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ORIGINAL ARTICLE

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A nonverbal test of knowledge attribution: a comparative study on dogs and children

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Abstract The sensitivity of eleven pet dogs and eleven 2.5-year-old children to others' past perceptual access was tested for object-specificity in a playful, nonverbal task in which a human Helper's knowledge state regarding the whereabouts of a hidden toy and a stick (a tool necessary for getting the out-of-reach toy) was systematically manipulated. In the four experimental conditions the Helper either participated or was absent during hiding of the toy and the stick and therefore she knew the place(s) of (1) both the toy and the stick, (2) only the toy, (3) only the stick or (4) neither of them. The subjects observed the hiding processes, but they could not reach the objects, so they had to involve the Helper to retrieve the toy. The dogs were more inclined to signal the place of the toy in each condition and indicated the location of the stick only sporadically. However the children signalled both the location of the toy and that of the stick in those situations when the Helper had similar knowledge regarding the whereabouts of them (i.e. knew or ignored both of them), and in those conditions in which the Helper was ignorant of the whereabouts of only one object the children indicated the place of this object more often than that of the known one. At the same time however, both dogs and children signalled the place of the toy more frequently if the Helper had been absent during toy-hiding compared to those conditions when she had participated in the hiding. Although this behaviour appears to correspond with the Helper's knowledge state, even the subtle distinction made by the children can be interpreted without a casual understanding of knowledge-formation in others.

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Introduction

The evolutionary emergence of coordinated interactions in social species involves the problem of predicting the behaviour of groupmates and is often assumed to be under strong selection. Premack and Woodruff (1978) initiated studying the underlying cognitive mechanisms of this behaviour prediction when they asked if chimpanzees had a 'theory of mind'. Since then the question has been in the focus of earlier (e.g. Heyes 1993, 1994; Povinelli 1994) and recent (e.g. Povinelli and Vonk 2003 and Tomasello et al. 2003a, b) debates. At present, studies investigating what chimpanzees know about seeing (see Call 2001 for review) provide the strongest body of results supporting the hypothesis that chimpanzees understand some psychological states of others (Tomasello et al. 2003a). Mental state attribution studies (e.g. Premack 1988; Povinelli et al. 1990, 1991; Gomez and Teixidor 1992; Whiten 2000; Hare et al. 2001; Kuroshima et al. 2002) may aim to assess if primates understand the casual connection between past perception and present knowledge ('seeing' leads to knowledge and 'not seeing' leads to ignorance) or on a lower level of explanation to assess whether animals are able to take their partners' previous experience or perceptual access into account. But, even for the second interpretation, it is not enough to answer the question (1) whether the behaviour of the subjects depends on the presence or absence of their partner (the act of the perceptual access). It is equally important to know (2) if they take into account specifically *what* the partners have or have not participated in (the object of the perceptual access) and to know (3) if they take into account specifically *which partner* has or has not participated in something (the subject of the perceptual access). If the subjects have some understanding of what a specific event (E) a specific individual (I) has or has not participated in, they should adjust their communicative behaviour about "E" with "I" to this and only this certain

Table 1 Different nonverbal methods used to test subjects' sensitivity to what others have or have not seen in object- or subject-specific way (see details in text)

		Number of partners whose knowledge state is manipulated systematically	
		One	More (method is suitable for testing subject-specificity)
Number of events of which the partner(s)'s knowledge state is manipulated systematically	One	'Competitive Conspecific' (e.g. Hare et al. 2001, Exp.1)	'Guesser-Knower' (e.g Call et al. 2000) 'Competitive Conspecific' (e.g. Hare et al. 2001, Exp.2)
	More (method is suitable for testing object-specificity)	'Ignorant Helper' (e.g. Whiten 2000) 'Competitive Conspecific' (e.g. Hare et al. 2001, Exp.3)	–

(I) individual's participation in this and only this certain event (E). To answer all the above three questions, the connection between the partners' past experiences and the subjects' behaviour has to be tested systematically with respect of the event to which a partner has had perceptual access and of the person who has or has not perceived an event. Such design necessarily involves the systematic manipulation of at least two partners and two relevant events. We review three different methods ('Guesser-Knower', 'Competitive Conspecific' and 'Ignorant Helper') that have been developed to asses the sensitivity of non-human animals to the perceptual access of others to past events (Table 1).

Guesser-Knower paradigm

The 'Guesser-Knower' paradigm (Premack 1988 and Povinelli et al. 1990) has been recently developed for studying knowledge attribution in a number of species (e.g. Rhesus monkeys (*Macaca mulatta*)—Povinelli et al. 1991; children (*Homo sapiens*)—Povinelli and deBlois 1992; chimpanzees (*Pan troglodytes*)—Call et al. 2000; tufted capuchin monkeys (*Cebus apella*)—Kuroshima et al. 2002, 2003; domestic pigs (*Sus scrofa*)—Held et al. 2001). In these studies the desirable reward is hidden into one of several hiding places in the way that the subject itself cannot see the hiding process but can see that one of its partners (the 'Knower') has perceptual access to the hiding (e.g. he hides the food himself or is turning to the hiding places during hiding) but its other partner (the 'Guesser') has not (e.g. leaves the room before the hiding, there is an occluder between him and the hiding places). After the hiding both the 'Knower' and the 'Guesser' appoint one of the hiding places by their behaviour and the subject is allowed to choose a hiding place to see whether it prefers the one appointed by the 'Knower'.

Because these studies examine the subjects' ability to discriminate between the cues provided by two different partners with different perceptual access to the relevant event, this method fulfils the condition of subject-specificity, but does not meet the condition for object-specificity because the partners' visual access is systematically manipulated toward only one important event (the location of the food). Additionally, the relevance of these studies on mindreading abilities has been criticized (Heyes 1993, 1998) because the behaviour of the subjects can be explained by discrimination learning about cues and reinforcers.

Competitive Conspecific paradigm

In the 'Competitive Conspecific' design (Hare et al. 2001; Hirata and Matsuzawa 2001) two animals compete for more food items but only one of them knows the locations of all of the rewards. One of the competitors can observe that the other individual has or has not perceptual access to the hiding processes. The subsequent food-choice and the behavioural tactics of the animals are recorded and analysed in order to answer the question whether the subjects were able to rely on the partner's previous visual access or not.

In Hare et al. (2001, Exp. 2), the subordinate competitor watched a dominant individual witnessing the hiding of a piece of food and after a while it was allowed to compete with this individual or with another 'naïve' ignorant dominant individual (which was introduced replacing the first dominant after the hiding process). Because the subordinates discriminated the witnessing dominant and the ignorant chimpanzee, this study presented convincing evidence that while competing with conspecifics for food chimpanzees took into account the subject-specificity of what dominant competitors had and had not seen if one piece of food was available. However, if two food items were hidden (Hare et al. 2001, Exp. 3) but the dominant was allowed to witness the hiding of only one of them, subordinates were not able to adjust their behaviour accordingly, that is, choosing the food item of which the dominant had no knowledge. This means that subordinate subjects showed no evidence for object-specificity.

