command to fetch the toy. Thus, if the dogs were sensitive to what E_1 had seen, upon hearing the command to fetch the dogs should preferably fetch the toy that E_1 had witnessed being placed, i.e., the toy that was placed second.

The behaviour of E_2 while placing the two toys was identical and independent from whether or not E_1 was watching. Also when E_2 placed the toys she was not looking at the dog at any time. As in Experiment 1 the dog was rewarded with play when she/he successfully retrieved a toy to E_1 . Importantly she/he was praised independently of which toy was fetched.

Each dog received 8 trials, 4 times E_1 witnessed the first being placed and 4 times E_1 witnessed the second being placed. In half of the trials the toys were identical and in the other half they were different. The positions of the toy which E_1 had witnessed (left or right) were counterbalanced across trials. All trials were videotaped and analyzed subsequently by the first author in basically the same way as Study 1. As before we focused our analyses on the first toy dogs approached.

Results

The subjects did not show a preference to approach one toy over the other if all trials are combined and approaches to witnessed and un-witnessed are compared (paired-sample t -test: $t_7 = 1.97$, $p = 0.197$, mean number of trials dogs approached the toy the human witnessed being placed = 3.63). If conditions are analyzed separately, dogs also did not show any preference if the toys were identical (paired-sample t -test: $t_7 = 1.87$, $p = 0.104$, mean number of trials dogs approached the toy the human witnessed being placed = 1.5) or different (paired-sample t -test: $t_7 = 1$, $p = 0.351$, mean number of trials dogs approached the toy the human witnessed being placed = 2.13).

Discussion

In contrast with chimpanzees in a competitive paradigm (Hare et al., 2001), dogs in the current study did not take into account what a human had seen in the immediate past. The dogs in the current study, thus, did not show any differentiation between the two toys on the basis of whether or not the human had seen them being placed at a certain location. This could reflect the fact that the general course of events in the experiment, with the human coming and going from the room, was too complex for the dogs and that they could not follow the general procedure. But just as likely it reflects a true inability to understand visual perception based on past events, either because they do not understand that seeing leads to knowing, or that they do not understand a connection between a 'fetch!' command and a human's knowledge (as opposed to perceptual) states. Our results are at odds with a recent study in which dogs indicated the location of a hidden toy more often if the human who could retrieve the toy was uninformed about its location than when she was informed (Viranyi et al., 2006). However, in this study the knowledge of the human was established by her being present during the hiding of the toy the entire time or her being absent and reentering after the toy had been placed. It is conceivable that dogs' behaviour in this study reflected their different levels of arousal rather than being evidence for understanding of past visual access.

Interestingly and importantly, the fact that dogs in this study did not prefer one toy over the other provides further evidence that the results from Study 1 (along with blind scoring of E_1 's behaviour in that study) were not due to inadvertent cues the experimenter was giving at the moment of telling the dog to 'fetch!'. If such cues were present and effective, the dogs should have been successful in the current study as well.

General discussion

Recent research has established that many non-primate species are sensitive to what others see, either by following gaze direction or knowing when they are being watched (ravens: Heinrich & Pepper, 1998; Bugnyar et al., 2004; scrub jays: Emery & Clayton, 2001; goats: Kaminski et al., 2005) — in some cases even using gaze direction and/or gestures as communicative cues (goats: Kaminski et al., 2005; seals: Scheumann & Call, 2004; dolphins:

Tschudin et al., 2001). Dogs have been shown to be particularly sensitive to human cues of attention in competitive (Call et al., 2003; Bräuer et al., 2004; Schwab & Huber, 2006) as well as in cooperative/communicative contexts (Hare et al., 2002; Miklosi et al., 2003). The current study gives further evidence however, that dogs' sensitivity may go beyond reading overt cues. This has interesting implications in terms of the evolution of visual perspective taking. Just recently it was found that goats tested in a similar experimental paradigm as the chimpanzees also maximized their food uptake by exploiting another individual's visual access to food. However, the behaviour of the goats depended on the level of intra-group competition. While subordinate goats from a group with high intra-group competition preferably approached the piece of food hidden from their competitor, goats from groups with relaxed intra-group competition did the opposite. These goats preferred the 'at risk' piece of food which was the piece visible to the competitor (Kaminski et al., 2006).