Ignorant Helper paradigm

The 'Ignorant Helper' design (Gomez and Teixidor 1992, see in Gomez 1996; Whiten 2000) tests the subjects' sensitivity to others' past visual access in an object-specific way. Both studies involved human-raised apes (one orangutan and three chimpanzees respectively) with human contributors in a cooperative situation in which the ape could get

some out-of-reach food by indicating it to a human partner. The essence of this design is that two relevant objects—a piece of food and a tool necessary for getting the food—are involved in the procedure. To make it obvious, the subjects receive several warm-up trials, in which the cooperative human partner (the Helper) uses the tool to get the food that was hidden by another human (the Hider) and provides the food to the subject if it indicated the correct location of food (simple request task). Following the warm-up sessions, probe trials are introduced in which the Helper's knowledge about the locations of the food and the tool is systematically manipulated. That is, the Helper may be ignorant of either the location of both the food and the tool, or the food only, or the tool only, or none of them. In the first study (Gomez and Teixidor 1992), however, the subject faced only two types of probe trials: the Helper never saw where the food was hidden and the location of the tool was either known by him or not. In Whiten's (2000) study, the Helper was ignorant with respect to the whereabouts of the food or the tool. Importantly, however, neither of these studies involved all of the four possible combinations of the Helper's knowledge regarding the food and the tool (i.e. food only, tool only, both food and tool, neither of them).

Nevertheless, irrespective of the methods used, most researchers agree that in order to understand the evolution and function of social cognitive skills we need well designed comparative studies involving both human and animal subjects. Recently, the dog has been proposed to be a promising species for studying the evolutionary emergence of social cognition (Miklósi et al. 2003). The complexity of the social environment (i.e. human social settings) could have represented such an adaptational demand that has driven the evolution of social cognitive skills in domestic dog. The hypothesis predicting that dogs may have evolved some special social skills for understanding cues of human communication was supported by several lines of research (see Miklósi et al. 2004, for a recent review). Dogs use sophisticated skills in interspecific communication with humans (Miklósi et al. 1998; Hare and Tomasello 1999; Agnetta et al. 2001; Soproni et al. 2002) even when compared to their ancestors, the wolf (Miklósi et al. 2003) and when compared to apes (Soproni et al. 2001 and Povinelli et al. 1999; Hare et al. 2002). Moreover, pet dogs are sensitive to the attentional component of the human gestures: they are able to use gaze alternation between human and the goal-object in problem solving situations (Topál et al. 1997; Miklósi et al. 2000) and can recognize gazing as behavioural sign of other's attention (Call et al. 2003; Gácsi et al. 2004; Virányi et al. 2004). Accordingly, the question arises if dogs' social cognitive skills go beyond relying on humans' behavioural cues and reach to some deeper understanding, but very few results exist yet (Ashton and Cooper, unpublished data; West, unpublished data, both reported in Cooper et al. 2003). In these studies, after being trained to locate food in three or four hiding places, the dogs were prevented from seeing the baiting itself during test trials but could see if two partners of them had or had not visual access to the hiding process. The partners were two dogs (trained to fixed locations previously—a method applied by Held et al. 2001) housed in either a covered or an uncovered box or two humans being either in a position where she could see the baiting or outside the room. After the invisible hiding, the subjects were allowed to choose between the different indications of the two partners to see if they prefer that of the partners that could see the baiting. Although the dogs always followed one of the dog-partners, they failed to discriminate between the apparently informed and uninformed partners. When the partners were humans, 14 out of 15 dogs chose the location indicated by the knowing human in the first trial, but there was no preference for the knowing partner in the subsequent five trials. Considering the ambiguity of these results and the theoretical criticisms relating the 'Guesser-Knower' paradigm applied also in these studies dogs' capabilities to understand others' mental states clearly need further examination.

The 'Ignorant Helper' paradigm has the advantage of having the possibility of testing the subjects' capabilities to adjust to others' perceptual access in an object-specific way, and seems to be the most relevant method if one wants to study if dogs (as compared to human infants) are sensitive to the "knowledge states" of humans. First, both dogs and children can be easily tested in cooperative situations like the request task in the 'Ignorant Helper' method (see Miklósi et al. 2000 for dogs, O'Neill 1996 for human infants). Second, the trials in the 'Ignorant Helper' procedure are comparable to the daily problem solving situations for dog and human subjects who both can inform the human helper by nonverbal communicative behaviours (orienting response: pointing and/or gazing cues, for dogs see e.g. Miklósi et al. 2000).

Accordingly, we used a modified version of the 'Ignorant Helper' procedure (Gomez 1996; Whiten 2000) to study the behaviour of adult dogs and 2.5-year-old human infants. Experimental trials were playful, object-hiding situations, which differed according to whether the Helper participated in the hiding of a toy (reward) or a stick (a tool necessary for getting the out-of-reach toy). That is, the Helper was ignorant of either the location of (1) both the toy and the stick, (2) only the toy, (3) only the stick or (4) neither of them.

The main goal of the current study was to investigate if dogs are able to discriminate between request tasks in which the human Helper has different knowledge states concerning the whereabouts of the reward and/or the tool, relying upon the Helper's engagement/disengagement in the hiding processes of the two objects and to compare their behaviour to that of 2.5-year-old children tested in the same conditions.

Children of this age were selected to make comparisons with dogs in this situation because evidence for mental understanding of causal intentions starts to accelerate around the end of the second year, with the comprehending pretence in others, a systematic understanding that visual attention causes knowledge, and the routine use of protodeclarative gestures to induce or modify intentional states in others appear (Wellman and Phillips 2001). A mature understanding of mental agency (i.e., naïve theory of mind) however,

is still not present at this age because a number of studies report that this ability arises around 4 years of age (see Perner 2000 for review).

Methods

Subjects

Eleven adult pet dogs (5 females, 6 males; mean age: 4.9 years, range: 1–10 years) and 11 children (5 girls, 6 boys; mean age: 29.4 months, range: 26–35 months) participated in the experiment. The dogs were from different breeds (3 mongrels, 3 tervuerens, 2 German vizslas, 1 boxer, 1 sharpei and 1 malinois). The dog-owner pairs were recruited from among the volunteer participants of our Family Dog Research Program. Only dogs living in the flat together with their owners and keen on retrieving objects and playing with toy were selected. All the owners were women, their age ranged between 20 and 35 years.

All children were from Hungarian middle-class families and were recruited through the register of the IPHAS (Institute of Psychology, Hungarian Academy of Sciences). Five additional children were excluded from the study because of motivational problems and/or because their mothers neglected the instructions in course of the experimental trials.

Experimental arrangement

Testing was done in a familiar room (minimal size: 3×5 m) of the subjects' home (Fig. 1). A stick (1 m long) was placed out of reach of the dog/child in a position (standard place) where it could not be seen by the Helper from her predetermined position, which was indicated by a chair. The experimenter also determined four additional hiding places for the stick and three hiding places for the toy where the hidden objects were out of reach of the dog/child. The hiding places were located under (or on top of) heavy pieces of furniture (e.g. bed, cupboard, book case) from where the dog/child could not get the toy/stick out. The distance between any two possible hiding places was at least 1.5 m. The Helper's chair was positioned in a way that she could see the entire room (all hiding places) from there.

For the dogs, the hidden object was a favourite toy (e.g. tennis ball) whilst the toy was chosen by the children from a set of rollable toys (mainly small cars and balls), which were offered by the experimenter prior to the experiment.

The owners/mothers did not know the scientific goal and the hypothesis of the study in advance; they were informed that its purpose was investigating the manners of the dog/child-human communication in nonverbal situations. Before the experiment the experimenter thoroughly instructed the owner/mother about the experimental trials, the owner/mothers received written instructions as well. The children were told only that the experimenter came to play a rolling game with them and their mothers.

Procedure

Prior to the experiment the experimenter (Zs.V.) visited the dog/child at home to choose the appropriate room and the hiding places for the toy and the stick. Then she placed the stick and the chair at their predetermined places.

Warm up play session (retrieval tasks and toy hiding trials)

In order to make the dogs and children familiar with the experimental situation and to make them familiar with the

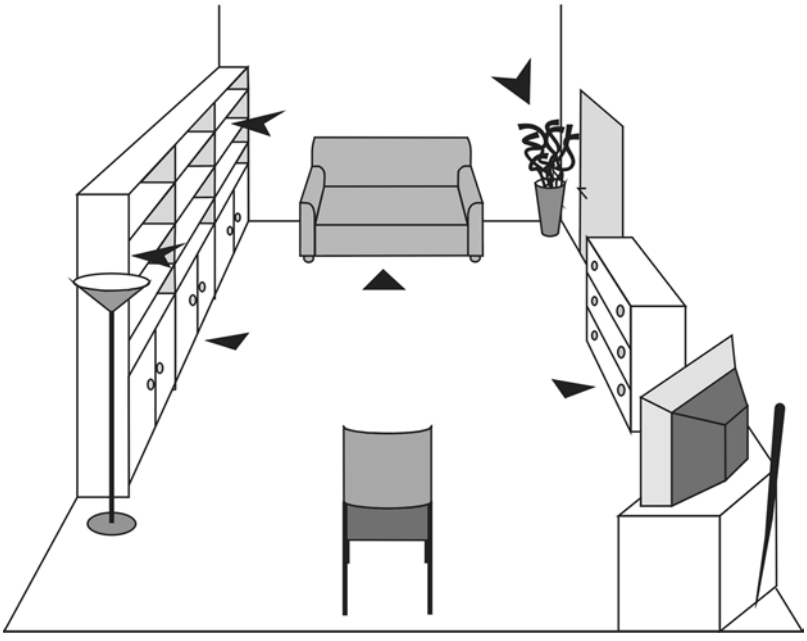

Fig. 1 The experiment took place in a room of the subject's home. The picture shows one example. In the foreground a chair is positioned for the Helper and the stick is in its usual place (behind the TV). In the background, on the right side the door can be seen where the participants can enter and leave the room. The triangles sign the hiding places for the toy and for the stick (➤): three-three out-of-reach hiding places for both of the objects

use of stick and the toy, 'Warm up play sessions' were introduced. Because we assumed that dogs had less experience with sticks and their use, 7 consecutive daily sessions with 3 trials in each were run in the case of the dogs and only a single 3-trial session was provided for the children. The procedure of the warm up trials was also different to some extent for the dogs and the children.

1st step: The owner/mother initialized playing with the dog/child

In case of the dogs, the owner first put the toy into one of the three predetermined hiding places and then called the dog by its name. When the dog responded, the owner tried to reach the toy with her hand 3-4 times unsuccessfully. Then she went to the stick, took it from its standard place and got the ball with it. Finally, she replaced the stick, called the dog and initiated a retrieval game.

In case of the children, the mother took the toy that the child had just chosen, sat down on the floor, called her child and initiated playing with the toy (she said: 'I roll it, you have to catch it').

2nd step: Three consecutive warm up trials

In case of the dogs, the owner stood and threw the ball at a distance of 2–3 m and encouraged the dog to retrieve it. After retrieving the toy the dog was praised and the owner threw/rolled the ball again. After the dog retrieved the toy at least three times the owner threw/rolled the toy into one of the three predetermined hiding places apparently by accident. From here the dog could not retrieve the toy, so the owner went there and tried to reach the toy with her hands but did not succeed. Then she went to the standard place of the stick, removed it from its place and got the ball with it. Meanwhile, she called the dog if it did not pay attention. After replacing the stick the owner resumed playing with the dog and the next warm up trial started with the same procedure, except that the toy was thrown/rolled into another hiding place. In the course of the three warm up trials the toy was thrown/rolled "accidentally" once into all three hiding places. The 15-minute long playing session was interrupted by the owner two times when she sat down on the chair with the toy in her hands for a few seconds then she resumed playing.

In the children's warm up trials the mother and the child bowled the toy to each other while sitting on the floor facing each other. After bowling the toy to each other at least three times the mother rolled it into one of the three hiding places apparently by accident. Since the child could not get the toy from there, the mother went there and tried to reach the toy with her hands unsuccessfully. Then she removed the stick from its place and got the toy with it. She called the child if she/he was not attending to her actions. After replacing the stick she resumed playing with the child and the next warm up trial followed with the same procedure except that the toy was rolled into another hiding place. In the three warm up trials the toy was rolled "accidentally" into each of the three hiding places. The mother was instructed to finish the session in 10 minutes.

The owners were asked to repeat the warm up sessions once a day for a week. The first warm up session was made in the presence of the experimenter who corrected the owner's behaviour if it was necessary. The next six sessions were completed by the owner, and on the eighth day the experimental trials followed.

The children received only one warm up session, and the experimental trials were executed on the same day.

Experimental trials

Following the warm up sessions four experimental conditions were introduced in which both the owner/mother (who played the role of the Helper) and the experimenter (playing the role of the Hider) participated. Importantly, experimental situations were designed so that the Helper's knowledge concerning the whereabouts of the tool (stick) and the goal object (toy) were systematically manipulated and all trials consisted of six different phases (see Fig. 2).

1. Entering phase: All experimental trials began in the same way: the Helper (owner/mother), the Hider (experimenter) and the subject (dog/child) entered the room. The next two phases, however, were different in the different conditions based on the timing of the Helper's leaving and re-entering the room:

'Introductory Stick & Toy' condition (The Helper participated in hiding of both the stick and the toy.)

2. Stick-hiding phase: The Hider called to the subject to gain his attention ("Name + Look here!" was said to the dogs and "I will play with you, but before, please, look what we are doing!" was told to the children). Then the Hider and the Helper went to the place of the stick, removed the stick into one of the four predetermined hiding places. The Hider called the subject if he was not attending to the actions.
3. Playing and toy-hiding phase: Following this, the Helper sat down (the owners sat on their chair, the mothers sat on the floor in front of their chair), and the Hider took the toy out from her pocket and staying standing and throwing the toy to the dog or sitting down on the floor forming a triangle with the child and the Helper and rolling the toy to the child initiated retrieval/rolling game with the subject in a way which was similar to that was played in warm up trials. In this case, however, the Hider was also involved to the game: The Hider threw/rolled the toy alternately to the subject and the Helper. (The dogs fetched the toy while the children and the Helper threw/rolled it back to the Hider.) When the Hider got the toy back for the third time, she threw/rolled it into one of the three predetermined hiding places apparently by accident. She looked at the subject, shrugged her shoulders ("Oh sorry!" she said) and finally left. The Helper stayed in the room.

'Toy only' condition (The Helper participated only in the hiding of the toy.)