Several species have been shown to be sensitive to cues of human attention. Some of those data may be best explained by seeing the eyes as an aversive stimulus (black iguanas, *Ctenosaura similes*: Burger et al., 1992; hognose snakes *Heterodon platirhinos*: Burghardt & Greene, 1990) while other data supports the idea that animals are sensitive to others' attentional focus (ravens, *Corvus corax*: Bugnyar et al., 2004; bottlenose dolphins, *Tursiops truncatus*: Tschudin et al., 2001; Xitco et al., 2004). Moreover, various corvid species, like chimpanzees, are sensitive to others' current (Emery & Clayton, 2001; Bugnyar et al., 2004; Dally et al., 2004), and past visual access to events (Dally et al., 2006). If distantly related species show comparable skills (but see Hare et al., 2003) this may be evidence that a phenomenon is more widespread than formerly thought and it may represent a skill that evolved quite early. However, an alternative hypothesis and more likely explanation would be that the same mechanism is not involved for all species and are the result of convergent evolution (Emery & Clayton, 2004). In this regard it is perhaps important that the dogs in the current study failed in the second experiment. Chimpanzees are successful in a similar task (Hare et al., 2001), and human children seem to possess the relevant skills from around the middle of the second year of life (Moll & Tomasello, 2004). This suggests the possibility that dogs are skillful in the first study for different reasons than apes and humans. Apes and humans may understand the visual perspective of others in analogy with their own perspective, which enables

them to quite readily transfer to the immediate past and, thus, to know that seeing leads to knowing. Dogs, and probably also goats, may interpret the situation in some other, externalist way that does not enable or require this transfer. It is conceivable that dogs in this study may be using an egocentric strategy based on maximizing the opportunities for tracking the human as opposed to an allocentric strategy based on tracking the attentional relation between the human and the toy. This hypothesis predicts that the dogs' behaviour would be based on the perception of certain stimuli (e.g., the eyes) rather than on the comprehension of the attentional state of humans. Future research is needed to determine the strategy that underlies dogs' behaviour in these situations.

Another possibility that could explain the dogs' failure in study 2 is that such tasks require subjects to understand some causal relation between the human's past visual experience and the 'fetch' command — and dogs do not make this causal connection. At least some evidence for this hypothesis comes from studies showing that dogs' understanding of causal relations in general is not nearly as sophisticated as that of apes and humans (Osthaus et al., 2003, 2005; Bräuer et al., 2006). However, dogs' sensitivity to humans' current visual perception is at least flexible as dogs do seem to adjust their behaviour to the context. While in competitive contexts they avoid being seen and prefer to be hidden by a barrier when approaching a piece of food (Bräuer et al., 2004), in this more cooperative paradigm they would change their strategy and upon hearing the command to fetch would actually approach the toy *not* hidden by the opaque barrier as this is the one the human does have visual access to.

Another hypothesis would be, that domestication may have enhanced the development of special skills in dogs which are expressed especially in cooperative/communicative contexts (Hare & Tomasello, 2005). It is interesting that virtually all of the animals who effectively use human gaze direction as a communicative signal come from domesticated species, or else they have had extensive interaction with and/or training from humans (e.g., the seals and dolphins in zoo shows for the public). In addition dogs have been shown to be in general more sensitive to the human eyes than other species (Call et al., 2003; Miklosi et al., 2003; Kaminski et al., 2004). Therefore, one could hypothesize that close contact with humans may have led to the development of human like social cognitive skills in dogs and also other domesticated species (Hare & Tomasello, 2005). It would be interesting for example to

know whether dogs' closest living relatives, wolves, would also take the perspective of others in a cooperative situation, analogous to the one presented in the current study or a competitive situation used in previous studies with other species.

However, as has been mentioned above, dogs' sensitivity towards human visual access does not seem to be restricted to cooperative contexts. Also goats, even though domesticated to some extent, have a very different domestication history than domestic dogs (MacHugh & Bradley, 2001) but also seem to be sensitive to others current visual access (Kaminski et al., 2006). Therefore, it is more likely that dogs' abilities in this current paradigm reflect general mammalian skills rather than a special adaptation to the human environment, which, if at all, becomes most apparent in their flexible use of human communication (Kaminski, 2008). However, until more species have been tested in visual perspective taking tasks all hypotheses about the evolution of these abilities and also about the mechanisms involved must remain rather speculative.

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