2. Stick-hiding phase: After spending a few seconds together in the room the Helper left saying to the subject:

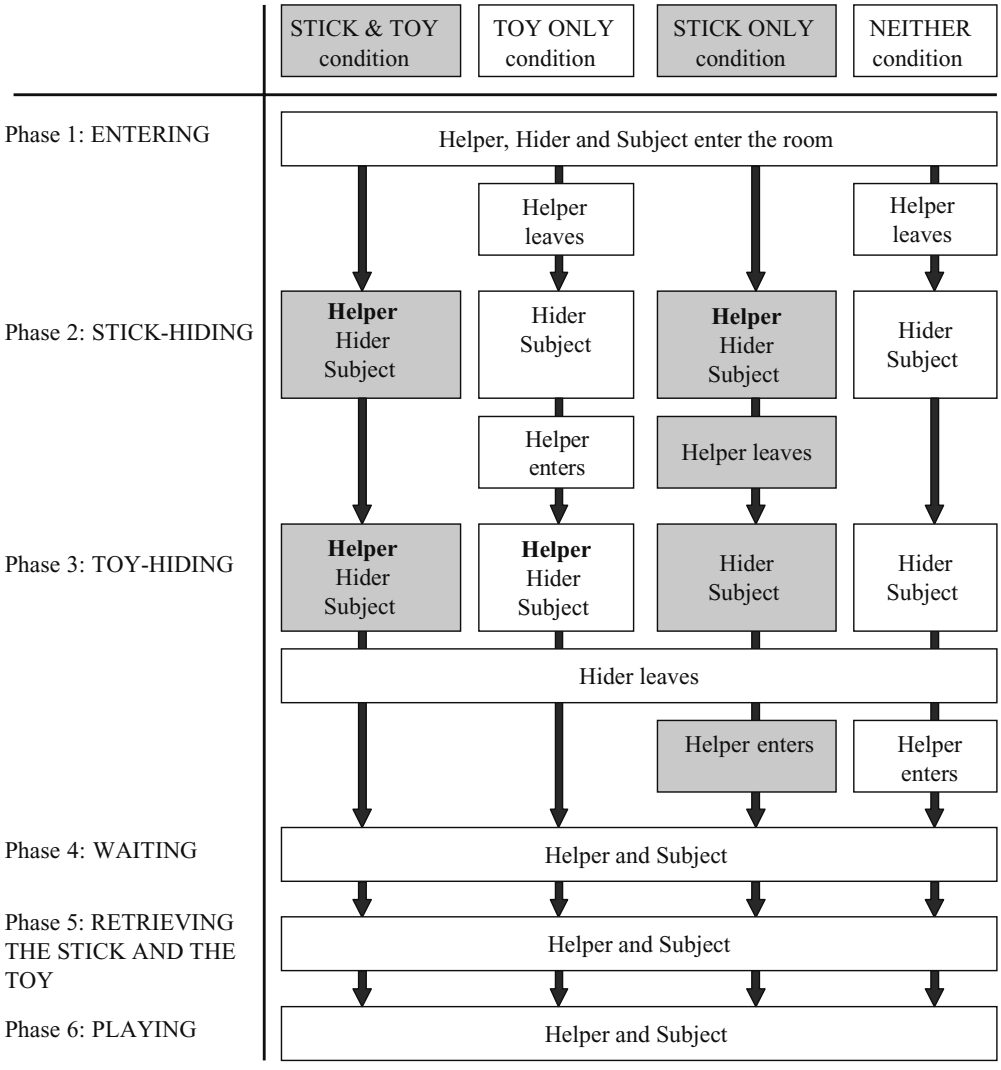

Fig. 2 Experimental schedule for the four experimental conditions based on the presence of the three participants. All trials began and terminated in the same way, the Helper, however, left and re-entered the room in different phases of the different conditions and accordingly she participated in hiding 1) both the stick and the toy, 2) only the toy, 3) only the stick or 4) none of them. Participants who were present in the different phases are shown in the boxes

"I will come back soon, stay here!". Then the Hider called the subject ("Name + Look what I am doing!") and went to the place of the stick, removed it and put it into one of the four predetermined hiding places. Care was taken that the subject was clearly attending and following each step of manipulation.

3. Playing and toy-hiding phase: After hiding the stick the Hider went to the door, opened it and invited the Helper into the room. After the Helper sat down the Hider played with the subject and the Helper, and hid the toy in the same way as described in the 'Stick and Toy' trial.

'*Stick only*' *condition* (The Helper participated only in the hiding of the stick.)

2. Stick-hiding phase: After entering the Helper stayed in the room and participated in hiding the stick in the same way as described in the 'Stick and Toy' trial.
3. Playing and toy-hiding phase: After hiding the stick, however, the Helper left the room saying: "I will come back soon, stay here!". After the Helper closed the door the Hider took the toy out from her pocket and initialized a fetching/rolling game with the dog/child which was similar to that played in warm up sessions. After throwing/rolling the toy to the subject three times, the Hider threw the toy into one of the three predetermined hiding places apparently by accident. She looked at the subject, shrugged her shoulders ("Oh sorry!" she said) and left. At the same time the Helper entered.

'Neither' condition (The Helper did not participate in the hidings of either of the stick and the toy.)

2. Stick-hiding phase: After spending a few seconds together in the room the Helper left in the same way as in the 'Toy only' condition, so the Hider hid the stick on her own while calling the subject's attention to these actions (see 'Toy only' condition).
3. Playing and toy-hiding phase: After hiding the stick (without inviting the Helper into the room) she took the toy out from her pocket and played with the subject and hid the toy in the same way as in the 'Stick only' condition. Then she left the room but in the same time the Helper entered.

From this point on all experimental trials continued in the same way.

4. Waiting phase: After the Hider's disappearance, the Helper sat on the chair at her predetermined place for 30 s without saying anything and followed the subject with her attention by turning only her head. Looking in other directions than the subject was not allowed; she had to focus her attention on the subject only.
5. Object retrieval phase: After 30 s had passed, the experimenter knocked at the door, and the Helper retrieved the stick and the toy as soon as possible. To achieve this she could rely on her knowledge if she had participated in hiding any objects and/or on the subject's behaviour during the waiting phase (behaviours indicating the place of the objects) and/or she could visit systematically the possible pre-determined hiding places (known-well by the Helper). Importantly, when searching for the objects, the Helper had been asked to ignore the subject, and verbal communication was not allowed to prevent the subject from receiving feed back with regard to his/her behaviour. When the Helper got the stick she had to work the toy off by the help of the stick and then to replace the stick to its original, standard place as soon as possible.
6. Playing phase: After the Helper got the toy and replaced the stick she initiated a short fetching/rolling game with the subject.

All dogs and children were observed in all four types of conditions in a session with 3–5 min breaks between the trials. The first experimental trial was the 'Introductory Stick and Toy' condition for all subjects since this condition—having the owner/mother continuously present—was the most appropriate to introduce the novel elements of the experimental situation (playing with the Hider, etc.). The order of the other three conditions and also the hiding places of the stick and toy in all four trials were randomised and predetermined. The children received only one session, however the dogs were re-tested on the subsequent day in similar way except that the order of all four trials were randomised. In this way the children participated in one trial of each condition whereas the dogs received two trials of each conditions on two consecutive days. Experimental trials were recorded by two video cameras in fixed positions and the behaviour of the subjects was analysed later.

Behavioural variables

The behaviour of the dogs and the children was observed during the waiting phases of the experimental conditions (i.e. in the half a minute when the Helper was passive and looked at the subject attentively) and the analysis was focused on the 'indicative behaviours' of the subjects.

Indicative behaviours

Recently many have argued that dogs are skillful not only in understanding human gestural communication (see Miklósi et al. 2004 for review) but also in directing the attention of a human to places of interest. It has been shown that in food request tasks the dogs' gazing at the location of the food preceded and/or followed by gazing at the owner and/or accompanied by vocalization fulfils criterion of functionally referential communication (Miklósi et al. 2000). This behaviour can be described by a characteristic temporal pattern in which gazing toward the requested object (directing component) is accompanied with gazing at the owner and/or vocalization (attention-getting component) (Hare et al. 1998). It is important to note, that this behaviour can be considered as functionally analogue to human pointing gesture. The indicative character of gaze alternations between the goal-objects and the human participant while informing human partners in request tasks has been reported also in studies on children (O'Neill 1996) and a similar definition can be used for children's gazing at the place of the toy/stick accompanied by verbal communication (e.g. "There!", "Give it to me!" or "Let me have it!" etc.).

Accordingly gaze-alternations between the toy/stick and the Helper and gazing at the toy/stick accompanied by vocalization (barking, whining) in dogs and verbal communication in children were defined as indicative behaviours. In the case of human infants, pointing (with extended arm) at the place of the toy/stick (while the child was either looking at the place of the object or at the mother) was also regarded as signalling behaviour. Gaze-alternation was defined as behaviours when gazing at the Helper (owner/mother) was followed directly by a gaze at the place of the toy/stick or vice versa.

We should note that children (and dogs) often combined different types of signalling behaviours and gaze alternations. For example children often alternated their gaze from their mother to the place of the toy, pointed to it and said "Give it to me!" at the same time. In these cases the different types of signalling overlapping in time were counted as one single indication. The direction of gazing was recorded on the basis of head/face orientation of the dogs/children.

In accordance with these definitions the number of indicating behaviours (behaviours referring to the goal objects) was measured later from the videotapes separately toward the toy and the stick. Reliability of measuring the direction of gazing and the direction of pointing was assessed by means of parallel coding of the 25% of the total sample by two observers, one of whom was blind to the experimental condition. Their inter-observer agreement yield the Cohen kappas of 0.90 for the dogs' orientation, 0.90 for the children's gazing direction and 0.99 for the children's pointing direction.

Scores for situation-relevant signalling

In order to analyse whether the presence or absence of the Helper during changes of the location of the toy/stick had a functionally relevant effect on subject's behaviour, we recorded both the focus and the sequence of indicative behaviours (i.e. what is indicated and what the sequence of indication is if more than one location is indicated). In

Table 2 Establishing the 'Scores for situation-relevant signalling' in the four experimental conditions based on which object(s) the dog/child indicated in which order

Condition	Scores for relevant signalling behaviour		
	1	0	−1
Stick & Toy	No signalling behaviour	Indicating either the place of the toy or the stick	Indicating both the place of the toy and the stick
Toy only	Indicating only the place of the stick, or first the place of the stick and then the toy	No signalling behaviour, or indicating first the place of the toy and then the stick	Indicating only the place of the toy
Stick only	Indicating only the place of the toy, or first the place of the toy and then the stick	No signalling behaviour, or indicating first the place of the stick and then the toy	Indicating only the place of the stick
Neither	Indicating both the place of the toy and the stick	Indicating either the place of the toy or the stick	No signalling behaviour

line with this approach (e.g. Gomez 1998), the 'Scores for situation-relevant signalling' were established for the different experimental conditions as shown in Table 2. Score 1 was given if the subject's signalling behaviour was properly adjusted to the knowledge state of the Helper in the sense that it provided information about each object the location of which was ignored by the Helper. Informing about the location of the object already known by the Helper (unneeded information) was allowed only after giving the needed information. Negative score (−1) was given when the subject signalled only the location of the object(s) known by the Helper and score 0 was given if the subject's signalling behaviour gave only partial information needed by the Helper (i.e. signalled only one of the unknown hiding places) or provided the necessary information only after giving unneeded information.

Because variables were not distributed normally, non-parametric statistical methods (Friedman ANOVA, Mann-Whitney U test, Wilcoxon matched pairs signed rank test) were used for the data analysis.

Results

Frequency of indicating behaviours towards the goal objects (toy and stick)

To determine if the subjects indicated the location of the specific object(s) of which the Helper was ignorant more intensively than the location of the object(s) of which she was knowledgeable, frequency of the toy-indicating and frequency of stick-indicating behaviours in the same condition were compared (Wilcoxon matched pairs signed rank tests). The dogs were found to signal the place of the toy significantly more often than the place of the stick in all conditions ($p<0.02$ in each condition for both sessions; Fig. 3a, b). At least seven dogs indicated the location of the toy in all experimental trials, whilst the location of the stick was signalled by more than two dogs in none of the conditions (Table 3).

In contrast, the children tended to show toy- and stick-indicating with similar intensity in those trials in which the Helper knew the places of both objects or neither of them ($Z=0.0$; $p=1.00$ for 'Stick & Toy' and $Z=-1.20$; $p=0.23$ for 'Neither' condition). In trials however, in which the Helper knew either the whereabouts of the stick or the toy, the children tended to show more indicating behaviours toward the place of the object which was unknown to the Helper (indicating the toy more frequently than the stick in 'Stick Only' condition: $Z=-2.2$; $p=0.028$; and indicating the stick more frequently than the toy in 'Toy Only' condition: $Z=-1.99$; $p=0.046$; Fig. 3c, see also Table 3).

To analyse separately if subjects tailored their toy-indicating behaviour to the Helper's knowledge state of the location of the toy and their stick-signalling behaviour to the Helper's knowledge state of the place of the stick the intensity of signalling an object was compared in the different conditions. Comparisons of the frequencies of indicating the toy across the four experimental conditions did not show significant differences in the first session for the dogs (Friedman ANOVA: $Fr(3)=1.500$; $p=0.682$), but the dogs in the second session and the children performed significantly different frequency of toy-indicating as a function of experimental condition ($Fr(3)=10.402$; $p=0.015$ for the dogs and $Fr(3)=9.592$; $p=0.022$ for the children). Considering the number of stick-indicating behaviours there were no significant differences among the four different conditions (Friedman ANOVA: dogs, first session: $Fr(3)=2.000$;

Table 3 Number (and percentage) of the dogs ($N=11$) and children ($N=11$) who indicated the toy or the stick in the different experimental conditions

	Indicating the	Experimental condition			
		Stick & toy	Toy only	Stick only	Neither
Dogs 1st session	Toy	7 (64%)	8 (73%)	11 (100%)	8 (73%)
	Stick	1 (9%)	1 (9%)	2 (18%)	0 (0%)
Dogs 2nd session	Toy	9 (82%)	7 (64%)	10 (91%)	10 (91%)
	Stick	2 (18%)	1 (9%)	1 (9%)	1 (9%)
Children	Toy	3 (27%)	3 (27%)	7 (64%)	7 (64%)
	Stick	3 (27%)	8 (73%)	4 (36%)	3 (27%)

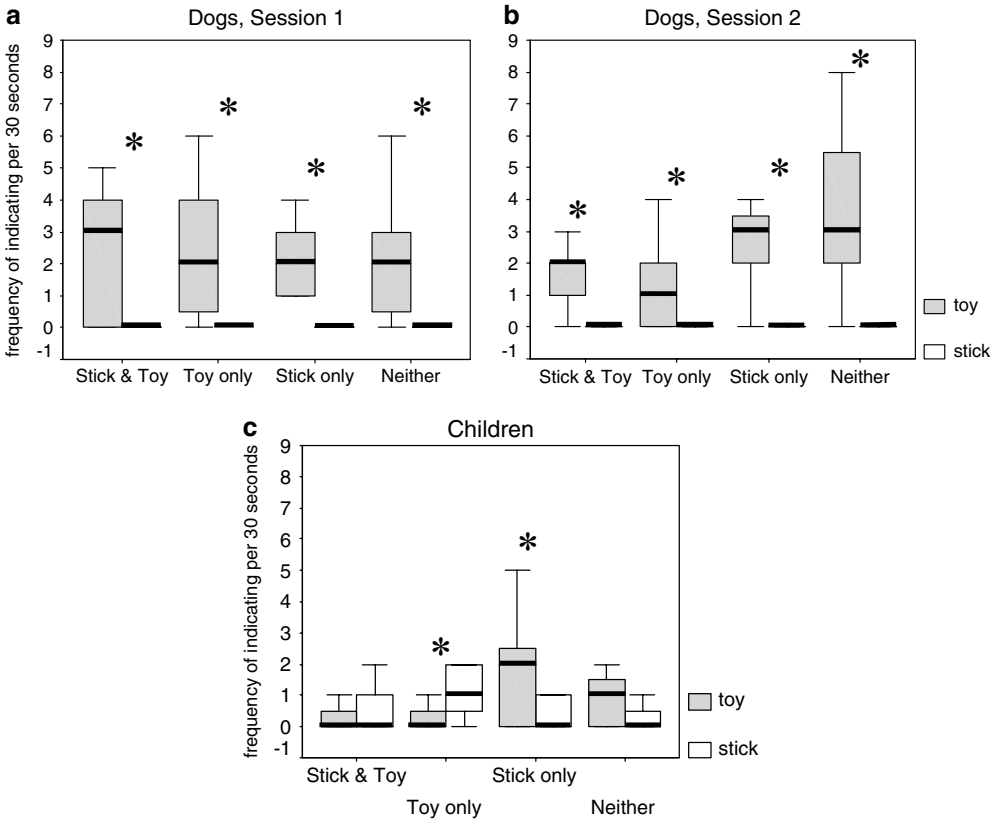

Fig. 3 Number of indicating the toy and the stick by the dogs (N=11) in the first (**a**) and second sessions (**b**) and by the children (**c**) (median, quartiles and extremes). Asterisk labels significant difference between the number of toy and stick indications (Wilcoxon matched pairs test) 'Stick & Toy' condition: Helper knows the places of both the stick and the toy. 'Toy only' condition: Helper knows only the place of the toy. 'Stick only' condition: Helper knows only the location of the stick. 'Neither' condition: Helper ignores the whereabouts of both the stick and the toy

p=0.572, second session: Fr(3)=0.692; p=0.875 and children: Fr(3)=5.535; p=0.137).

Similar results were found when the number of toy-indicative actions were summed for conditions in which the Helper was knowledgeable regarding the location of the toy ('Toy-Knowledgeable' trials ='Stick & Toy' + 'Toy Only') and in conditions in which she was ignorant ('Toy-Ignorant' trials ='Stick only' + 'Neither') and were compared to each other. 'Toy-Knowledgeable' and 'Toy-Ignorant' conditions did not show significant difference for the dogs in the first session (Wilcoxon matched pairs signed rank test: Z=−0.62; p=0.535) but both dogs in the second session (Z=−2.81; p=0.005) and children (Z=−2.719; p=0.007) were found to signal the toy more frequently if the Helper was ignorant of its location (Fig. 4a). A similar analysis based on the Helper's knowledge about the place of the stick ('Stick-Knowledgeable' trials ='Stick & Toy' + 'Stick Only' versus 'Stick-Ignorant' trials ='Toy only' + 'Neither') showed no significant differences in either the dogs (Z=−1.0; p=0.317 and Z=−0.38; p=0.705 in the first and second session) or the children (Z=−1.41; p=0.158) (Fig. 4).

Scores for situation-relevant signalling

In principle, the question of whether or not the subjects' indicating behaviour shows some understanding of the connection between the presence/absence of the Helper (when stick/toy was hidden) and her knowledge/ignorance can be answered by the analysis of individuals' mean scores gained in the four conditions. Interestingly, a comparison based on this consideration did not show significant differences between the dogs' and the children's overall performance (Mann Whitney U test, N_{dog}=$N_{children}$=11, U=39.0; p=0.171 for the comparison between children and dogs in the first session, and U=36; p=0.116 for the comparison between children and dogs in the second session) (Fig. 5).

However, if the children's and the dogs' performance was compared in all four conditions separately this similarity appeared only in the 'Stick & Toy' (Mann Whitney U test, N_{dog}=$N_{children}$=11, U=46.5; p=0.365 and U=38.0; p=0.151 for the first and second session respectively) and 'Neither' trials (U=52.5; p=0.606 and U=55.5; p=0.748 for the first and second session respectively). Importantly, however, the children showed significantly more relevant indicating behaviour in the 'Toy only' condition (U=15.5; p=0.002 and U=18.0; p=0.004 for the first and second session respectively), in which the 'situation-relevant' behaviour was indicating the stick, or first the stick and then the toy. In contrast, in the 'Stick only' condition, the dogs out-performed the children in the first session (U=27.5; p=0.028) although in the second session their scores were not significantly higher than those of the children (U=40.5; p=0.193) (Fig. 5b and Table 4).

There was another difference between the performance of dogs and children shown in scores for situation-relevant signalling. The children did not show differences in their scores as a function of experimental conditions (Friedman ANOVA, Fr(3)=6.0; p=0.112). The dogs, however,

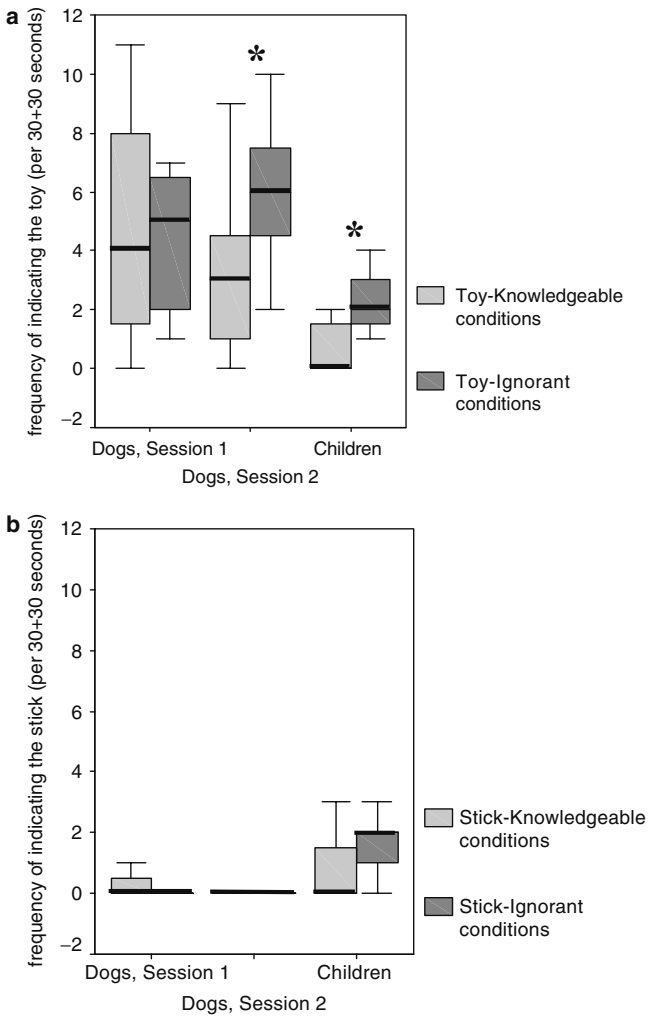

Fig. 4 (**a**) Sum of numbers of indicating the toy in the two Toy-Knowledgeable ('Stick & Toy' + 'Toy only') and the two Toy-Ignorant ('Stick only' + 'Neither') conditions (median, quartiles and extremes). (**b**) Sum of numbers of indicating the stick in the two Stick-Knowledgeable ('Stick & Toy' + 'Stick only') and the two Stick-Ignorant ('Toy only' + 'Neither') conditions (median, quartiles and extremes). Asterisk labels significant difference between the Knowledgeable and the Ignorant conditions (Wilcoxon matched pairs test)

Table 4 Number (and percentage) of dogs (N=11) and children (N=11) who performed 'situation-relevant signalling' behaviour (received score 1) in the different experimental conditions

	Experimental condition			
	Stick & toy	Toy only	Stick only	Neither
Children	7 (64%)	6 (55%)	5 (46%)	2 (18%)
Dogs 1st session	3 (27%)	0 (0%)	11 (100%)	0 (0%)
Dogs 2nd session	2 (18%)	0 (0%)	9 (82%)	1 (9%)

showed striking differences in both sessions (first session: Fr(3)=21.35; $p<0.0001$; second session: Fr(3)=19.35; $p=0.0002$). That is, the dogs performed more relevant behaviour in 'Stick only' trial compared to 'Toy only' condition (Dunn's post hoc test, $p<0.01$).

Discussion

The 'Ignorant Helper' design (Gomez 1996; Whiten 2000) is a useful method for studying sensitivity toward other's presence or absence in past relevant events in both non-human animals and in human subjects. Subjects' ability to recognize what the Helper had perceptual access to should be manifested in the adjustment of signalling the place of the toy and the stick across the experimental conditions. To draw a well-grounded conclusion, however, all the possible experimental conditions should be examined in contrast to methods of earlier studies using the 'Ignorant Helper' paradigm (Gomez 1996; Whiten 2000). According to our results the dogs' performance varied extremely as a function of experimental condition. Whilst the dogs' behaviour appeared to be highly relevant in the condition in which the Helper was ignorant regarding the whereabouts of the toy ('Stick only' condition), they show less relevant signalling in the other conditions (predominantly indicated the place of the toy). On the contrary, although significant differences were not found in the overall performance of the two experimental groups, the children's scores of situation relevant signalling did not vary across the experimental conditions.

These results were confirmed by analysing frequencies of indicating the two objects. Whilst dogs indicated more often the place of the toy compared to the place of the stick

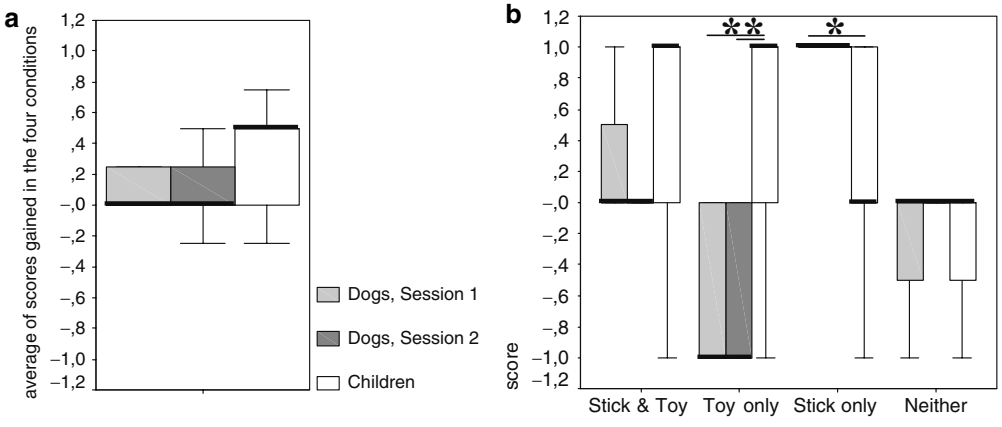

Fig. 5 (**a**) Mean scores of dogs (in session 1 and 2) and children gained in the four experimental conditions (median, quartiles and extremes). (**b**) Scores for situation-relevant signalling of dogs (in session 1 and 2) and children gained separately in the four experimental conditions (median, quartiles and extremes)

in all experimental conditions, children showed object-specific changes in their signalling behaviour. The children showed similar frequency of indicating the toy and the stick in trials in which the Helper had the same information regarding the whereabouts of the toy and the stick (i.e. either participated or not in the hiding of both objects—'Stick & Toy' and 'Neither' conditions). In trials however, in which the Helper had information only about one of the objects ('Toy only' and 'Stick only' conditions), the children specifically signalled the object more often the location of which was ignored by the Helper (more stick-indicating than toy-indicating in 'Toy only' condition and more toy-indicating than stick-indicating in 'Stick only' condition).

Comparing the dogs' performance to that of the children, one of the most striking differences is the infrequency of stick-indicating behaviours in dogs. One could assume that this relates to the species-specific differences in their object-manipulation abilities. Namely, 2.5-year-old children are predisposed to be more skilful in problem situations involving tool-use. Children, undoubtedly, have a lot of individual experience in using and manipulating objects as tools. All of the human participants have already practiced using different stick-like objects to retrieve other objects from out-of-reach places before the experiment whereas dogs had only indirect experiences of these actions via observing humans. Accordingly, dogs had difficulties in recognizing the role of the stick in getting the toy, and the warm-up trials were insufficient to establish this relationship between the stick and the toy.

In addition, this species difference may be explained by working memory problems in dogs. Memory demands of the task could have exceeded the capacity of the dogs and they forgot the location of the stick because it had been hidden before the toy in all trials and approximately 5–6 min elapsed between the stick-hiding process and the waiting phase when the dogs' signalling behaviour was observed. In a recent object permanence study dogs' working memory for hidden objects was found to deteriorate with retention intervals longer than 30 s but their accuracy to find the disappearing object was above chance even after a 4-minute delay (Fiset et al. 2003).

Moreover, the lack of interest in the stick in dogs may be the result of the different 'motivational value' of the two goal objects (stick and toy). Dogs were probably over-motivated in order to get the toy, and therefore they were less attentive when the stick was manipulated and hidden. As a consequence, they were less motivated to show behaviours referring to the place of the stick. It should be noted that any of the combination of the afore-mentioned possibilities could be responsible for why the dogs indicated predominantly the place of the toy but not the stick in all conditions. In summary dogs seemed not to take into account the stick in the experimental game, so the object-specificity of their indicating behaviour cannot be investigated (as if only one object had been involved in the situation).

On the contrary, the behaviour of children provided evidence for object-specificity. Our findings are consistent with some recent results (O'Neill 1996; Dunham et al. 2000) showing that children as young as age 2.5 may be able to take into account which events their partner has witnessed and to tailor their communication accordingly. In these studies 2.5-year-old children were found to communicate (verbally and nonverbally) about the location of a desirable toy more intensively if their partner had not seen where another human participant hid the toy compared to the condition in which the toy-hiding had been seen by the partner. In these studies, hiding the toy was the only conspicuous event happened while the partner was out of the room or was closing her eyes. Therefore, from these results it cannot be inferred how specific the response of the children was in taking into account the partner's previous participation/disengagement in different, parallel events. In our study, however, the partner's knowledge was manipulated regarding to not only the location of the toy but also to that of the stick. Our results support a certain level of object-specific understanding because the children signalled the object (more often) the place of which was not known by the Helper.

Going beyond the question of which object the subjects chose to signal more intensively, the frequencies of indicating a special object were compared in the pair of trials when the Helper was knowledgeable of the place of this certain object to the other, ignorant pair of trials in order to test if the subjects communicated about a certain object more intensively when the Helper was ignorant of the place of this object. Although the dogs hardly showed any stick-related behaviours and even their toy-indications were not influenced by the experimental conditions in the first session, in the second session the dogs proved to be sensitive to the fact that the Helper had or had not participated in the hiding of the toy. They showed changes in the frequency of toy-indication that corresponded to the Helper's knowledge/ignorance regarding the place of the toy (less signalling when the Helper participated in the hiding of the toy). It is quite unlikely that this change in the dogs' behaviour from the first session to the second one was the result of quick trial-and-error learning because the dogs did not receive any feedback from the Helper in the course of the trials (i.e. any reinforcement about the appropriate action). All experimental conditions were finished the same way: when half minute (passive phase) elapsed, subjects were rewarded by the Helper within few seconds. Apart from trial-and-error learning, subjects might have learnt about the general meanings of the experimental situation. For example they may have learnt that the Helper is ready to get the toy and to play with them even in those conditions when she had not participated in the retrieval game and in hiding of the toy ('Stick & Toy' and 'Toy only' conditions). The adequate changes in the frequency of indication of the toy in dogs may mirror a fast 'insightful process' learning (Gomez 1998) rather than trial-and-error mechanism. This finding and facing an already familiar situation in the second session could have increased the willingness of the dogs to behave in a more active, initiating way, which resulted in indicating the place of the toy more intensively if the Helper had not participated in hiding the object.

Similar to the dogs' behaviour in the second session, the children adjusted the frequency of their toy-indicative behaviour to the Helper's previous participation/absence in hiding the toy. But the Helper's knowledge regarding the whereabouts of the stick did not influence the frequency of the stick-indicating behaviours. However, given that human infants under three years show only limited ability of mental state attribution (e.g. Wimmer et al. 1988; O'Neill et al. 1992), the 2.5-year-old children's performance in this study still seems to be beyond expectation. There is a debate regarding to children's abilities between 2 and 3 years of age to understand the relationship between perception and knowledge coming from the conclusions of two different approaches of research. The ability to solve conceptual perspective taking or theory of mind problems is believed to show a significant developmental improvement in human infants between 3 and 4 years of age (e.g. Chandler et al. 1989). Some suggest however, that these tasks underestimate younger children's abilities (see O'Neill 1996, for review). One criticism is that these studies rely on verbal skills at a level that exceeds younger children's verbal capabilities. This is supported by some results suggesting that theory of mind skills manifest in nonverbal behaviour (e.g. gazing, pointing) earlier than children become able to perform it explicitly in their verbal responses (e. g. Clements and Perner 1994; Garnham and Ruffman 2001; Carpenter et al. 2002). The other source of results—studies referred to as communicative development research—suggests that children as young as age 2 are able for example to adjust their speech to the experience of particular partner, to repair episodes of miscommunication, etc., but these tasks are often regarded to overestimate the earliness of the age when children show sophisticated communicative skills sensitive to the partner's specific lack of information (e.g. Shatz and O'Reilly 1990; Samuelson and Smith 1998) partly because the factors influencing children's communication are often difficult to determine.

Our results seem to support that children younger than 3 year-old may be able to tailor their communicative behaviour to their partner's previous participation/disengagement in conspicuous events. Considering their toy-indicating behaviour in the second session, dogs were also found to show more frequent toy-related behaviours in accordance with their partner's lack of information based on making distinction between conditions when the partner was involved or disinvolved in the toy-hiding process. Since this behaviour of both the dogs and the children can be interpreted at different—mentalist and non-mentalist—levels, we should make a clear distinction between the 'blindly' associationist explanations and the hypotheses inferring theory-based causally interpretive use of relevant perceptual cues (Gergely and Csibra 1997).

'Arousal' Hypothesis

First, it can be argued that the subjects gestured and/or vocalized more and/or alternated their gaze more often in the 'Ignorant Helper' trials because the Helper had left the subject alone in the room with the experimenter, which could be more arousing for the subjects. This argument, however, cannot explain why these more frequent gestures, vocalizations and gazes were so specific, restricted to only the object that the Helper had not witnessed being hidden.

'Discriminative cue' hypothesis

A second possible explanation is that the Helper provided discriminative cues in conditions in which she was ignorant of the whereabouts of the toy (for example was looking at the subject more attentively) and dogs (and children) gradually learned to recognize these cues as asking for information of the place of the toy. Two arguments are against it. First, the procedure of the study was carefully designed not to allow the Helper to give any feedback to the subjects on what particular information (place of the toy and/or place of the stick) she needed (i.e. she had to be passive and to orient to the dog/child without any specific verbal or gestural cue). It is possible, however, that the subjects could have used also subtle, unconscious cues given by the Helper (mother or owner) to ask for information. However, it is quite unlikely that these subtle cues could indicate to the subjects what particular information (place of the toy, place of the stick, both places) the Helper needed.

Consequently it seems reasonable to conclude that the subjects' toy-indicating behaviour was influenced specifically by the Helper's previous participation in hiding the toy and not by discriminative cues given by the Helper during the half a minute of passivity.

'Specific experiences' hypothesis

However, it is still possible to use the partner's overt, observable features of her participation or disinvolvement as 'past discriminative cues' without any understanding of what others have or have not had perceptual access to. In this case, the subject could come to discriminate the relevant conjunction of stimulus preconditions (Helper present/absent) and to use them to form her signalling behaviour discovering the correlation between Helper's presence/absence and her knowledgeable/ignorant behaviour. Because this mechanism is less likely to allow more than using specific cues in specific situations, it seems to be unsuitable to explain the children's object-specific discriminating ability in this complex situation. In case of the dogs, however, it is possible that over the course of their life-long experiences with humans, individual dogs learned to use the absence of the owner in the close past when a desirable object was getting out of reach of them as a discriminative cue that informs them that they are needed to indicated the place of this object more intensively.

If we assume some understanding of the partner's participation/involvement which goes beyond using specific cues only, the question remains as to whether this understanding is limited to representing the behaviour of the partners or

it turns into representing the mental states of the partners based on understanding the casual connection between participating and knowing. What do the subjects take into account? Do they tailor their indicating behaviour directly to the helper's involvement or absence in relevant past events or to the helper's knowledge or ignorance inferring from her past participation?

'Disinvolvement-ignorance-informing' hypothesis

If the subjects are able to attribute knowledge and ignorance to their partners, and they are ready to react in an active, initiating and complementary way, then they are expected to provide the information which the partner's ignorance requires. This interpretation implies the ability to understand the casual connection between seeing and knowing as has been observed in three-year-old children (e.g. Wimmer et al. 1988; O'Neill et al. 1992) as opposed to the previous three and the next non-mentalist explanations.

'Disinvolvement-informing' hypothesis

There is, however, a lower lever explanation that relies on a direct relationship between the partner's participation/disinvolvement in certain past events and her predicted behaviour without an intervening variable (Whiten 1996) of a mental state attributed to her. When interpreting the results that 2.5-year-old children tailored their toy-signalling behaviour to the previous visual access of the parent to the hiding of the toy, O'Neill (1996) suggested that "2-year-old children tailored their communication by, first, taking into account the parent's disengagement from the events taking place and, second, by wanting to update the parent about the relevant events that happened while the parent was disengaged" (O'Neill 1996, p. 673). This ability "may have rested not on a sophisticated, casual understanding of knowledge and its relation to sensory experiences but, rather, on a simpler, precursory understanding of the form "Tell other people about significant happenings they did not take part in with me". (p. 674). This hypothesis may explain the inconsistency regarding children's capability for adjusting to others previous perceptual access between the age of two and three.

The present study is the first one which systematically tested and compared children and dogs as to whether each is able to tailor their signalling behaviour to a human's past participation/disengagement by understanding the social situation with especial regard to the contribution of the human partner in the manipulative actions (hiding the stick/toy). We found that dogs show some sensitivity to past perceptual access of humans, which is in line with earlier studies (Call et al. 2003; Gácsi et al. 2004; Virányi et al. 2004; Bräuer et al. 2004) that have demonstrated in different situations that dogs can recognise what a human can or cannot perceive (see) at present. This sensitivity of dogs can provide the grounds for tailoring their behaviour to the past perceptual access of others.

Experimental studies argue that well-developed social cognitive skills in dogs support the hypothesis that the complexity of human social systems provides the main adaptational demand in the course of the evolution of the domestic dog, and this may have led to the emergence of sophisticated social cognitive skills in this species. Mindful of this unique evolutionary history (Vilà et al. 1997; Schleidt 1998), we suggest that understanding the functioning and limits of dog's social intelligence in particular may significantly contribute to our understanding the evolution and function of social cognitive skills in general.

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